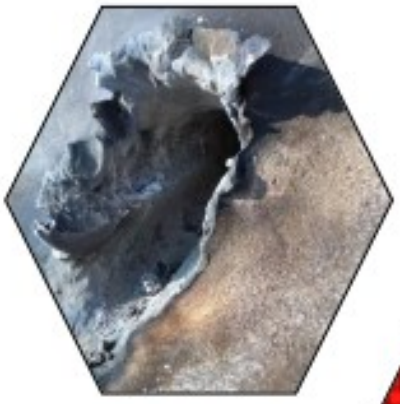
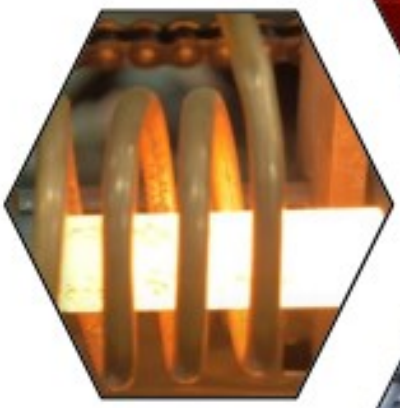
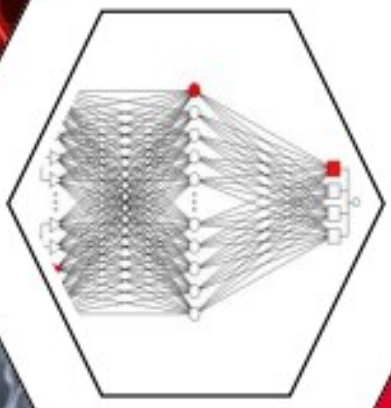
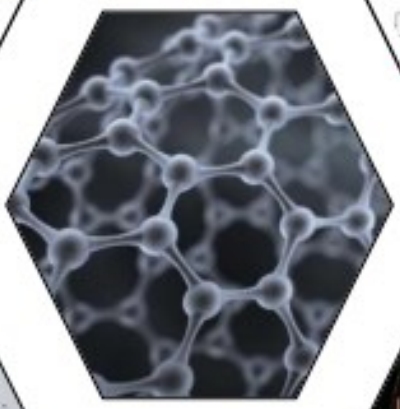
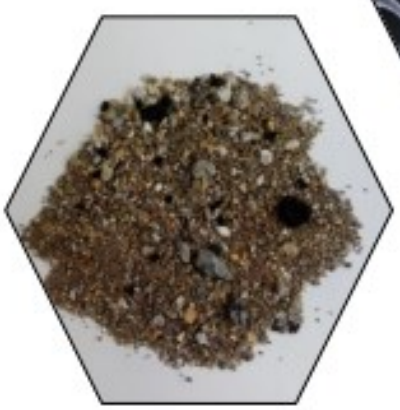
VŠB TECHNICKÁ UNIVERZITA OSTRAVA

FAKULTA MATERIÁLOVĚ TECHNOLOGICKÁ

DEN DOKTORANDŮ 2021




FMT

DEN DOKTORANDŮ 2021

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Úvodní slovo

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Den doktorandů 2021 Fakulty materiálově-technologické VŠB-TU Ostrava

Na naší fakultě se stalo již tradicí pořádat v závěru kalendářního roku „Den doktorandů“. Tuto tradici dodržíme i v roce 2021. V průběhu měsíce září proběhlo hodnocení studentů doktorských studijních programů a mohu konstatovat, že v případě studentů prezenčního studia zanechalo studium 8 studentů. U studentů kombinované formy studia byly výsledky méně příznivé a studium bylo na vlastní žádost ukončeno 19 studentům, z důvodu neplnění studijních povinností pak 4 studentům. Studium úspěšně ukončilo obhajobou své disertační práce 10 studentů.

Do programu letošního „Dne doktorandů FMT“ se s prezentacemi přihlásilo celkem 49 studentů a zastoupení jednotlivých studijních programů je následující: V rámci studijního programu Metalurgická technologie je přihlášeno celkem 8 přednášejících, v oboru Chemická metalurgie 2 přednášející, v programu Tepelná technika a paliva v průmyslu 1 přednášející, v rámci studijního programu Chemické a environmentální inženýrství se přihlásil 1 přednášející, ze studijního programu Procesní inženýrství 4 přednášející. V rámci studijního programu Materiálové vědy a inženýrství se v tomto roce přihlásil 1 přednášející. Do studijního programu Řízení průmyslových systémů se pak přihlásilo 29 přednášejících. Nově se do této akce přihlásili i 3 studenti studijního programu Nanotechnologie.

„Den doktorandů“ Vám nabízí možnost prezentace dosažených výsledků v oblasti výzkumu a vývoje a jejich konfrontaci s výsledky ostatních studentů doktorského studia. Vaše prezentace by měla vyústit v plnohodnotnou publikaci v recenzovaném časopise, případně v časopise s impakt faktorem. Ke zvýšení publikačních aktivit Vás zajisté povedou i Vaší školitelé.

Do organizačního zajištění této akce se v rámci projektu SGS opět zapojili iniciativně i studenti a doufám, že jejich dobrá práce přispěje k hladkému průběhu celého programu. Vzhledem k velkému počtu účastníků probíhá společně jednání studentů programů Metalurgická technologie, Chemická metalurgie, Chemické a environmentální inženýrství, Procesní inženýrství, Tepelná technika a paliva v průmyslu, Materiálové vědy a inženýrství a Nanotechnologie. Paralelně s tímto jednáním bude probíhat jednání doktorandů oboru Řízení průmyslových systémů.

Do další odborné práce Vám přeji mnoho úspěchů a těším se na spolupráci v rámci projektů řešených pracovníky Fakulty materiálově - technologické VŠB-TUO.

Prof. Ing. Miroslav Kursa, CSc.

proděkan FMT

Studijní program:

Metalurgie

Obor:

Metalurgická technologie

PHYSICAL MODELLING OF STEEL FLOW IN AN ASYMMETRIC FIVE-STRAND BLOOM CONTINUOUS CASTING TUNDISH

FYZIKÁLNÍ MODELOVÁNÍ PROUDĚNÍ OCELI V PĚTIPROUDÉ ASYMETRICKÉ MEZIPÁNVI PRO ODLÉVÁNÍ BLOKŮ

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Abstract

The paper presents with the study of steel flow in the tundish using the method of physical modelling. Experimental device was a physical model of an asymmetric five-strand tundish, on which a number of experiments were performed. The aim of the paper is to compare the influence of the shape of the impact pad and the position of the ladle shroud towards the impact pad.

Key words:

Continuous casting of steel, tundish, steel flow, physical modelling, impact pad

1. INTRODUCTION

At present, the requirements for the final quality of steel are constantly growing. Continuous casting of steel is a technological process in which liquid steel is processed into billets, which are of the desired shape with an almost unlimited length and are most often intended for further processing. Continuous steel casting largely replaces the older method of ingot steelmaking, and currently up to 95% of steel is cast worldwide [1].

The tundish is a very important part of continuous casting. It supplies liquid steel and distributes steel between casting strands. The tundishes are made of a welded steel shell and lined with a refractory material. The steel flows into the tundish from the ladle through a ladle shroud made of ceramic material, which ensures the inlet flow conditions and prevents reoxidation of the melt. The surface of the steel in the tundish is covered with slag, which prevents reoxidation and heat loss of the melt. Another task of the slag is to ensure the ideal course of chemical reactions and the absorption of non-metallic inclusions from the melt. To control the flow of steel from the tundish, each casting strand is equipped with a stopper rod or a slide valve [1, 2].

Optimum steel flow in the tundish is essential for continuous casting equipment. Impact pads, baffles, dams and weirs can be used to optimize the flow. The so-called retention time is related to the nature of the flow. It is the time for which a certain element of melt remains in the tundish. Under physical modelling conditions, the residence time is determined by injecting a dye, acid or salt, the concentration of which is recorded on the tundish submerge entry nozzles. Concentration curves are compiled from the result of modelling [1].

The flow in the tundish can be divided into active and passive. Active flow is referred to as the active volume of the tundish, being divided into a well-mixed volume and a plug flow volume. In the case of a well-mixed volume, it is a turbulent flow that occurs mainly in the vicinity of the ladle shroud. It follows the area of the tundish with a predominantly plug flow volume, which is characterized by a slow, orderly flow. Passive volume is referred to as dead volume. There is almost no flow in this area, which reduces the effective space of the tundish. The dead volume is characterized by achieving almost twice the residence time compared to the so-called theoretical residence time, which is defined as the ratio of the volume of the tundish and the volume flow of steel into the tundish. It is important to increase the active volume (especially the plug flow volume) as much as possible and to eliminate the passive (dead) volume [1].

2. EXPERIMENTAL CONDITIONS OF PHYSICAL MODELLING

Optimization of the character of the steel flow in the tundish is difficult under operating conditions. Therefore, in laboratory conditions so-called modelling is used, where the original prototype is replaced by a model. In the case of physical modelling, a method is used, in which the real system is replaced by a water physical model, which is as close as possible to the behaviour of the real system. The basis of physical modelling consists in the targeted utilization of the similarities of the processes that take place within the actual device and its model [3, 4]. For physical modelling, a plexiglass model on a scale of 1:4 (see Figure 1) is used for the operating tundish. Part of the physical model are two ladles, ladle shroud, stopper rods, SEN and moulds. The character of the steel flow in the tundish is simulated at physical modelling by the model liquid (water).

Figure 1 The Physical model of five-strand tundish with accessories. Source: (own)

Water is most often used as a medium for physical modeling of metallurgical processes. Water is characterized by low costs and its high availability. The important physical properties is the kinematic viscosity, which is similar to water at 20 °C as to steel at 1520 °C. A comparison of the basic physical properties of water and steel is shown in table 1 [1].

Table 1 Comparison of the basic physical properties of water and steel. Source: [1]

Physical properties	Symbol	Unit	Steel	Water
Temperature	t	[°C]	1520	20
Density	ρ	$[kg \cdot m^{-3}]$	7000	998
Dynamic viscosity	η	$[kg \cdot m^{-1} \cdot s^{-1}]$	$5{,}0 \cdot 10^{-3}$	$1{,}0 \cdot 10^{-3}$
Kinematic viscosity	v	$[m^2 \cdot s^{-1}]$	$0{,}913 \cdot 10^{-6}$	$1{,}02 \cdot 10^{-6}$
Surface tension	σ	$[kg \cdot s^{-2}]$	1,69	0,09

Geometric and dynamic similarity must be observed for physical modelling. The model and the prototype are geometrically similar if all dimensions on the prototype are reduced to the same scale. If the model has the same dimensions as the prototype, it is a model that is geometrically identical to the prototype. Dynamic similarity is also described between the model and the prototype. The systems are similar if the ratio of forces at the corresponding places and times is constant, and their direction of action is the same. Dynamic similarity is most often determined on the basis of dimensionless similarity criteria. For fluid flow, the most important criteria are Froude's and Reynolds'. In this paper, similarity was approached according to Froude's criterion [3, 4].

For physical modelling there were used three types of impact pads (ULP3 – basic square configuration, ULPX - rectangular configuration, ULP4X – same as ULPX with convex bottom), which were constructed with heights (30, 40 mm), with position of ladle shroud at 131 and 146 mm above the impact pad.

3. RESULTS AND DISCUSION

In table 2 are shown the minimum residence times for all configurations. The minimum residence time was determined by the Dirac impulse method, where the aqueous KCl solution was injected into the ladle shroud and its concentration was monitored on the SENs. This is the time after obtaining the first KCl detection on the SEN. It is important to obtain the highest possible minimum residence time with the lowest possible variability, which is set by the coefficient of variation.

Table 2 Minimal residence times for all experimental configurations. Source (own)

Impact pad	IP height (mm)	Height of LS (mm)	τ_{min}						
			CS1 (s)	CS2 (s)	CS3 (s)	CS4 (s)	CS5 (s)	Ø (s)	CV (%)
ULP3	30	131	87,0	47,7	18,5	18,8	47,0	43,8	64,1
	30	146	64,0	34,5	13,0	16,0	41,0	33,7	61,4
	40	131	76,5	43,3	22,2	21,0	50,2	42,6	53,6
	40	146	77,8	43,8	16,5	19,3	50,5	41,6	60,4
ULPX	30	131	107,7	52,2	23,3	23,2	47,7	50,8	67,9
	30	146	97,8	42,5	22,7	26,3	39,2	45,7	66,3
	40	131	90,0	42,7	25,0	21,2	53,5	46,5	59,5
	40	146	89,5	34,5	24,8	25,2	52,2	45,2	60,0
ULP4X	30	131	92,8	42,6	25,2	24,8	57,2	48,5	58,1
	30	146	91,2	48,2	28,0	24,7	49,0	48,2	55,0
	40	131	101,5	55,0	27,2	18,2	51,0	50,6	64,2
	40	146	107,0	55,1	25,3	25,3	47,0	52,0	64,4

The most important thing is to achieve the highest minimum residence times at the nearest outflows (CS3, CS4) and at the same time to achieve low variability (CV). For this reason, the ULP4X-30-131 and ULP4X-30-146 configurations performed best, as shown in Figure 2. The configurations with the ULP3 impact pad were the worst, with the reach low minimum residence time on CS3 and CS4.

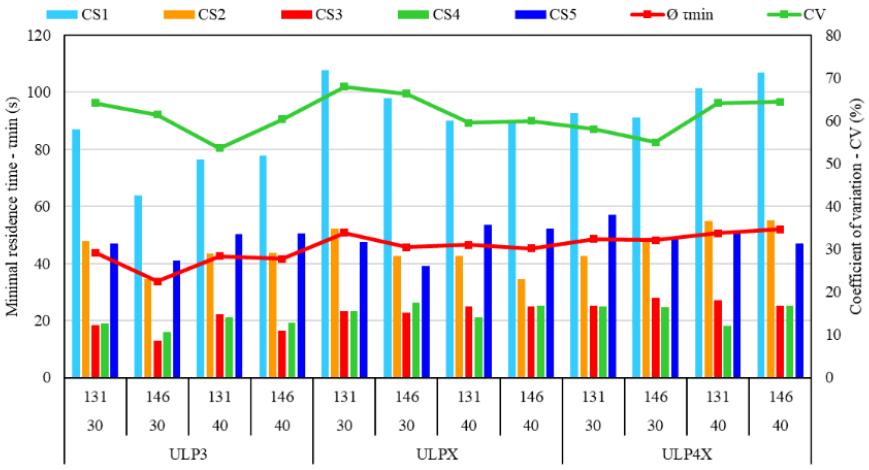

Figure 2 Minimal residence times for all experimental configurations. Source: (own)

The Volume fraction of the flow was determined based on the residence times. Graphic results are described in Figure 3. The aim was to obtain the highest volume with plug flow and the minimum dead volume.

All ULP3 impact pads configurations are characterized by high dead volume. The ULP3-30-146 configuration was the worst, with a dead volume of 47.92%.

ULPX type impact pad significantly improves flow. The dead volume was reduced and the plug flow volume was increased.

Further improvement was achieved with the ULP4X impact pad, where the lowest dead volume was achieved and the plug flow volume was increased. The ULP4X-30-131 variant with the lowest dead volume of 13.55% proved to be the best of all configurations.

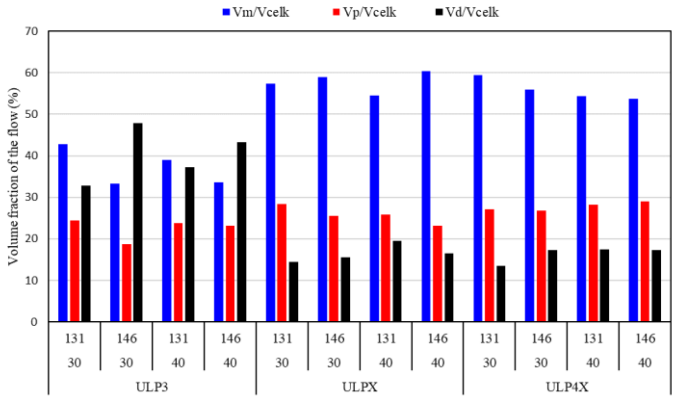

Figure 3 Volume fraction of the flow for all experimental configurations. Source: (own)

The same results were shown in the visualization using KMnO4 solutions. Images 30 and 90 seconds after solution injection are shown here. From the gradual staining in Figure 4, it is possible to see the largest dead volume at the ULP3-type impact pad. ULPX and ULP4X behaved similarly, in any case better results were obtained with an impact pad of the ULP4X type.

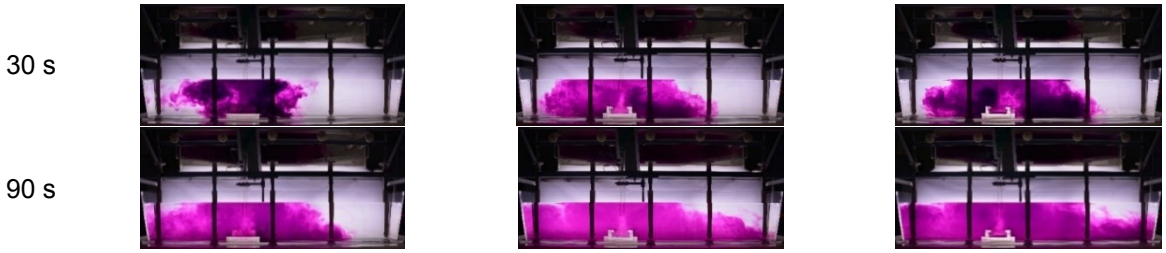

Figure 4 Visualization of the flow in time for individual of the impact pads: a) ULP3; b) ULPX; c) ULP4X. Source: (own)

4. CONCLUSION

In this paper, 12 internal configurations of the tundish were compared. The configuration of the ULP4X-30-131 impact pad worked best. The residence time on the nearest casting strands has been maximally increased, which prevents short-circuit flow. At the same time, the dead volume, which describes the effective area of the tundish, has been reduced.

In the next phase of research, emphasis will be placed on numerical simulations. The flow results obtained from the physical modelling will be verified by numerical modelling. Further attention will be paid to non-stationary flow states, slag emulsification and distribution of inclusions in the tundish.

ACKNOWLEDGEMENT

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EFFECT OF MULLING ONTHE PROPERTIES OF SAND-WATER-BENTONITE MOULDING MIXTURES

EFEKT MÍSENÍ NA VLASTNOSTI FORMOVACÍCH SMĚSÍ PÍSEK-VODA-BENTONIT

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Abstract

The aim of this paper is to present the effect of mulling time and number of mulling cycles on the properties of sand-water-bentonite system, which is often neglected when dealing with green sand moulding mixtures*. The mulling time is based on the measurement of the effect of prolonged mulling on the changes in the properties of the green sand mixture due to progressive moisture loss. The monitored properties are mainly the compactability, the compressive strength and the water content at the beginning and end of mulling.*

Key words:

Green sand mixture; cumulative mulling; mulling time; compactability, compressive strength

1. INTRODUCTION

To produce quality castings on moulding lines using green sand moulding mixture, high quality is a prerequisite. The quality of this mixture depends not only on the quality of the raw materials used, but also significantly reflects the quality of the preparation and processing of the mixture [1]. In general, it is accepted for any mixtures that the mulling process occurs due to compressive forces with subsequent shear. For this purpose, wheels in various designs known as mullers in the foundry industry are used worldwide [2]. The time for one cycle of mulling the moulding mixture is most often in the range of 1 to 3 minutes. The short mulling time does not guarantee the quality of the bentonite dough formation and the uniform coverage of the basic sand grains, but after several mulling cycles these green sand mixtures already show sufficient strength properties. Cumulative mulling for 15 to 20 minutes may be equivalent to this multiple movement of the mixture through the system and re-mulling [3].

In order to control the correct humidity level, simple series of tests are carried out which allow the moisture content, and the resulting properties of the green sand mixture, to be determined very quickly and accurately. Besides the actual measured values, mutual relations and correlations between them are also used [4]. The actual toughness of a green sand moulding mixture can be defined by means of a compressive and split strength test. The compactability test is a very sensitive indicator of the bentonite-water ratio in the mixture and is the most commonly recommended procedure for evaluating mulling efficiency [2, 4]. As the mulling time increases, the compactability increases proportionally with the decrease in bulk density, since it depends on the development of the clay binding capacity and the quality of the sand grains' coverage by the clay dough, in addition to the uniform distribution of water [1].

2. MATERIALS AND METHODS

2.1. Cumulative mulling

For the evaluation of the cumulative mulling effect, the "mulling index" methodology according to E. C. Troy was chosen [2]. This procedure indicates that for each bentonite content in the mixture there is a binding constant A which is related to the actual moisture content of the mixture. Binding constant calculation is shown in the Equation 1:

$$A = \sigma_{Pt} W \sqrt{W} \quad (1)$$

where:
σ_{Pt} – green compressive strength (kPa),
W – moisture content of the mixture (%).

A procedure for calculating the addition of water also consider the amount of moisture yielded by the amount of bentonite added is commonly reported in the literature [1, 2]. In our case, the water content of the bentonite will not be considered, as it is a negligible amount in relation to the total amount of mixture and is not relevant for our purposes. In addition, in contrast to the literature, not distilled water [2] but water from a common water supply will be used, due to the use of this water in common foundry practice. The possible influence of contained minerals will not be evaluated here. According to the literature, the order of addition of raw materials plays an important role in determining the effective mulling time. The available information shows that, unlike Ca^{2+} bentonite, Na^{+} bentonite has different properties at the same mulling time and moisture content depending on whether the sand was first moistened and then the specified bentonite content was added or vice versa [2]. For our purposes, both of these variations will be evaluated under cumulative mulling on a wheel muller. The mixture will be evaluated at the upper moisture limit for press moulding (2.5 % moisture) and for the green moulding mixture (3.5 % moisture).

2.2. Materials and equipments

The following materials were selected for the conditions for determining the optimum mulling time. The parameters of the mixture to be used for cumulative mulling are given in Table 1.

- Foundry quartz sand Biala Góra BG 27 with d50 = 0.27 mm.
- Bonding agent: activated Na^{+} Bentonite Sabenil 65, manufacturer Keramost a.s.

Table 1 Parameters of the used moulding mixture (own)

	Basic sand	Binder	Moisture 1	Moisture 2
Weight percent (%)	100	8	2.5	3.5
Weight (g)	8 000	640	200	280

The equipment of the laboratory of moulding materials at the Technical University of Ostrava was used for mulling the moulding mixture and measurements. The equipment was supplied by Multiserw-Morek. Cumulative mulling was performed on a laboratory wheel sand muller LM-2e. It is designed for preparation of moulding mixtures as well as for mixing and grinding of ceramic materials with Mohs hardness less than 5. The muller is automated, with the possibility of setting a precise mulling program. It determines both the speed and the exact mulling time. Furthermore, a universal strength device LRu-2e was used for the experiment to measure the strength properties of the bentonite mixture and a semi-automatic laboratory ramming machine LUA-2e/Z was used for the preparation of test specimens and determination of compactability.

3. RESULTS AND DISCUSION

Figures 1-3 show graphically the changes in the development of the individual properties of the green sand mixture during the different cycles of cumulative mulling. The individual cycles of mulling are shown by lines. Subsequent individual points in the graphs, in cycles 7 and 8, show the measured values of samples taken after the 1st and 3rd minute of mulling after the cumulative mulling has reached a constant value of A.

When comparing the moisture content curves of the mixture with 2.5 % water, it can be seen that in the case of the mixture where water is added after the addition of bentonite as 3rd in order, the moisture content drop is lower than in the case of the mixture where sand is wetted first and then bentonite is added (water 2nd in order). Nevertheless, this difference is in the order of hundredths of % and can be considered negligible. The gradual decrease in measured moisture content for all 3 mixture curves is a way of gradually changing the evaporation conditions during mulling due to the heating of the mixture by mulling and natural evaporation. This is a decrease of approximately 0.2 - 0.3 % moisture between the 1 and 3 minutes of mulling.

The compactability values show a continuously decreasing character. In contrast, the mixture with 3.5 % moisture increases only minimally and shows similar values after the 1 and 3 minutes of

mulling as after the 1st cycle of cumulative mulling due to the higher moisture content. In terms of compactability, the 3.5 % moisture mixture showed values above the limit of measurability (above 55 % compactability).

Compressive and split have similar curves. In the case of mixes with 2.5 % moisture content, the strengths of the mixes increase up to a certain number of mulling cycles and then decrease after reaching their maximum. The mixture with water addition as 3rd order reaches its maximum at the 3rd mulling cycle, the mixture with water addition as 2nd order reaches its maximum at the 2nd cycle. Thus, wetting the sand before the addition of bentonite helps the mixture to reach its strength maximum faster, after fewer mulling cycles, but on the contrary it does not reach the same compressive strengths as the mixture with the addition of water in the 3rd order. In contrast, this mixture with the addition of water as 2nd in order shows much better split strengths and thus better toughness of the mixture. The strength characteristics of the mixture with 3.5 % moisture reached lower values, and after the cumulative mulling and sampling cycles were completed after the 1 and 3 minutes, they reached almost the initial strength values as at the beginning of the mulling cycles.

The constant A tends to increase for a mixture with 3.5 % moisture content. This is due to the higher moisture content of the mixture. The values of the constant A after mulling the mixture after the 1 and 3 minutes correspond to the values after 5 cycles of cumulative mulling. In the case of mixtures with 2.5 % moisture content, on the contrary, we can observe a decreasing character of the curve during the cumulative mulling cycles, but after the 1 and 3 minutes of mulling the subsequent values are higher than the cumulative mulling values.

A mixture moisture content of 3.5 % was used only to show the development of the properties of the higher moisture after several mulling cycles. As it will not be used further in future experiments and so detailed evaluation of this mixture was abandoned.

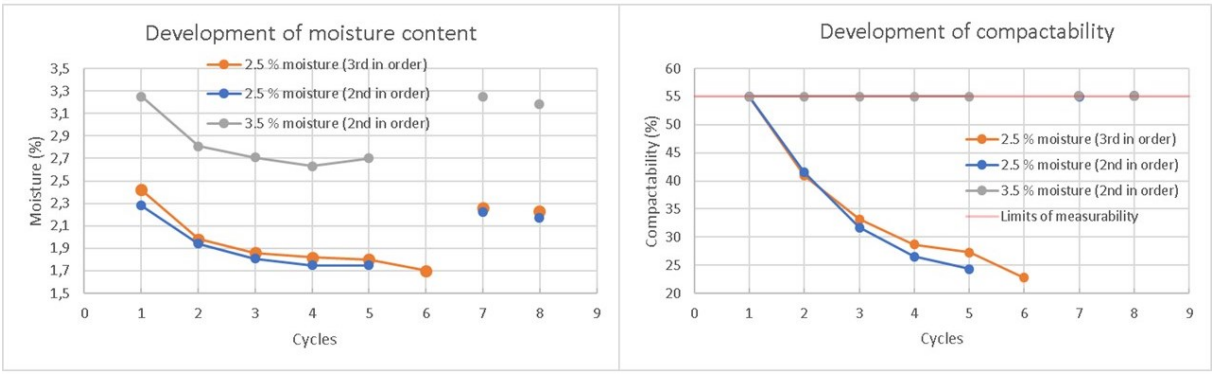

Figure 1 Development of moisture content and compactability. Source: [6]

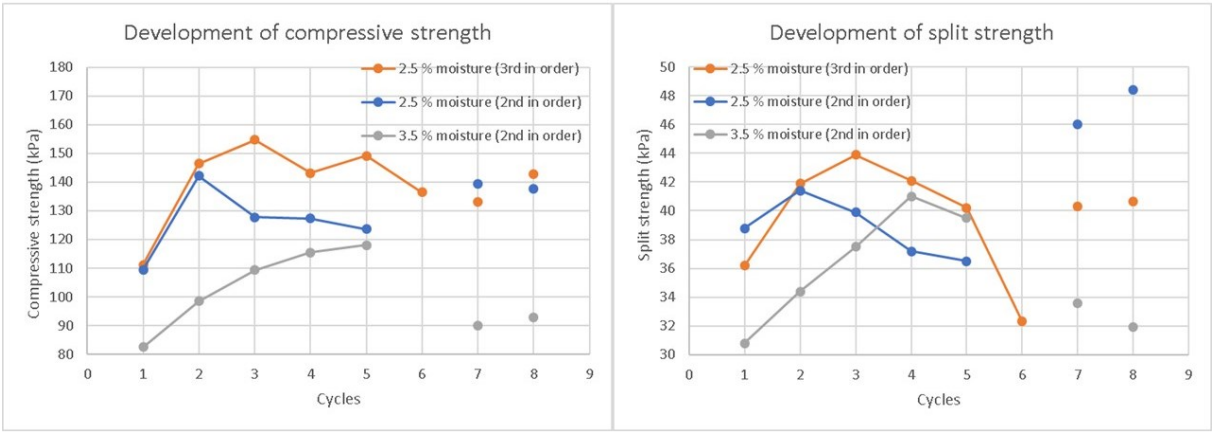

Figure 2 Development of compressive and split strength. Source: [6]

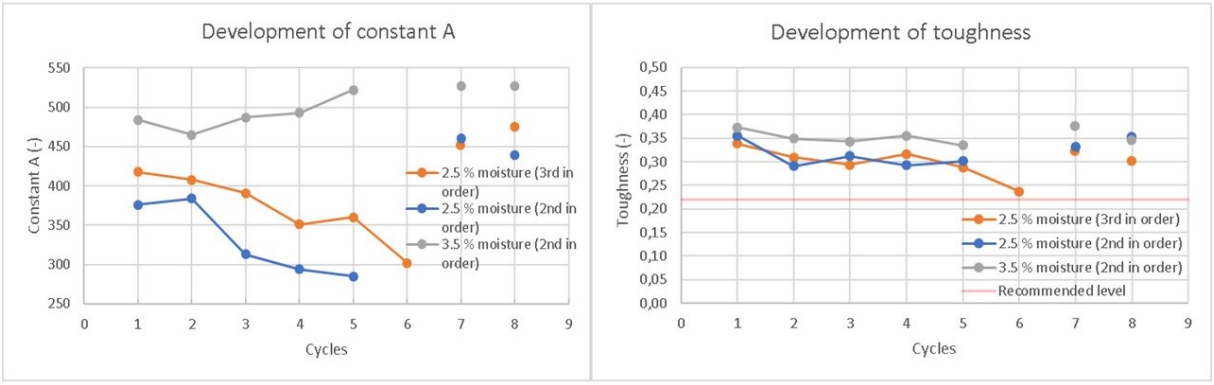

Figure 3 Development of constant A and toughness. Source: [6]

As a result of the comparison of mixtures with 2.5 % moisture content but different order of addition of raw materials, the mixture in which the sand was first moistened to the required level and then bentonite was added and mixed appears to be the more suitable final mixture for the next part of the experiment. Despite the fact that this mixture shows lower strength properties during the different cycles of cumulative mulling, on the contrary, after mulling and sampling after the 1 and 3 minutes, it shows higher strengths, and also shows better toughness of the mixture.

4. CONCLUSION

Based on the results obtained, it was confirmed that the order of addition of raw materials has an influence on the character of the resulting green sand mixture. If the basic sand is wetted first before the bentonite is added, a mixture with lower strengths but higher toughness after cyclic mulling will be obtained. This is a desirable parameter for mixtures used to form more complex castings. It was also verified that multiple or longer mulling of the mixture positively influences the development of the bonding properties of the bentonite and contributes significantly to the final strength or toughness of the mixture.

Furthermore, from the measured strength properties, the resulting moisture content of the mixture and the results of the cumulative mulling, the mulling index itself can be determined for a given wheel sand muller to evaluate its effectiveness. Determining the effective mulling time and efficiency of a given sand muller can significantly help to reduce the time and energy costs required to mix the mixture, in the event that the mixture has been mixed longer than strictly necessary. Conversely, extending the previously inadequate mulling time to its optimum can help to improve the quality of the bentonite mixture, thereby reducing the negative impact of the multiple costs associated with dealing with certain foundry defects. Finally, under operating conditions, knowledge of the effective mulling time, mixer efficiency and the evolution of the bonding properties of the mixture can help to optimise the dosage of not only the addition of water but also the amount of bentonite added.

ACKNOWLEDGEMENT

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USE OF DILATOMETER DIL805 A/D/T FOR DETERMINATION OF TEMPERATURES OF PHASE TRANSFORMATIONS OF STEEL AND THEIR SIGNIFICANCE FOR OPERATIONAL PRACTICE

VYUŽITÍ DILATOMETRU DIL805 A/D/T PRO STANOVENÍ TEPLOT FÁZOVÝCH TRANSFORMACÍ OCELI A JEJICH VÝZNAM PRO PROVOZNÍ PRAXI

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Abstract

The paper presents to get acquainted with the use of dilatometer DIL805 A/D/T for determining the temperatures of phase transformations of steel and with their importance for operational practice. Furthermore, the principle of dilatometry and the characteristics of the dilatometer are presented.

Key words:

Dilatometry, phase, transformation, temperature

1. INTRODUCTION

Steel changes its phase at different temperatures. The temperatures at which the state changes are referred to as the so-called phase transformation temperatures. The most important temperatures of phase transformations of steels include the liquidus temperature (or melting temperature) and the solidus temperature (or solidification temperature). The temperature zone between the liquidus and solidus temperature determines the so-called two-phase region, when the liquid phase changes to solid (knowledge of the range allows prediction of steel tendency to internal defects, determination of steel liquidus temperature allows correct setting of steel casting temperature).

Thermal analysis, dilatometry, or computational methods (using empirically determined equations or software) can be used to determine phase transformation temperatures. The results obtained after the computational determination of the phase transformation temperatures of the steel should also be verified by experimental methods.

2. PRINCIPLE OF DILATOMETRY

Dilatometry is one of the methods for determining the phase transformation temperatures, which can be used for the subsequent construction of decay diagrams based on significant changes in physical properties. When heated or cooled at a linear rate, the sample changes dimensionally, this method is based on their observation. Changes in the length of the sample are transmitted by quartz rods to the measuring part of the dilatometer. The result of the dilatometric analysis is a dilatometric curve, which graphically shows the dependence of the dilatation of the sample on time [1].

If a break occurs on the expansion curve, it means that a phase transformation has taken place. Two methods are used to evaluate these deviations, the tangent method or the dilatation curve derivation method. By evaluation, we obtain the coordinates of time and temperature for individual phase transformations, which are then used for the construction of isothermal and anisothermal decay diagrams of steel [1, 2].

2.1. Dilatometer DIL805 A/D/T

This type of dilatometer (Figure 1 - left) is a hardening dilatometer (A) with the possibility of deformation by pressure (D) and tension (T). Used to record phase and structural transformations. The determined deformation parameters can be used to create TTT - Time Temperature Transformation (IRA), CCT - Continuous Cooling Transformation (ARA), DTTT and DCCT (deformation-affected iso and anisothermal austenite decay) and/or curves. Measured, resp. the calculated parameters allow simulations of forging or rolling processes.

The solid or hollow sample is inductively heated in an atmosphere of air or inert gas or vacuum to a defined temperature level and then continuously cooled at different cooling rates (linear or exponential), even in the presence of gas. Phase transformations occurring during the continuous cooling process or in the isothermal endurance phase (may be multi-stage) may be registered as changes in length. The set of cooling curves forms an ARA or IRA diagram. The beginning and end of the transformation define the regions of ferrite, carbide, graphite, perlite, beinite, martensite or other eutectic mixture mixtures. The working space of the dilatometer with the prepared steel sample is shown in Figure 1 (right).

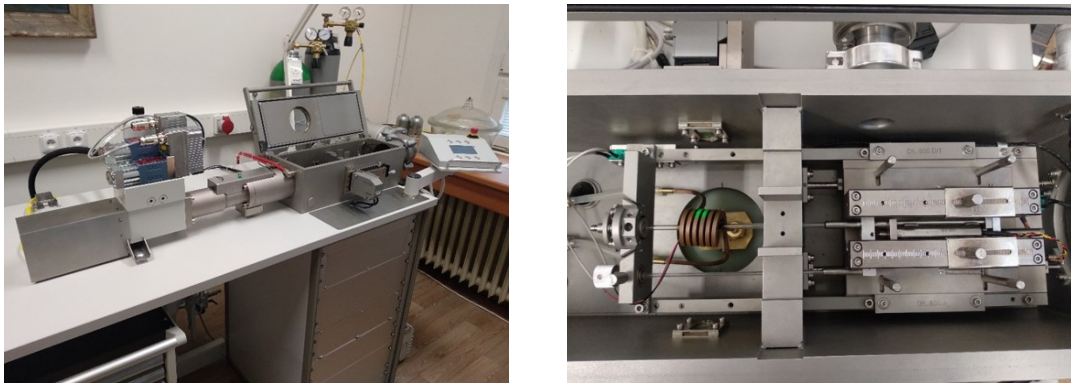

Figure 1 Dilatometer DIL805 A/D/T (left), working space of dilatometer with prepared steel sample (right). Source: (own)

3. USE OF DILATOMETRIC ANALYSIS

3.1. Heating and cooling transformation diagrams

These diagrams show the microstructural components that result from the given heating and cooling conditions and are an invaluable tool for the metallurgist in characterizing steels with respect to their reaction to heat treatment. The dilatometric curve obtained by measurement on a dilatometer is shown in Figure 2.

• The ability to accurately identify the final temperature of the perlite dissolution process makes dilatometric analysis a useful technique for determining the most suitable intercritical temperature to obtain two-phase microstructures consisting only of ferrite and martensite, widely used in the automotive industry [3].

• Because the presence of carbides in the hardened microstructure of steels has a decisive influence on their wear properties and corrosion resistance, it is important to study the carbide dissolution process to optimize these materials. In this sense, dilatometric analysis plays an important role in detecting the temperature at which the carbide dissolution process is completed during continuous heating [4].

• Starting with a given initial microstructure, the heating rate and temperature are the two factors that most directly affect the kinetics of the processes taking place in the steel. High-resolution dilatometry is used to analyze the effects of these parameters, and its results are represented in what is generally called a CHT diagram. Such diagrams are time-temperature-transformation graphs that are able to detect critical temperature fluctuations that define the progress of processes during steel heating in real conditions, not in equilibrium. A simple observation of this diagram clearly reveals the significant effect of the heating rate on critical temperatures, especially Acc and Ach, which increase considerably with increasing heating rate. Therefore, the temperature required to reach a given austenitization state in the steel must be higher, as the heating rate of the process increases, and this temperature should not be considered as a processing parameter that depends solely on the chemical

composition of the steel. Ignoring the effect of heating rate on the austenitization state is a mistake that can have major consequences for the final properties of this type of steel [3, 4].

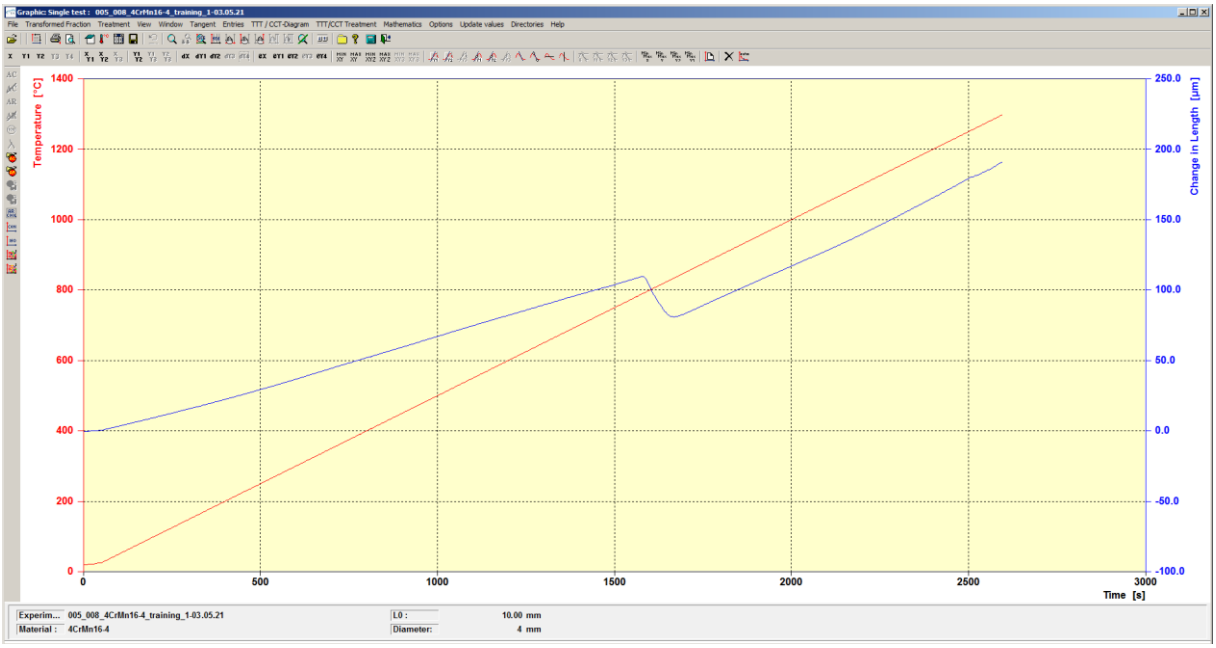

Figure 2 Steel heating dilatometric curve. Source: (own)

3.2. CCT diagrams

They help to represent the transformation characteristics of steels that are not isothermally heat-treated and to reveal the role of alloying elements in influencing the microstructures of steels. An example of a cct diagram is shown in Figure 3.

• Construction of CHT and CCT diagrams from dilatometric data allows prediction of microstructure for given heating and cooling rates. Method of quantitative relation of relative change of length to volume share of transformation - thanks to this method dilatometric analysis is a useful technique for verification of theoretical models of phase transformation [4].

• Dilatometry is one of the most popular methods for studying the high-temperature properties of steel and thermal expansion, it is considered an important factor regarding the formation of cracks during casting and rolling for tubular steels [5].

• In recent years, much attention has been paid to eliminating cracks in slab casting and rolling and improving the quality of steel tube products due to their widespread use for water, gas, oil, etc. Thermal expansion is considered an important factor in steel sensitivity to cracks. Dilatometry has proven to be one of the best methods for studying and monitoring the high-temperature physical properties of steel in real time and the transformation in terms of dimensional changes taking place in the sample over a given thermal history [5].

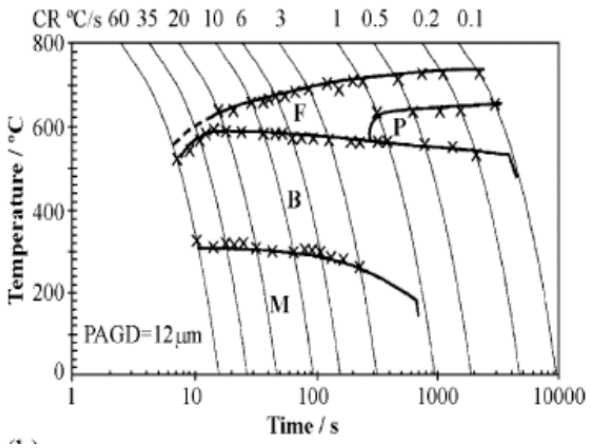

Figure 3 CCT diagram of microalloyed steel. Source: [4]

4. CONCLUSION

Dilatometry is one of the most effective techniques for studying solid phase transformations in steels because it allows real-time monitoring of the evolution of transformations in terms of dimensional changes that occur in a sample using the thermal cycle. It is also one of the classical techniques, together with differential thermal analysis and quantitative analysis of microstructures, which are most often used to determine phase transformation temperatures in steels, both in heating (Ac1, Ac7) and in cooling (Ar1, Ar3). The applicability of dilatometry in phase transformation research is due to the change in the specific volume of the sample during the phase transformation. As the material undergoes a phase change, the structure of the grid changes, and this is basically accompanied by a change in specific volume. By recording the transformations taking place in a number of conditions, it is possible to present the results in graphical form, which shows the formation temperatures of the microstructural components that can be obtained under the given cooling or heating conditions. These transformation diagrams are of immense value in metallurgical applications such as heat treatment and welding, and as a means of characterizing steels for specific processes.

The temperatures at which austenite transformation begins and ends at different cooling rates are important for the planning and construction of many industrial processes. In addition, there are other transformations that cause the steel to return to an austenitic state in which knowledge of transformation temperatures during heating is essential.

ACKNOWLEDGEMENT

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SURFACE TREATMENT POSSIBILITIES FOR THE INITIAL POLYMER FOAM PATTERN WITHIN METAL FOAM INVESTMENT CASTING TECHNOLOGY

MOŽNOSTI POVRCHOVÉ ÚPRAVY VÝCHOZÍHO POLYMERNÍHO PĚNOVÉHO MODELU V TECHNOLOGII PŘESNÉHO LITÍ KOVOVÝCH PĚN

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Abstract

The paper deals with the topic of the production of cast metal foams by the two-stage investment casting process using an evaporable polyurethane pattern. Particular attention is paid to the possibilities of surface treatment of the initial polyurethane foam pattern. The aim of the experiment was the design, laboratory verification and evaluation of the methodology for coating the initial pattern.

Key words:

Foundry; investment casting; metal foam; surface treatment; porosity.

1. INTRODUCTION

Foams and other highly porous materials with a cellular structure are known to have many interesting combinations of physical and mechanical properties, such as high stiffness relative to low specific gravity or high gas permeability combined with very good thermal conductivity. In parallel to the currently most industrially used polymer foams, metals and alloys can also be produced as porous cellular materials or foams, and these materials have numerous interesting properties, which determine the variety of their possible applications [1]. Even today, metal foams are a relatively young and still not fully characterized category of materials. They offer a variety of new combinations of useful properties, whether physical, mechanical, thermal, electrical or acoustic. Therefore, they represent a group of materials with a huge potential for use, e.g. in the production of lightweight structures, parts used to absorb impact energy or, for example, in thermal engineering (heat sinks, heat exchangers, etc.) [2].

2. THE TWO-STAGE INVESTMENT CASTING PROCESS USING AN EVAPORABLE POLYURETHANE PATTERN

One of the production methods of metallic porous materials is the use of foundry processes, specifically the investment casting method. This method stands out among other processes for the production of metal foams in enabling the production of a metal foam, or metal sponge [3], with stochastically (irregularly) arranged, fully open and interconnected pores, with a porosity of up to 97% [1], with a large specific surface area and a compact character of the metal matrix. Combined with the choice of an alloy with suitable desired properties (typically Al or Cu alloys), this makes it a material with a wide range of applications, especially in the field of functional components (passive heat sinks, heat exchangers, battery electrodes, electromagnetic shielding, vibration dampers, catalyst carriers, filters, etc.), but it also finds applications for its specific mechanical properties, especially its ability to absorb high levels of impact energy. This technology uses a disposable polymer pattern for the production of metal sponge castings, the most commonly used material being reticulated polyurethane (PUR) foam [4,5,6,7]. In many cases, the initial pattern is then additionally adjusted in order to change the mechanical and functional properties. By depositing various organic substances on the surface of

the PUR foam, a reinforcement of the ligaments is achieved, which has a positive effect on the mechanical and selected functional properties [5], [7]. However, the overall porosity and the specific surface of the produced metal sponge decrease significantly and the resistance to the flow of fluids through such a structure increases. Therefore, for some applications this treatment is unsuitable.

3. MATERIALS AND METHODS

In previous research [8], methods of applying different materials (technical waxes, synthetic paints) were tested for the purpose of reinforcing the ligaments of the initial pattern, both by soaking and by spraying. The use of waxes showed significant deficiencies in the form of sealing of the pores of the primary pattern and the uneven application. In the case of synthetic acrylic paints, these defects were less significant, but did not disappear completely. In addition, in the case of the use of pigmented paints, there was a problem with unburnt paint residues that caused complications during casting. Therefore, on the basis of these findings, a surface treatment method was designed to eliminate the aforementioned deficiencies. The method consists of soaking the primary pattern in a low-viscosity polyurethane-based transparent lacquer. After soaking, the patterns are centrifuged to remove any excess lacquer that might run off and seal the pores during drying.

For the purpose of the experiment, specimens were prepared according to the previously verified technological procedure in the form of PUR foam samples with dimensions 50x50x20 mm, equipped with a solid wax wall with a thickness of 1 mm and an inlet channel with a diameter of 5 mm. As a starting material for the production of the specimens, reticulated PUR foam Bulpren S 32450 (Eurofoam TP, s.r.o., Czech Republic) with a porosity of 10 ppi was used. The such prepared specimens were then mounted in fives on the central pole, thus creating a set of specimens for subsequent surface treatment. The whole system was mounted in a stand drill with continuously adjustable speed control and soaked in a prepared bath of acrylic-polyurethane waterborne lacquer Aquafin PLUS (BUILDING PLAST, spol. s r.o., Czech Republic) in a ratio of 1:1 diluted with water. This was followed by centrifugation at 900 RPM for one minute and drying at 20°C for 24 h. After drying, another coat of lacquer could be applied in the same way. In this way, samples with one to six layers of lacquer were then prepared. To determine the coating thickness, the individual specimens with different numbers of layers were moulded under reduced pressure in the two-component polyurethane resin Neukadur Multicast 1 (Altropol Kunststoff GmbH, Germany). Subsequently, a cut was made on the specimens prepared in this way at a distance of 10 mm from the end of the specimen, the cut surface was sanded and polished, and the thickness of the applied lacquer coating was evaluated using a non-contact measurement method on a KEYENCE VHX 6000 digital microscope.

The patterns coated with different numbers of layers were further used to produce castings for verification of the applicability of the given lacquer in the casting technology and for subsequent determination of the change in the resulting porosity. The production of the test castings was carried out according to the following procedure. The prepared patterns were moulded in Eurovest gypsum mixture (SRS - Ltd., United Kingdom) using InduMix equipment for the production of gypsum moulds under reduced pressure (250 mbar). This was followed by the annealing of the moulds according to the annealing cycle recommended by the manufacturer of the gypsum mixture, which was carried out in an electric resistance furnace Kittec HCB 2000 S. The actual production of the cast metal sponges from aluminium alloy AlSi10MgMn was carried out on a special casting machine Indutherm MC15. The melting and casting process was carried out under reduced pressure (20 mbar), solidification of the castings under overpressure (2 bar). The casting temperature was approximately 725°C, the mould temperature was 550°C. After the moulds cooled, the castings were unmoulded and cleaned of any residues of the moulding mixture trapped in the individual pores by the previously established method of blowing with pressurised air (10 bar) and subsequently finished using the leaching method in 1M HNO3 solution. From the resulting castings, samples with approximate dimensions of 2x2x5 cm (volume 20 cm3) were prepared on a Struers Secotom-10 precision saw, the exact dimensions were then determined using a digital caliper. The weight of each sample was determined by weighing on an analytical scale (RADWAG XA 82/220.4Y.A). From the values obtained, the bulk density of each sample was calculated and using the tabulated value of the theoretical density of the material (according to ČSN 42 4331), the porosity of each sample was determined using Equation 1:

$$\phi = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100; [\%] \quad (1)$$

where:
Φ – porosity
ρ_b – bulk density
ρ_t – theoretical density

4. RESULTS

In order to optimize the production technology of the metal sponges investment casting, the method of surface treatment of the initial reticulated PUR foam pattern by lacquering was verified. Samples with one to six layers of lacquer were prepared using the method described above. Figures 1 and 2 show the variation of the thickness of the applied lacquer coating for one layer (see Fig. 1) and for six layers (see Fig. 2).

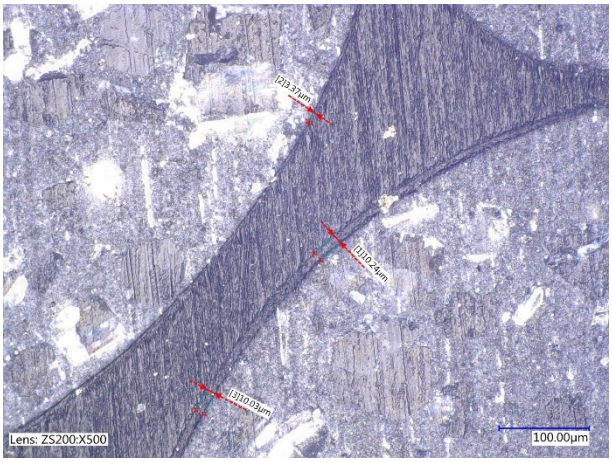

Figure 1 - Lacquer thickness, 1 coat applied

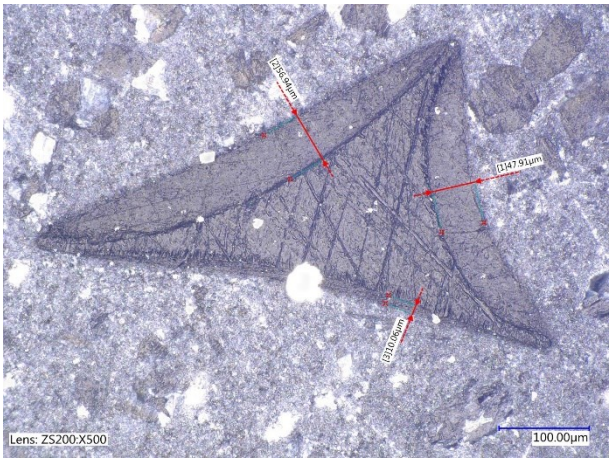

Figure 2 - Lacquer thickness, 6 coats applied

Table 1 then summarizes the results of the non-contact measurements of the applied coating thickness, showing some unevenness, which is likely, considering the repetitiveness in all cases, due to centrifugation.

Table 1 - Non-contact measurement of applied coating thickness

number of coats	coating thickness [µm]			
	1	2	3	average value
1	10.24	3.37	10.03	7.88
2	5.47	12.53	14.62	10.87
3	14.12	12.74	8.61	11.82
4	30.78	30.58	16.15	25.84
5	33.66	37.38	15.9	28.98
6	47.91	56.94	10.06	38.30

The possibility of using the tested acrylic-polyurethane lacquer in the mould annealing and casting process without any complications was then verified on the example of test castings of metal sponges made of aluminium alloy AlSi10MgMn. The influence of the surface treatment on the reinforcement of the ligaments expressed by the change of the resulting porosity of the casting was observed. The results of the measurements are presented in Table 2.

Table 2 - Porosity of metal sponge castings depending on the number of coatings of the initial PUR pattern.

number of coats	weight [g]	height [cm]	width [cm]	depth [cm]	volume [cm3]	density [g/cm3]	porosity [%]
1	1.32836	2.07	2.09	4.98	21.54	0.06166	97.66
2	1.35206	2.03	1.93	5.02	19.67	0.06874	97.40
3	1.47681	1.9	2.03	4.97	19.17	0.07704	97.08
4	2.1205	2.07	2.35	5.14	25.00	0.08481	96.79
5	1.8716	2.09	1.97	5.08	20.92	0.08948	96.61
6	2.00267	1.97	2.07	5.12	20.88	0.09592	96.37

Although the results clearly show a trend of decreasing porosity with increasing number of coats of lacquer, the overall decrease in porosity of less than 1.3% with six coats of lacquer is well below the author's expectations. Based on this observation, there is reason to believe that the lacquer used was over-diluted for the purposes of this application, leaving the layer too thin. In view of the above-mentioned uneven distribution of the applied layer, it is also highly likely that the RPM used for centrifugation was too high. In the next stage of the development of this method, it will therefore be necessary to use a coating with less or no dilution and to reduce the rotation speed during centrifugation. However, a suitable compromise will have to be found to avoid the individual pores becoming sealed.

5. CONCLUSION

The experiment tested and evaluated the method of surface treatment of the initial polyurethane foam pattern by lacquering. The tested lacquer and the application method were verified as functional, however, the applied coating, although appearing sufficient on a microscopic basis, has almost no effect on the final porosity of the casting on a macroscopic basis. The results will be taken into account in the further development of the doctoral thesis and the method will be further modified on the basis of these findings.

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EVALUATION OF THE COLLAPSIBILITY OF CORE MIXTURES

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Abstract

There are mainly two different ways of producing sand cores in the industry. The most used is the shooting moulding process. A mixture of sand and binder is injected by compressed air into a cavity (core), where it is then thermally or chemically cured. Another relatively new method of manufacturing cores is the use of 3D printing. The principle is based on the method of local curing of the sand bed. The ability to destroy sand cores after casting can be evaluated by means of tests which are carried out directly on the test core. In most cases, the core is thermally degraded and the mechanical properties before and after thermal exposure are measured. Another possible way to determine the degradability of core mixtures can be performed on test castings, where a specific casting is designed for different binder systems. The residual strength is measured by subsequent shake-out or discharge tests.

Keywords:
Foundry, cores, de-coring, collapsibility

1. INTRODUCTION

The main essence of this issue is to make it possible to remove the cast cores using conventional methods. The essence is to separate all sand from the metal surfaces before subsequent machining. In general, core removal is often referred to in the literature as core knock-out or de-coring. The process then consists of removing the internal inorganic or organically bound sand cores from the castings [1, 2].

For aluminium alloy castings, due to the lower heat load achieved, more effort is usually required to remove the sand cores from the castings. In the case of resin-bonded sands, the heat introduced during the casting process is sufficient to break the surface layer of the core.

Measurements of disintegration can be made directly on the manufactured test cores, where, after heat exposure for a period of time, the mechanical properties of the cores will decrease. The reference values are then compared with the results obtained for the mechanical properties of the cores after thermal exposure [3].

However, there are also types of collapsibility testing that are performed on cast samples. These types of tests are more reflective of the real collapsibility of core systems. Selected collapsibility tests of core mixtures are described below [3, 4]:

- Determination of the number of pulses required to remove the cores from the casting
- Evaluation of the time required to remove sand cores on cast samples
- Evaluation of strength or abrasion characteristics of sand cores after thermal exposure
- Mechanical stress testing of cores with heating
- Deformation tests of cores with thermal exposure

The aim of the work was to design a collapsibility test of core mixtures and to evaluate the collapsibility of selected core systems using cast samples.

2. MATERIALS AND METHODS

In order to evaluate the collapsibility of core mixtures, it was necessary to design a knock-out methodology for cores. This test was derived from the VŠB-TUO test methodology for evaluating the collapsibility of moulding mixtures with sodium silicates. Using a mandrel placed in a laboratory tamping device, a number of hit of a well-defined force (3.3 joules) was measured. The mandrel was designed to be both taller than the length of the test casting and smaller in diameter than the square opening of the casting.

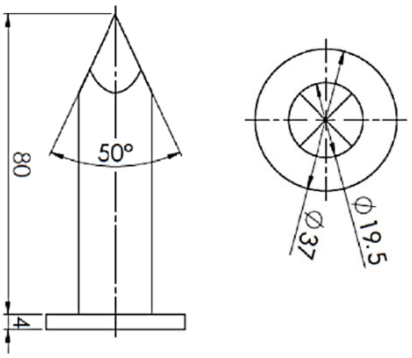

Figure 1 mandrel used in collapsibility testing. Source: (own)

In the context of testing the collapsibility of cores, a test casting weighing 196 g with an average wall thickness of 5.0 mm and dimensions of 32.5 mm × 65 mm × 60 mm was designed to simulate the production of thin-walled castings with relatively massive cores, in which sufficient core heating does not occur and thus thermal destruction of core mixtures with organic binders is greatly reduced. The low core heating is then the cause of impaired cleanability of the castings, or impaired collapsibility of the organic binder mixtures. In this study, the low thermal stress of the cores was ensured by a low core-to-cast weight ratio of approximately 1:2. The castings were made of aluminium alloy with chemical composition AlSi7Mg0.3. In order to achieve the soundness of the castings, a casting simulation was performed in MAGMA.

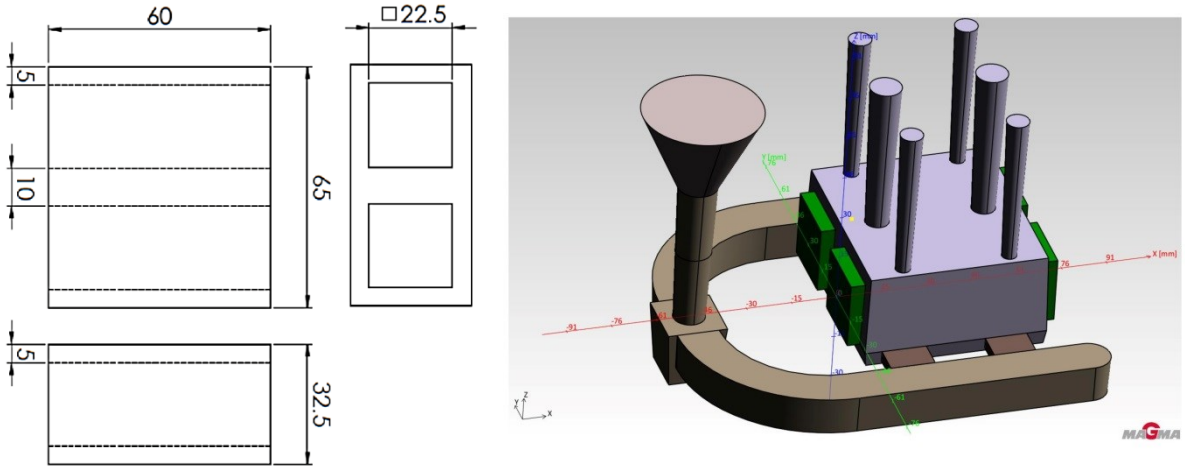

Figure 2 dimensions of the casting (left), 3D model from the MAGMA simulation program (right). Source: (own)

Four different core systems were used to verify the possibility of using core mixtures: Resin coated sand (RCS), GEOPOL, Furan resin and 3D printed sand bounded with furan resin. For each binding system, 2 results were measured.

Cores from RCS (marked CB20B, medium grain size 0.20 mm) and GEOPOL (marked W 303, medium grain size 0.24 mm) were produced on a laboratory shooting device LUT from Morek

Multiserw with a metal core box with three cavities. Due to the different properties of these binder systems, the production parameters are different, but natural and recommended by the manufacturer. The following are the production parameters:

RCS mixtures:

- core box temperature 280 °C, shooting time 2 sec., curing time 120 sec., shooting pressure 2 bar

GEOPOL mixtures:

- core box temperature 150 °C, shooting time 6 sec., curing time 120 sec., shooting pressure 6 bar

Furan cores were produced by the conventional method of production, where a mixture was poured into the core box and then compacted by three standard punches. Although chemically bonded cores are not normally compacted in this case, it was desirable to do so in order to comply with the production conditions. Two sizes of sand were selected for the research, namely BG 27 (0.27 mm medium grain size) and BG 21 (0.21 mm medium grain size)

The cores produced by 3D printing were printed on a 3D printer from ExOne, hereafter these cores are referred to as 3DSP. The size of the medium grain is given by the manufacturer, specifically 0.14 mm.

3. RESULTS AND DISCUSION

The collapsibility of the mixture was defined as the impact energy required to penetrate a core stuck in the test casting. The resulting values are shown in Figure 3

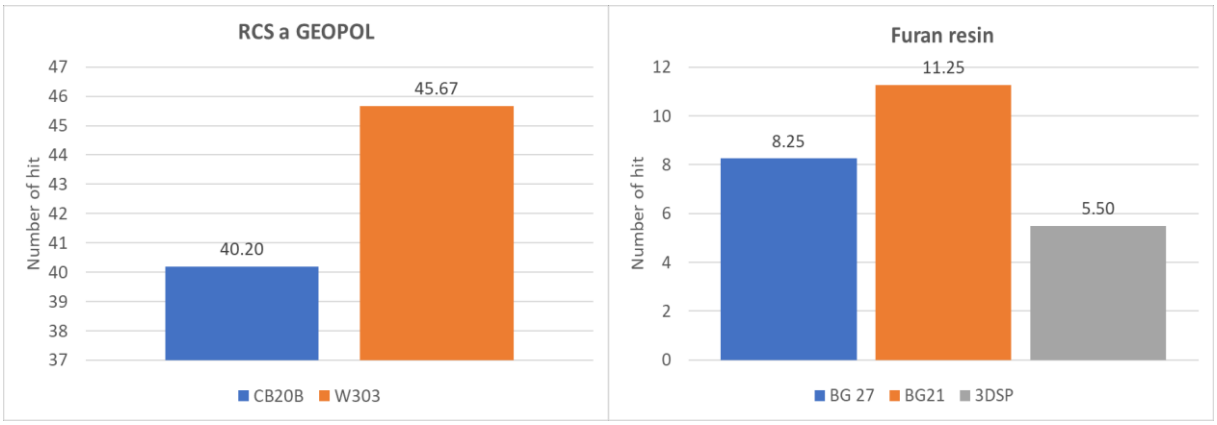

Figure 3 number of hit required to remove the cores. Source: (own)

From the results obtained for the RCS and GEOPOL mixtures, it is clear that the resulting collapsibility of the cores, reaches different levels. For cores made from the RCS mixture, the measured values are lower than for the GEOPOL system. It could be said that this fact is significantly determined by the parameters of the core production, especially the injection pressure.

The results obtained for the furan resin, the resulting collapsibility of the cores produced by 3D printing is better than that of the cores produced by the conventional moulding method. Then, if we compare only furan cores produced by the conventional method, the cores with larger medium grain size (BG 27) achieve better collapsibility than the cores with smaller medium grain size (BG 21).

4. CONCLUSION

One of the most important properties of the binder is the collapsibility of the moulding or core mixtures. This is especially true when using aluminium alloys, where the temperature is not quite sufficient for core collapse. Therefore, this test was designed and tested under realistic conditions using different binder systems. As reported in the results, furan cores have excellent decay rates, with

3D printed cores having the lowest values. On the other hand, cores made from RCS and GEOPOL blends have significantly higher decay rates.

ACKNOWLEDGEMENT

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LEACHING METHOD OF GALVANIC SLUDGE RECYCLING FOR THE DAY OF PH.D. STUDENTS 2021

RECYKLACE GALVANICKÉHO KALU METODOU LOUŽENÍ NA DEN DOKTORANDŮ 2021

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Abstract

The paper deals with the possibility of obtaining zinc and iron from waste galvanic sludge, which arises during galvanic plating. Galvanic sludges, which contain more significant amounts of heavy metals, form wastes that are suitable for hydrometallurgical recycling. The aim of the experimental and practical part was to obtain zinc and iron after leaching of galvanic sludges. Leaching was performed in sulfuric acids at different temperatures and time intervals with the addition of oxidizing agents and subsequent chemical analyzes of leachate.

Key words: *Metals, galvanic sludge, leaching*

1. INTRODUCTION

Hydrometallurgical processes have been the subject of much research because they allow the processing of complex ores, concentrates and wastes and reduce environmental pollution.
Recovering waste materials and recovering metals from various secondary sources is of major importance due to the economic and environmental benefits. Zinc is one of the most popular and versatile metals that finds a wide range of applications including plating, coating and alloying with other metals [1-2]. The high demand for zinc has also led the industry to exploit secondary sources such as zinc waste, zinc slag and leach residues as potentially valuable resources [3]. Empirical data collected on the performance of galvanized steel in environments ranging from industrial to marine to suburban and rural suggest that zinc can prevent corrosion of the underlying steel more than other surface treatments because it corrodes at a rate of about 1/30th that of iron [4].

Zinc sludge can be treated by hydrometallurgical methods [5-9]. Literature data on hydrometallurgical treatment of wastes mainly considers the leaching method in sulphuric [6] or hydrochloric acid [5]. This paper reports the results of preliminary studies on the hydrometallurgical treatment of galvanic sludge produced by industrial sources. Currently, this waste is managed domestically by zinc producers or sold to foreign recyclers. The objective of the research was to determine the effect of solid to liquid ratio, agitation rate and temperature on the efficiency of zinc leaching with sulfuric acid with the addition of the oxidizing agents hydrogen peroxide and ozone. The results obtained will help to develop further process for recycling zinc and iron and their further use as secondary raw material [8-11].

The aim of the work is to obtain zinc and iron from leaching of galvanic sludge. A sub-objective is a theoretical analysis of hydrometallurgical processes. The practical part aims at sample treatment, subsequent leaching of waste sludge in 10% and 30% sulphuric acid. The thesis concludes with an evaluation of the conditions under which the highest yield of zinc and iron is obtained after leaching of galvanic sludge and a proposal for further procedure.

2. BASIC CHARACTERISTICS OF ZINC AND IRON-CONTAINING WASTES AND THE LEACHING PROCESS

The galvanic sludges, which contain larger amounts of heavy metals, constitute waste that is suitable for recycling. These sludges are classified as hazardous waste because of the potential release of metals into the environment. Their disposal consists mainly in landfilling [12]. In Germany, sludge is treated in an incinerator, if the composition of the sludge permits, or in hazardous waste

landfill. Currently, there is a great desire to avoid the negative impacts associated with landfilling of sludge, and different treatment routes are being sought [7-9]. These are generated during the treatment of waste water from the operation of the galvanic plant. It is a mixture of metal hydroxides mainly iron, zinc, chromium and others. The sludge is sedimented in reaction pits and pumped to a sludge lagoon after sedimentation is complete. From there they are dewatered by a sludge pump in a sludge tank. The dewatered sludge is then collected in containers. Hydrometallurgical methods are used for sludge treatment. Acid or alkaline leaching is used to convert the metals of interest into a leachate. Most of the waste substances do not dissolve in the environment or are converted to a difficult-to-dissolve compound. The leachate is then treated by electrolysis to separate the individual metals [5-11].

3. EXPERIMENTS

The aim of the experimental part was to verify the leaching conditions for the extraction of zinc and iron metals of interest from the waste galvanic sludge. The sludge sample was treated by drying and crushing to the desired particle size. This was followed by a leaching process where sulphuric acid was chosen as leaching agent. This selection was made according to the analysis of literature sources dealing with leaching of waste materials. The leaching solution was prepared from concentrated acids by diluting to 20% solution. Further leaching conditions were set at 40 °C and 60 °C for 6 hours. The oxidizing agents hydrogen peroxide and ozone were added to the leaching process.

The next part of the experimental work was to determine the most suitable conditions for obtaining the maximum yield of zinc and iron from the waste galvanic sludge. Sulfuric acid was chosen for this type of experiment too. It was prepared concentrations of 10% and 30%. Other conditions were kept identical. It was kept hydrogen peroxide and ozone as oxidizing agents. The input chemical analysis of the sample is given in Table 1. The input samples of the waste galvanic sludge were analyzed for zinc and iron content by ED-XRF method in the laboratories of the Faculty of Materials and Technology.

Table 1 The amount of metals of interest in galvanic sludges. Source: (own)

Galvanic sludges				
Element	**Measurement [%]**			**Average**
	1	2	3	
Zn	15.63	15.72	15.99	15.78
Fe	5.7	5.74	5.78	5.74

Waste sludge samples were pretreated by drying under normal conditions and grinding by hand to the required particle size and shows the leaching process. (see Figure 1).

Figure 1 Preparation of samples for leaching and the leaching process. Source: (own)

Leaching procedure

The beakers containing the prepared samples (200 ml of 20% acid together with 50 g of the weighed sample, 1:4 ratio) were placed on electromagnetic stirrers. The desired temperatures (40 °C and 60 °C) were individually set on each electromagnetic stirrer. After the specified time (6 h), the leaching process was terminated and the leaching substance and leachate were separated by filtration. The samples obtained after leaching were chemically analyzed for zinc and iron content. (see Table 2).

Table 2 The resulting content of zinc and iron content in the leach. Source: (own)

	40°C			60°C		
	Addition, time	**Zn [mg/l]**	**Fe [mg/l]**	**Addition, time**	**Zn [mg/l]**	**Fe [mg/l]**
sample after leaching H_2SO_4	H_2O_2 2 h	26600	15600	H_2O_2 2 h	18700	10000
	H_2O_2 4 h	25000	14600	H_2O_2 4 h	23500	12800
	H_2O_2 6 h	24200	14200	H_2O_2 6 h	29600	16700
	O_3 2 h	29600	17500	O_3 2 h	25200	13600
	O_3 4 h	33000	19500	O_3 4 h	29100	16100
	O_3 6 h	31500	18500	O_3 6 h	31800	18300

The next part of the experiments were done with the prepared samples in a beaker of 200 ml of 10%, 30% sulphuric acid along with 50 g of weighed sample of waste electroplating sludge, (1:4 ratio) were put on electromagnetic stirrers. The desired temperatures (40 °C and 60 °C) were individually set on each electromagnetic stirrer. After the specified time (6 h), the leaching process was terminated and the leachate and leachate were separated by filtration. The leach was collected after two hours to determine more accurately the amount of metal that had passed into the leach. The leachate was collected after the experiment was completed after 6 h. Hydrogen peroxide and ozone were used as oxidizing agents in the experiments. The samples obtained after leaching were chemically analyzed for zinc and iron content. (see Table 3).

Table 3 The resulting content of zinc and iron content in the leach (H_2SO_4). Source: (own)

	40°C			60°C		
	Addition, time	**Zn [mg/l]**	**Fe [mg/l]**	**Addition, time**	**Zn [mg/l]**	**Fe [mg/l]**
sample after leaching 10% H_2SO_4	H_2O_2 2 h	10800	0.805	H_2O_2 2 h	16400	4.52
	H_2O_2 4 h	11100	2.77	H_2O_2 4 h	24400	15.8
	H_2O_2 6 h	11400	5	H_2O_2 6 h	36100	18.6
	O_3 2 h	18600	4.7	O_3 2 h	17300	344
	O_3 4 h	19900	75.7	O_3 4 h	22300	820
	O_3 6 h	40000	2150	O_3 6 h	40200	4360
sample after leaching 30% H_2SO_4	**40°C**			**60°C**		
	Addition, time	**Zn [mg/l]**	**Fe [mg/l]**	**Addition, time**	**Zn [mg/l]**	**Fe [mg/l]**
	H_2O_2 2 h	40200	6980	**H_2O_2 2 h**	47500	8480
	H_2O_2 4 h	31600	5781	**H_2O_2 4 h**	35400	6890
	H_2O_2 6 h	31700	6200	**H_2O_2 6 h**	43700	8420
	O_3 2 h	29700	5140	**O_3 2 h**	42400	7260
	O_3 4 h	19500	3660	**O_3 4 h**	27920	5200
	O_3 6 h	15600	4000	**O_3 6 h**	13700	4360

Results of research

The measured values showed the effect of increasing leaching agent concentration with temperature and time. The values of zinc and iron transfer to the leachate increased with increasing temperature, time and additional oxidizing agent. The theoretical assumption of the transition of the metal of interest into the leach with higher concentration of leaching agent was confirmed.

4. CONCLUSION

The aim of this work was to obtain zinc and iron by hydrometallurgical method from waste galvanic sludge and find optimum conditions for leaching of waste galavanic sludge with high Z and Fe content. The waste sludge sample was treated and leached in sulphuric acid solution under the given conditions. The outputs of the leaching process product was analyzed by ED-XRF and AAS. The zinc and iron content of the solution was determined by atomic absorption spectrometry with flame atomization.

Sulfuric acid were applied at different temperatures and leaching times, possibly with the addition of hydrogen peroxide or ozone. The oxidizing agent ozone proved to be the most successful. However, the recovery of metals from electroplating sludge using inorganic acids is still limited. Acid alone without other oxidizing agents showed poor leaching properties. In terms of the research being conducted, it is necessary to select process parameters that will increase the concentration of zinc and iron, which are the highest in the electroplating sludge, in a single test.

The next procedure will be to convert the zinc and iron metals of interest from the leach by electrolysis or chemical precipitation.

ACKNOWLEDGEMENT

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OPTIMALIZATION FLOWABILITY IN CENTRIFUGAL CASTING WITH PARAMETER OF ROTATION SPEED

OPTIMALIZACE ZABÍHAVOSTI ODSTŘEDIVÉHO LITÍ, PARAMETREM RYCHLOSTI ROTACE

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Abstract

The aim of the experiment was to determine the appropriate rotation speed at which the best values of flowability can be achieved. An initial opinion was given that flowability will improve with increasing rotation speed. In designing the experiment, an attempt was made to achieve the highest possible stability of the other casting parameters, so that the only influencing change was the change in rotational speed. Other parameters affecting casting are the casting temperature, the amount of melted material to be cast, the mould temperature, the horizontal pressure on the mould and the choice of melt to be cast. The Zinc alloy used for this experiment was ZnAl4Cu3 with the company name Zamak.

Keywords:

Tekcast, centrifugal casting, precision casting, rubber mold, flowability

1. INTRODUCTION

Centrifugal casting is a technology that uses rotational movement of the mould. This rotation creates a centrifugal force that helps to improve the flowability of the liquid metal into the mould cavity. The method is divided into two categories, centrifugal casting with the axis of rotation coinciding with the geometric axis of the casting (true centrifugal casting) and centrifugal casting with an axis different from the geometric axis of the casting (false centrifugal casting) [1, 2, 3, 4].

An ideal example of true centrifugal casting is the process of centrifugal casting of cylinders, e.g. for rolling mills. True centrifugal casting can be divided into horizontal and vertical casting, but in both cases a similar casting process can be observed. The process begins with the start of the mould rotation. When the mould reaches the desired rotation speed, the mould is ready to be filled with melt. After the melt begins to fill the mould cavity, the rotation of the mould surface by centrifugal force distributes the molten material throughout its volume. The rotation continues until solidification. This method allows the casting of hollow rotational products without the use of a core [1,2,4,5,7].

In the case of false centrifugal casting, at first glance it looks similar to true centrifugal casting, but it is not. The rotation is in the vertical axis, but the product cavities are positioned around this axis. The axis of rotation and the geometric axis of the product are different. One of the methods of false centrifugal casting is a technology referred to, for example, by the trade name Tekcast. Primarily, this method is used for high serial production of small casting products [1,3,6,7,8].

2. EXPERIMENT

2.1. Mould

The research was carried out on test specimens placed in the mold cavity, arranged in a semicircular pattern as shown in Figure 1. The specimens are steel bars with a length of 100mm and diameters of 1, 1.5, 2, 2.5, 3, 4 and 5mm. The models represent the gate diameters of the inlet system. This semicircular pattern is placed twice in the mould to obtain two castings of the same diameter, in one casting.

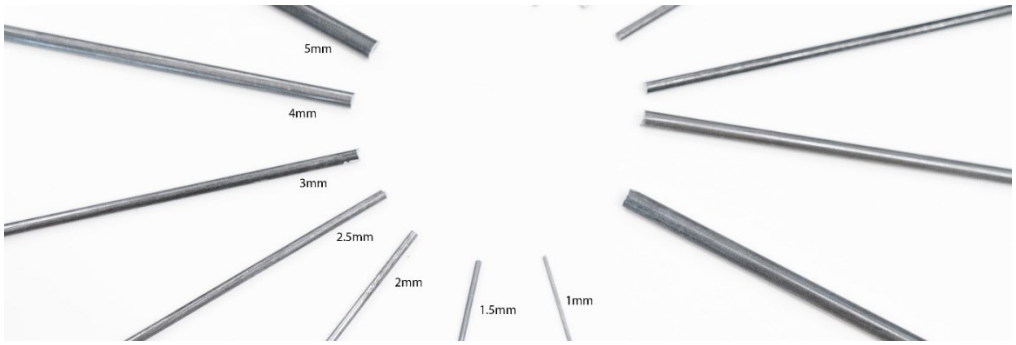

Figure 1 Placement of models in the form Source: (own)

The Tekcast method uses moulds made of rubber, which are then cured by vulcanisation. For this research, a rubber compound called "ivory" was chosen to produce the mould with a size of 300mm in diameter. This rubber material is characterised by its higher hardness and high resistance to mechanical wear. Its detailed specifications can be seen in Table 1. The mould is vulcanised according to the values set by the manufacturer. The vulcanisation process was carried out at a temperature of 150 °C and a pressure of 150 bar for 110 min. Due to the high vulcanisation temperatures, it is necessary to insert models into the mould that can withstand these temperatures without breaking.

Table 1 Specifications for rubber mould material. Source: [9].

COLOUR	RESTORATIVE CHARACTER	LABEL OF HARDNESS SHORE	TYPE OF MODEL	TEMPERATURE OF VULCANIZATION RUBBER	VULCANIZATION TIME
IVORY	HARD	70/74	FLAT	120 °C - 180 °C	2.5-3 min for mm

The models are placed in the mould at a distance of 5mm from the inlet, so it was necessary to make a gate to them to allow for filling. A 2.5mm wide chisel was used to create the gate. This width was maintained for all castings examined.

Figure 2 Detail of gates. Source: (own)

Casting was carried out on Tekcast equipment enabling centrifugal casting with a maximum rotational speed of 900RPM. The rotational speeds we tested were 500, 900 and 700RPM, in that order. The following tables are also ordered according to this sequence. All of these tests were tested using the manufacturer's recommended 3.5bar of pressure on the mould surface. The rotation time was 1 min.

2.2. Evaluation

The evaluation of the flowability after casting was assessed by measuring the resulting lengths of the tested castings. These lengths are given in the following tables, which are divided according to the individual rotation speeds. In an effort to achieve results that were as unaffected as possible, the mould temperature and melt pour temperature parameters were monitored. The mould temperature parameter was monitored in the range of 45-55 °C. The melt temperature value was in the range of 435±3 °C.

Table 2 Resulting values of flowability at speed rotation 500RPM. Source: (own)

1. (500ot.min)	mould temp. (°C)	melt temp.(°C)	rotation (RPM)	pressure (bar)	1	1.5	2	2.5	3	4	5
1.	54	435	500	3,5	6	19	12	20	0	88	89
					15	7	23	51	14	62	52
2.	52	435			13	16	46	64	48	57	77
					20	60	43	44	37	77	43
3.	49	432			53	47	65	82	100	100	100
					59	100	48	100	76	100	100
4.	51	435			11	44	34	62	73	87	100
					28	54	46	100	100	88	100
5.	52.5	438			9	28	56	73	70	100	100
					22	27	49	100	81	100	100
					23,6	39	42,2	69,6	59,9	85,9	86,1

Table 3 Resulting values of flowability at speed rotation 900RPM Source: (own)

2. (900ot.min)	mould temp. (°C)	temp. furnace (°C)	rotation (RPM)	pressure (bar)	1	1.5	2	2.5	3	4	5
1.	46.6	435	900	3,5	9	27	61	100	100	100	100
					19	51	65	80	100	100	100
2.	45.7	436			25	45	32	100	100	100	100
					15	31	60	63	100	100	100
3.	50.5	436			15	51	45	79	100	100	100
					5	8	27	55	71	100	100
4.	52.1	436			13	07	44	89	100	100	100
					8	21	60	66	83	100	100
5.	51.7	435			26	71	65	100	100	100	100
					25	29	55	83	100	100	100
					16	34,1	51,4	81,5	95,4	100	100

Table 4 Resulting values of flowability at speed rotation 700RPM. Source: (own)

3. (700ot.min)	mould temp. (°C)	temp. furnace (°C)	rotation (RPM)	pressure (bar)	1	1.5	2	2.5	3	4	5
1.	51.5	435	700	3,5	16	39	46	88	100	100	100
					13	39	59	60	77	100	100
2.	52.2	434			11	27	49	49	52	100	100
					12	1	17	48	62	100	100
3.	53	435			7	35	38	65	100	100	100
					11	30	29	59	100	100	100
4.	52.1	436			23	13	42	76	100	100	100
					10	62	87	79	78	100	100
5.	52.7	435			17	48	40	78	100	100	100
					22	53	56	59	69	100	100
					14,2	34,7	46,3	66,1	83,8	100	100

With increasing rotation speed, flowability values improve only for wider sample diameters. In the case of thin samples, the opposite is true and better flowability values are achieved with slower rotation.

2.3. Surface of the casting

Evaluation of the casting surface at 500,700 and 900RPM showed that the best surface was offered by casting at 900RPM. This surface quality decreases with decreasing rotational speed. However, the better surface quality at maximum speed is accompanied by melt flow into the mould parting plane. This unwanted run-in also occurs at a mean value of 700RPM, but to a lesser extent.

3. CONCLUSION

As a result of this work, it was found that the increase in flowability cannot be solved only by increasing the rotation speed. This statement is valid only in the case of test castings with a diameter above 1.5 mm. Increasing the rotation speed showed that for test castings with diameter below 1.5mm, the ability to fill the mould is reduced. In the case of test castings above 1.5mm, there was an improvement with the increase in rotation speed. This phenomenon was also evident in the case of a mean rotational speed of 700RPM, where the increase in flowability occurred only in the 2-2.5mm diameter range.

Continuation of this research will seek to achieve results in rotational speeds of 400, 600 and 800RPM to complete the rotational speed parameter. Subsequently, the research will continue to investigate the other parameters affecting the flowability, which are mould temperature, melt temperature and horizontal pressure on the mould during casting.

ACKNOWLEDGEMENT

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EXPERIMENTAL SMELTING OF LADLE SLAGS INTENDED FOR STEEL DESULFURISATION

LABORATORNÍ EXPERIMENTÁLNÍ TAVBA PANVOVÝCH STRUSEK URČENÝCH PRO ODSÍŘENÍ OCELI

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Abstract

The paper presents an analysis of laboratory melting furnaces used in refining slag studies, especially for comparing of calculated desulfurization of steel using FactSage software. The result of the analysis is the design of a suitable laboratory experiment, which deals with the optimization of the steel desulfurization process.

Key words:

Slag, desulfurization, secondary metallurgy, low sulphur steel, ladle slag.

1. INTRODUCTION

Improving the competitiveness of steel companies is linked to sustainable and satisfactory steel production. Ladle metallurgy is the last place where the chemical composition of steel can be further modified, steel inclusions can be partially removed and negative elements in steel such as sulfur can be reduced. Under operating conditions, it is often very difficult to perform a series of targeted experiments to verify the effectiveness of the chosen metallurgical process in reducing the sulfur content, so in many cases experimental experiments in laboratory conditions are used [1, 2, 3].

The topic of the expert article is an outline of the method and implementation of a desulfurization experiment of steel under refining slag in laboratory conditions. After melting and metal sampling, the sulfur content of the steel will then be analyzed in a combustion analyzer available from the Department of Metallurgy and Foundry. The sampling of refining slag will also be carried out, which will be analyzed in the laboratory in cooperation with iron and steel works (Třinecké železárny). The Department of Metallurgy and Foundry has a few laboratories equipment at its disposal, from the combustion analyzer to the physical models of the refining ladle to the induction melting furnaces. In our case, for laboratory simulation of desulfurization of steel by refining slag, we will use the generator HFR 25 for induction melting and for determining the sulfur content in metal Combustion analyzer G4 ICARUS CS HF. Among other things, the Department of Metallurgy and Foundry has purchased a relatively new software FactSage, which is used to evaluate the course of metallurgical processes. FactSage is a thermodynamic / thermochemical software which, based on thermodynamic calculations of energy functions from empirically obtained values of thermophysical properties of materials (heat capacity, enthalpy, phase change temperatures, etc.), steels and slag, determines eg phase or chemical transformations during metallurgical processes.

Due to the application of the relatively new FactSage software in metallurgy, the aim of the presented article is to perform a literature search dealing with experimental melting of refining slags in laboratory conditions. The results from laboratory smelting should serve to confirm the accuracy of calculations and simulations of steel desulfurization in SW FactSage.

2. CHARACTERISTICS OF LABORATORY MELTING AGGREGATES

This part of the chapter will deal with the analysis of melting furnaces, which the authors of the articles [4-6] used for their experiments. These findings will help us to understand and develop our own methodology for performing experimental desulfurization melting.

Experiment description

The authors of the articles [4-5] performed an experimental melting dealing with the properties of two types of shot mixtures based on MgO and Al_2O_3.

The laboratory experiment was performed for aluminum deoxidized low carbon steels. A sample of steel weighing 200 g was melted in a pre-prepared corundum crucible using a laboratory resistance furnace LaCrO3 element (see Figure 1) under inert gas. Steel sampling was performed during melting using a corundum tube with a diameter of 4 mm. Samples were taken at 5 g at intervals of 30, 60, 90, 120 min. Analysis of the samples was performed using an emission scanning electron microscope and a dispersion spectrometer (EDS, Model: Le350 PentalFETx-3) to analyze the microstructure of the metal. Phase changes of the refractory material were performed using an X-ray diffractometer. The phases that were detected based on X-rays were subsequently confirmed by FactSage software. Thanks to the FactSage 6.1 software, the melting points Fe_2SiO_4, $CaMgSi_2O_6$, $CaFe_2O_4$ and $CaFeSi_2O_6$ could be detected at 1211.1 ° C, 1376.6 ° C, 1229.7 ° C and 1173.1 ° C using the equilibrium function. The FT-oxide database was used in the calculation [4-5].

Another experimental experiment is the desulfurization of the super-nickel alloy Incoloy 825 with a refining slag based on $CaO-Al_2O_3-MgO-TiO_2$. Nickel-based super alloys, which are characterized by excellent high temperature strength and corrosion resistance, are used mainly in the aerospace industry. Reducing the sulfur content of the nickel alloy does not impair the tensile strength and the resistance to crack propagation. Therefore, it is necessary to reduce the sulfur content of nickel-based alloys [6].

The experiments were performed using a high frequency induction furnace (see Figure 2). Prior to melting the alloy sample, the working chamber of the melting furnace was cleaned of atmospheric air. A sample of super alloy weighing 500 g was placed in a melting MgO crucible (inner diameter 51 mm, outer diameter 60 mm and height 100 mm), which was covered with insulation. After reaching a temperature of 1500 ° C, a sample of 50 g was injected into the sample furnace through a quartz tube before the prepared slag-forming mixture. Samples of the alloy were taken at intervals of 5, 10, 20, 30, 60 minutes. The sulfur content of the slag and metal were measured using a combustion analyzer (CS 800, ELTRA). The chemical composition of the nickel alloy was determined by inductively coupled plasma atomic emission spectrometry (ICP-AES, ACROS, SPECTRO) [6].

It was experimentally confirmed that the level of MgO saturation in the slag was 5.5 to 7 wt. %. The results of the saturation of the MgO slag during melting coincided with the obtained results determined by the FactSage 7.3 software, namely 6-8 wt.% MgO [6].

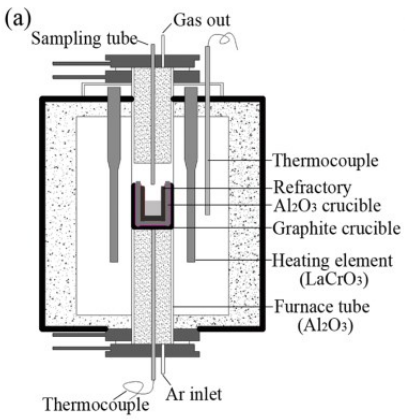

Figure 1: resistance furnace LaCrO3 element. Source: [4]

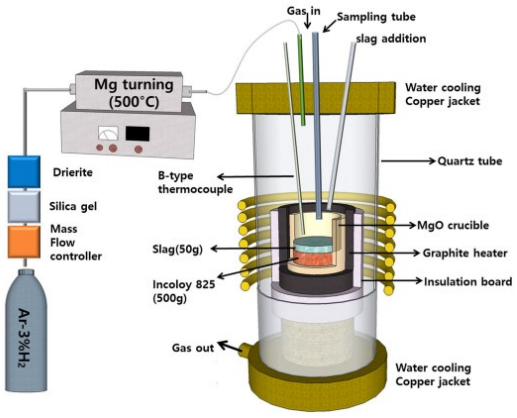

Figure 2: high frequency induction furnace. Source: [6]

Electric melting furnaces can be divided into three basic groups: arc, induction, and resistance furnaces. Electric induction furnaces are furnaces where the charge is heated and melted by eddy currents, the formation of which is related to electromagnetic induction. On the other hand, we have electric resistance furnaces, in which heat is generated by the passage of an electric current through resistance cells. Each of the furnaces in question has advantages and disadvantages [2].

The disadvantage of the induction furnace is the low temperature of the slag and the associated worse course of the reaction between the metal and the slag. The advantage of the induction furnace is the precise regulation of the bath temperature, there is no carburization of the molten bath, the charge swirls and there is better mixing of the melt, minimal loss of alloys [2].

3. DESIGN OF AN EXPERIMENTAL EXTRACTION OF STEEL DESULFURIZATION BY REFINING SLAG IN LABORATORY CONDITIONS

Performing experimental smelting in operating conditions is financially and time consuming, so companies turn to research centers with a request to perform experimental simulations of metallurgical processes in laboratory conditions. As mentioned above, the goal of my research is to confirm the accuracy of the simulation result with FactSage software and a laboratory experiment.

To imitate the experiment in our laboratories, it was necessary to perform a literary analysis by foreign authors and, according to them, to imitate the experiment.

Experimental melting

An electric induction furnace HFR 25 (see Figure 3), which is in the metal melting laboratory at the Department of Metallurgy and Foundry, will be chosen for the experimental melting. The HFR 25 induction furnace is used to melt the sample and monitor eg overburden. Furthermore, it can be used to study the chemical composition of samples after melting under different conditions, eg when using different refining slags. Corundum crucibles are used for melting.

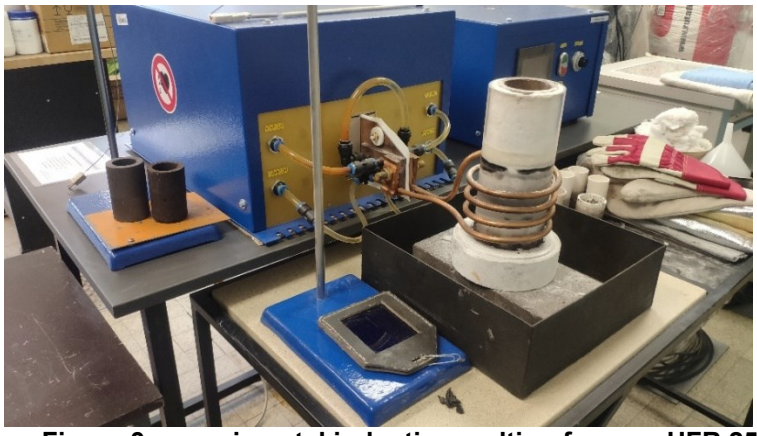

Figure 3: experimental induction melting furnace HFR 25.
Source: (own)

To simulate the desulfurization of steel with refining slag, a steel with a higher sulfur content will be selected, for which we will know the initial sulfur contents in the metal. Free-cutting steel samples are prepared so that their weight is 250 g, diameter 29 mm and height 50 mm. For these sample parameters, the correct crucible size must be selected. A corundum crucible with a diameter of 51 mm and a height of 78 mm, which are prone to cracking, will be chosen for the experiment, so it is necessary to observe a gradual heating. An important part for melting is the preparation of slag-forming additives. The preparation of slag-forming additives consists in creating a table with the chemical composition of the four basic raw materials Al_2O_3, SiO_2, CaO, MgO. These raw materials are weighed 20 g according to Table 1 and then crushed and mixed in a ceramic mortar.

Table 1: Ranges of chemical composition of the examined ladle slag. Source: (own)

Chem. composition				Total	Chem. composition converted to wt%				Total
Al_2O_3	CaO	SiO_2	MgO		Al_2O_3	CaO	SiO_2	MgO	
[g]				[g]	[Wt %]				[hm %]
5	11	2,6	1,4	20	25	55	13	7	100

The metal sample of the free-cutting steel is placed in the space of the induction melting furnace and allowed to melt. During the melting of the sample, we will blow inert gas argon, which protects the metal sample from atmospheric air. When we reach the liquidus temperature (1500 ° C) of the metal sample, we then inject slag-forming additives with a funnel and let it react with the metal for

20 minutes. After reaching 20 minutes, we take a sample of the slag and allow the metal with the slag to cool in a crucible. When the metal crucible cools, a sample of the metal is taken in the form of chips, which are analyzed for the presence of sulfur in the metal in a combustion analyzer G4 ICARUS CS HF paced in laboratory of crystallization simulation and combustion analyzes.

The output would be a comparison of the sulfur content before and after the refining of free-cutting steel depending on the chemical composition of the refining slag. The optimal chemical composition of the slag intended for desulfurization reactions is determined based on the degree of desulfurization. The determination of the optimal chemical composition of the slag should theoretically correspond to the results of the simulation by the FactSage software.

4. CONCLUSION

This article was created to perform a literature analysis of the issues dealing with laboratory experiments of desulfurization of steel and to find the system of performing the experiment in our laboratories. Great emphasis was also placed on the use of SW FactSage to optimize refining processes and compare with experimental results. It is not always easy to achieve an optimal laboratory experiment so that the results are usable in operation. The analysis I performed can be summarized in the following points:

- The authors of the article (4-5) performed an experiment that dealt with the effect of the shotcrete mixture on the purity of steel. They found that the MgO-based shot mix had higher metal penetration effects and therefore evaluated it as unsuitable for use. Another Al_2O_3-based shot mix was evaluated positively because the metal was not wetted with a protective coating and therefore no penetration occurred. The phases that formed in the interaction of the metal with the protective surface were confirmed both experimentally and SW FactSage 6.1.
- Desulfurization study Ni-based superalloy (Incoloy 825 superalloy), which was melted together with slag based on CaO-Al_2O_3-MgO-TiO_2. Where the saturation of MgO in the slag in the range of 5.5 -7% by weight was confirmed experimentally. This was confirmed by the calculation of SW Factsage 7.3, which stated a saturation of MgO slag from 6 to 8% by weight.
- The output of the experimental simulation of steel refining in laboratory conditions would be to determine the sulfur content of the metal before and after refining and compare the experimental results with calculations with SW FactSage.

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Obor:

Tepelná technika a paliva v průmyslu

THE OPTIONS FOR REDUCING NO_X EMISSIONS FROM WASTE INCINERATION

MOŽNOSTI SNIŽOVÁNÍ EMISÍ NO_X PŘI SPALOVÁNÍ ODPADU

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Abstract

The aim of the experiment was to verify the possibility of nitrogen oxides (NO_x) reduction by iron compounds dosed into the flue gas stream under different combustion conditions. The motivation for conducting the experiment was to find cheap and available compounds that could streamline the process of existing denitrification methods in use. Such substances could be, for example, iron scale. The results of the present research confirm that the use of additives in the form of iron compounds can, with appropriate combustion process configuration, reduce the amount of NO_x emissions produced, which can thus be crucial in meeting the increasingly stringent legislative requirements for reducing emission limits.

Key words:

Combustion, reduction of NO_x, additive, ammonia.

1. INTRODUCTION

The present research focused on selective non-catalytic reduction, which is conceptually a simpler process for NO_x control under laboratory conditions. The reducing agent is injected and thoroughly mixed with NO_x containing flue gas at temperatures between 870 and 970 °C, whereby NO_x is selectively reduced by a rapid homogeneous reaction. Ammonia can be non-selectively oxidized to N_2O and NO in the presence of oxygen, which is considered as an undesirable reaction. In most cases, ammonia or urea is used as a reducing agent in industry. A detailed review on the studied issue of NO_x emission reduction in flue gas is given by sources such as [1], [2], [3], [4], [5], [6]. While NO_x reductions of up to 90 % have been achieved under laboratory conditions, in real operations the SNCR efficiency varies much less due to the many parameters that affect the achieved efficiency. The SNCR issue includes several key areas: the size and position of the temperature range (temperature window), the design of the ammonia application nozzle, the effect of the amount of oxygen, the effect of other components (SO_2, H_2O), the effect of additives (CO, hydrocarbons, H_2, metal oxides, surfactants), the effect of the NO_x/NH_3 molar ratio, the effect of the initial NO concentration, the residual ammonia emission, the N_2O emission, the effect of the contact time, the effect of the pressure, and others.

2. EXPERIMENT DESCRIPTION

The experiment was carried out on a periodically operating two-chamber furnace for waste incineration with a maximum output of 30 $kg \cdot h^{-1}$ at a net calorific value of 17 $MJ \cdot kg^{-1}$. In the first part, emissions were measured only when natural gas was burned while ammonia and iron additives were added to the flue gas stream. In the second part, measurements were made of the composition of emissions and the effect of the dosed additives on the amount of NO_x contained during RDF combustion with simultaneous thermal stabilization of the process by natural gas burners. Substances contained in the flue gas entered the reaction. In the case of pure natural gas combustion, mainly CO_2, H_2O and NO_x were generated. In the case of natural gas and RDF combustion, in addition to these substances, gaseous products of RDF combustion such as SO_x and other VOC-based flue gases were involved in the reaction. The atmosphere for the ongoing reactions was oxidative due to the high amount of O_2 (≥ 11 vol%) in the flue gas. Gaseous NH_3 was used as a reducing agent injected into the flue gas stream and dosed through a nozzle located at the bottom of the horizontal flue gas duct

downstream of the ABC. The iron-based additives in the form of ground powder were dosed through the nozzle into the flue gas stream in the direction of flow. The dosing of the additives was carried out by a screw doser at the bottom of the vertical flue gas duct downstream of the ammonia application point. Pressurised air was used as the carrier medium for the additives.

THE ADDITIVES USED

The iron-based additives used during the experiment were siderite and iron scale. Ferric carbonate ($FeCO_3$) so called siderite (also known as steel in older literature) is a brownish yellow mineral that was formerly a more widely used iron ore. It contains 25 to 40 % of iron. Before reduction, it was treated by roasting to oxidize the carbon and increase the iron content. Iron scale is a waste material from metallurgical processes. Its composition is highly dependent on the type of process and its conditions (temperature, atmosphere, etc.). They are mainly composed of wüstite (FeO), magnetite (Fe_3O_4) and hematite (Fe_2O_3) [7].

CALCULATION OF DENITRIFICATION EFFICIENCY (CONVERSION)

The amount of NO_x is expressed as the sum of the NO and NO_2 components as reported in practice in authorised measurements. The measured and calculated values are related to normal temperature and pressure (273.15 K, 101 325 Pa) and to dry flue gas with a reference oxygen content (11 % by volume). In order to objectively evaluate the efficiency of denitrification, it was necessary to calculate the so-called conversion, which is the relative change in the amount of NO_x after reduction relative to the values before reduction according to relation (1) below [7].

$$K_{NO_x} = \frac{C^0_{N,S,R,NO_x} - C^{red}_{N,S,R,NO_x}}{C^0_{N,S,R,NO_x}} \cdot 100 \quad (1)$$

where:

K_{NO_x} – conversion of formed NO_x (%),

C^0_{N,S,R,NO_x} – mass concentration of NO_x without applied deNO_x measures ($mg \cdot m_N^{-3}$),

C^{red}_{N,S,R,NO_x} – mass concentration of NO_x after application of deNO_x measures ($mg \cdot m_N^{-3}$).

DETERMINATION OF NO_X EMISSIONS FROM NATURAL GAS COMBUSTION

Table 1 shows the measured and calculated NO_x values in the flue gas only from natural gas during ammonia injection in the temperature range 868 to 878 °C. The initial NO_x concentration for the conversion calculation (measured in the mode without injection of both ammonia and additives) was 113.03 $mg \cdot m_N^{-3}$ [8].

Table 1 Measured and calculated values of natural gas combustion. Source: (own)

Reference value of NO_x = 113.03 $mg \cdot m_N^{-3}$ 0 $l \cdot min^{-1}$ of NH_3/without additives	Temperature range of injected NH_3 868 to 878 °C Amount of injected NH_3 ($l \cdot min^{-1}$)		
	1	4	5
Amount of NO_x in flue gas ($mg \cdot m_N^{-3}$)			
Without additive	116.93	103.02	103.15
Siderite	116.81	100.95	101.24
Dried scale	117.32	103.83	102.63
Conversion of NO_x in flue gas (%)			
Without additive	-3.45	8.86	8.74
Siderite	-3.34	10.69	10.43
Dried scale	-3.80	8.14	9.20
Difference in conversion after and before additive application (%)			
Siderite	0.11	1.83	1.69
Dried scale	-0.35	-0.72	0.46

It is clear from the calculated values that the maximum NO_x conversion in the flue gas (10.69 %) occurred in the siderite dosing mode and simultaneously when ammonia was injected into the flue gas stream in the amount of 4 l·min^{-1}.

DETERMINATION OF NO_X EMISSIONS FROM THE COMBUSTION OF NATURAL GAS WITH RDF

In the second phase of the experiment, the NO_x reduction by iron compounds was verified by burning refuse derived fuel (RDF). In the experiment, 4 l min^{-1} of ammonia was injected at an injection temperature range of 875 to 894 °C. The baseline NO_x concentration for the conversion calculation (measured in the mode without injection of both ammonia and additives) was 194.90 mg·m$_N^{-3}$. The additives used were again siderite and dried scale. The measured and calculated values are shown below in Table 2 [8].

Table 2 Measured and calculated values of natural gas combustion with RDF. Source: (own)

Reference value of NO_x = 194.90 mg·m$_N^{-3}$ 0 l·min^{-1} of NH_3/without additives	Temperature range of injected NH_3 875 to 894 °C Amount of injected NH_3 4 l·min^{-1}		
	Without additives	Siderite	Dried scale
Amount of NO_x in flue gas (mg·m$_N^{-3}$)	140.26	130.63	130.06
Conversion of NO_x in flue gas (%)	28.03	32.98	33.27
Difference in conversion after and before additive application (%)	–	4.94	5.23

Significantly higher NO_x conversions were found in the mode of natural gas with RDF combustion. This behaviour can be explained by the presence of hydrocarbon radicals formed during its combustion. The NO_x conversion values for siderite and scale are comparable.

COMPARISON OF RESULTS

The experimental results support the conclusions of some foreign studies [9, 10] that the conversion of NO_x by iron compounds is also enhanced by the presence of hydrocarbon radicals in the reaction zone. In this case, their source was the combustion of RDF. The comparison of the obtained results for the used additives depending on the presence of compounds from RDF combustion is expressed graphically in Figure 1. The comparison is made for a comparable application temperature of ammonia and based on the same amount of injected NH_3, which had a value of 4 l·min^{-1}.

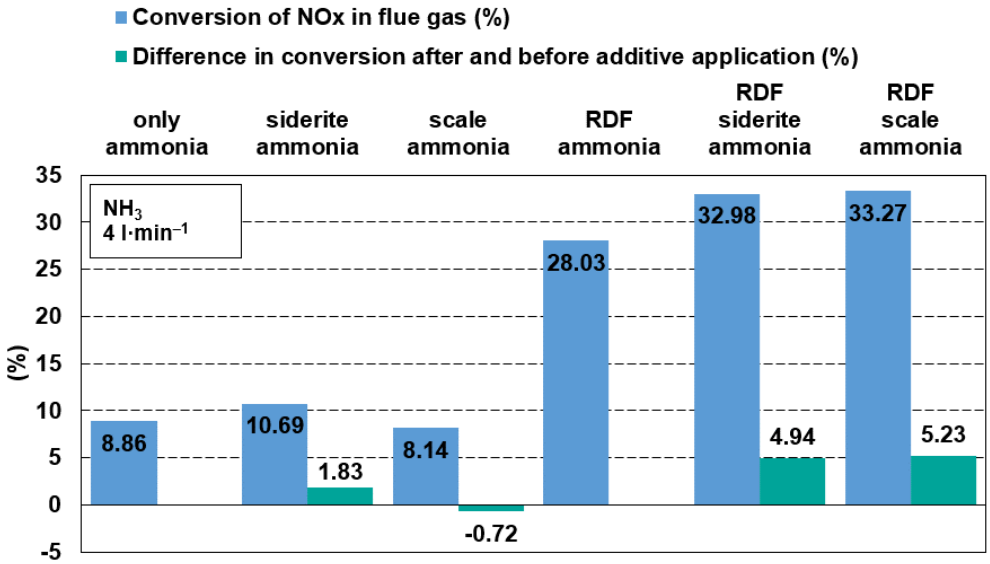

Figure 1 Comparison of results. Source: (own)

It is evident from all the measured data that it is not possible to find trivial dependencies and thus simply describe the behaviour of additives due to changes in ambient conditions. The behaviour of additives is highly variable depending on the injection temperature of the reducing agent, the

amount of reducing agent, the design of the application nozzle, the distance of the injection point of the reducing agent from the point of dosing of the additive and also the type of additive. In some cases, elevated CO concentrations were measured in the flue gas, which were due to reactions taking place in the flue gas duct. The highest CO concentration in the flue gas was measured in the siderite dosing regime. The formation of CO may have occurred during the thermal decomposition of siderite. For a detailed understanding of the dependence of the behaviour of iron compounds in NO_x reduction, experiments at a larger range of reaction temperatures and also at a wider range of ammonia injection rates will be necessary. In the experiment conducted, the limiting factor was the maximum adjustable ammonia flow rate of 5 $l \cdot min^{-1}$ and the limited possibilities in setting and stabilizing the injection site temperatures. It would also be useful to make measurements when changing other parameters of the experiment. For example, measure data for different shapes and nozzle designs for ammonia injection and determine the dependence of nitrogen oxide reduction on these parameters.

3. CONCLUSION

The experiment verified the possibility of NO_x reduction by iron compounds dosed into the flue gas stream. The results showed that the reduction efficiency is highly dependent on many parameters. The highest and comparable NO_x conversion was achieved using two different additives, namely siderite and dried scale, under almost identical conditions in the refuse derived fuel combustion regime. The results therefore confirm that the use of additives in the form of iron compounds can, with a suitable combustion configuration, reduce the amount of NO_x emissions produced, which can thus be crucial in meeting the increasingly stringent emission limits. The results from the comparison of combustion of natural gas only and the combination of natural gas and RDF support the claim of some foreign studies that the presence of hydrocarbon radicals is necessary for the intensification of the denitrification process, which in our case originated from the combustion of RDF. The results are interesting in terms of the possibility of increasing the efficiency of the SNCR method with very little increase in operating costs due to the use of scale, which is a waste product from metallurgical production. Considering the results obtained, it is certainly relevant to further address the issue of reducing nitrogen oxides in flue gas by iron compounds.

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Obor:

Chemická metalurgie

REVIEW ON COMMON HEAT TRANSFER FLUIDS USED IN CONCENTRATING SOLAR–THERMAL POWER SYSTEMS

PŘEHLED BĚŽNÝCH TEPLONOSNÝCH KAPALIN VYUŽÍVANÝCH V CSP SYSTÉMECH

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Abstract

This paper presents a brief insight into the matter of heat transfer fluids, particularly the most widely used alkali metal nitrate salts operating in concentrated solar–thermal power systems as heat carriers. Although it is not a typical scientific article but rather a mini-review, attention was paid to the preparation methodology and mainly to the measurement of heat transfer fluids of my future concern. The primary outcome is to describe the current state of scientific knowledge and present my dissertation's future orientation.

Key words:

Heat transfer fluids, solar salt, nitrates, rheological properties.

1. INTRODUCTION

With the growing interest in sustainable energy production and the need to reduce carbon dioxide emissions, renewable energy sources are making their mark on the world's energy requirements. The forecast of renewables favors solar energy, as shown in Figure 1, with high expectations for energy harvesting through photovoltaics and concentrated solar power.

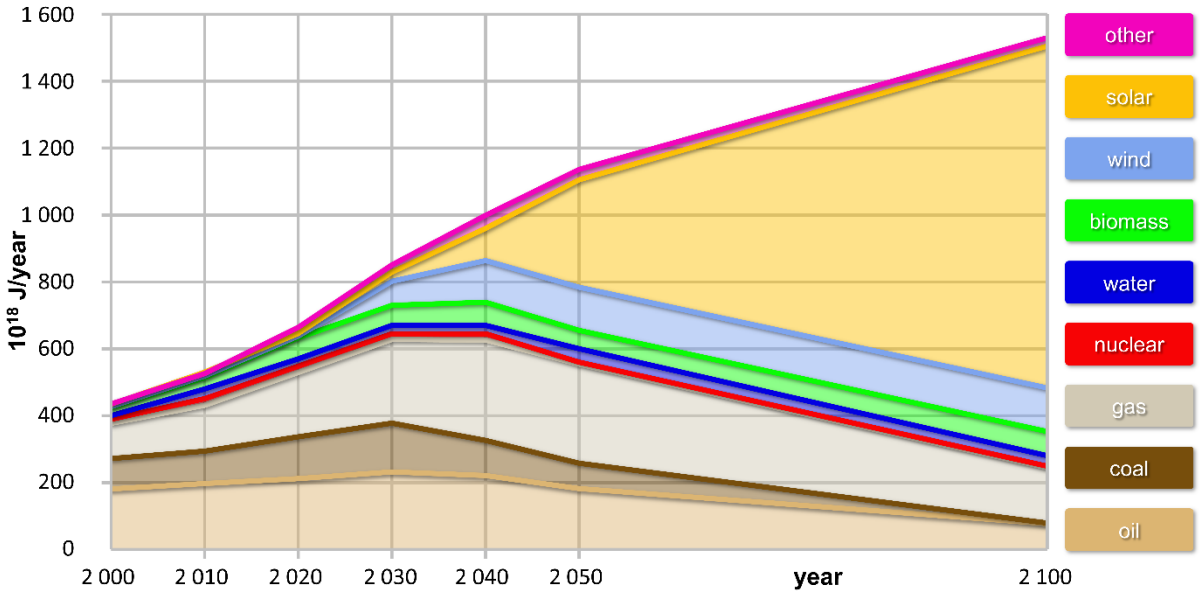

Figure 1 Global energy supply until 2100. Source: [1]

Concentrated solar–thermal power systems, which have been profiled in various configurations, such as parabolic, linear (Fresnel reflector), or solar energy tower, share in common their purpose, i.e., conversion of solar radiation to heat. Typically, a solar thermal power plant

comprises four main components: the solar concentrating system, the receiver, the thermal energy storage, and the thermodynamic cycle coupled with the electric generator. They can vary in reflector configuration, concentrating sun rays onto a line or a central point where the receiver is located. The receivers absorb concentrated radiation and pass it to a heat transfer fluid (HTF). The final transmission stage is represented by the working fluid circulating in the thermal block, transforming the heat into mechanical energy. Heat can be stored either in a thermal energy storage tank, which, incidentally, is a significant advantage over competitive photovoltaic systems, or converted into electricity via a turbine generator [2, 3].

Since there are various solar power system arrangements, the heat transfer fluids are tailored to specific demands, e.g., they must be compatible with pipe lining and storage media, act in the required temperature range, thus having a low melting point and a high maximum temperature, which increases the efficiency of heat transfer cycles. Speaking of heat transfer properties, the temperature difference between the receiving surface and the HTF should be moderate to ease thermal stress on the surface. Furthermore, high thermal conductivity and low viscosity are beneficial too. A large specific heat capacity allows direct thermal storage, although indirect solutions with a secondary medium are also possible. In terms of economic aspects, good material compatibility with HTF is necessary to reduce maintenance costs [4, 5].

This literature search was carried out to provide a comprehensive understanding of HTFs, their key properties, optimization, and measurement methodology, which will be used in planned rheological and calorimetric experiments.

2. PREPARATION OF HTFs BASED ON NITRATES

Routinely, the mixtures are prepared from particular salts of analytical purity. Then, these salts are dried under an inert atmosphere, mixed in crucibles, and heated to a liquid state. For the salts where hydration is expected, drying takes longer time to allow water to evolve slowly [6].

Preparation of molten salt-based nanofluids needs a two-step approach. Firstly, nanoparticles are dispersed in distilled water and sonicated to break the agglomerates. Then, the eutectic salt is added to this solution and dissolved in the suspension by further sonication. Finally, the nanofluids are heated up till the water is entirely evaporated [7-9].

3. MEASUREMENT METHODOLOGY

The methods of importance for assessing HTF properties are differential scanning calorimetry and rheometry. Tests are performed in the desired temperature range at a low heating rate. The temperature program for analysis of rheological properties consists of temperature dwells where viscosity is measured after the normal force and torque are stabilized. The measurements are conducted in either air or an inert atmosphere. In the case of both methods, a platinum measurement system is usually involved, whose implementation is costly. Nevertheless, there are suitable alternatives, such as the Inconel alloy, which can sufficiently resist the hostile conditions of melted salts. The measurement of thermal properties, such as heat capacity, is challenging owing to many factors, e.g., heat transfer mechanisms, sample purity, etc. It is not an exemption to observe positive or negative slopes and even constant values when measuring heat capacity as a function of temperature for the same salts. As for the rheological properties, the temperature dependence of the viscosity commonly obeys the Arrhenius equation. Pure salts and eutectic mixtures exhibit Newtonian behavior, while Newtonian and non-Newtonian behavior is expected for suspension. On the contrary, some studies suggest that nanofluids tend to behave as Newtonian fluids in a wide temperature range [6, 8-12]. The Department of Physical Chemistry and Theory of Technological Processes is sufficiently equipped in terms of instrumentation. We possess a high-temperature observation furnace CLASIC, a high-temperature rheometer (FRS 1600), apparatus for differential thermal analysis and differential scanning calorimetry (Setaram Setsys 18_{TM} instrument equipped with S-type thermocouples), enabling optimization of the heat transfer fluid parameters mentioned earlier. However, it should be noted that the matter of HTFs is challenging, and intensive negotiations are currently ongoing with suppliers to purchase a suitable measurement system that is capable of withstanding the aggressive behavior of molten salts.

4. IMPORTANT PROPERTIES OF NITRATE MELTS

The main properties of heat transfer fluids are heat capacity, thermal conductivity, viscosity, melting temperature, and operating temperature range. Solar salt is the basic HTF used in CSP

technology, expressed in mass fractions as 60 wt.% $NaNO_3$ and 40 wt.% KNO_3. It can be used in the whole operating temperature range from 260 °C to 600 °C, with a liquidus temperature of 221 °C, while pure KNO_3 has a melting point of 334 °C and pure $NaNO_3$ of 307 °C. Hitec is a ternary molten salt having a composition of 53 wt.% KNO_3, 40 wt.% $NaNO_2$, and 7 wt.% $NaNO_3$. It is stable and liquid in the range of 142–535 °C. This shows that eutectic mixtures of two or more salts can significantly decrease the melting point while maintaining a very high boiling point [13].

The rheological properties are important to assess the flow characteristics of the melted salts. They have a relatively high viscosity compared to other HTFs and, therefore, have poor flow properties, which causes follow-up costs. Since the Reynolds number is superior to 4 000 for most HTFs over a wide temperature range, only turbulent flow is considered in the pipelines. It should be noted that turbulence increases heat transfer in a heat exchanger [2].

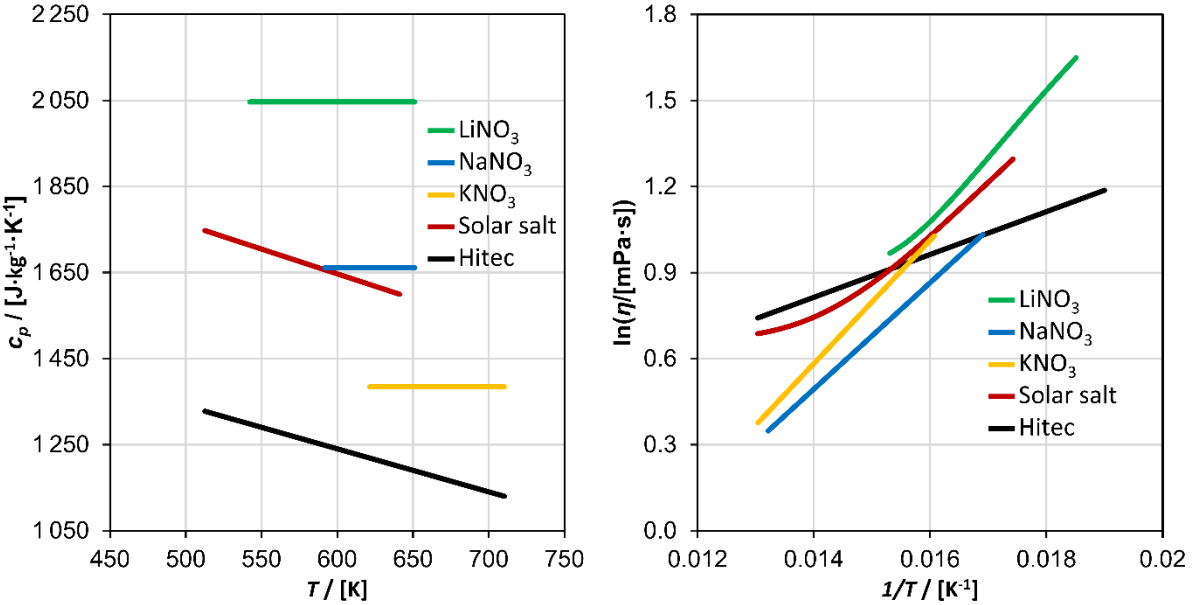

Figure 2 Linearized forms of temperature dependence of viscosity and heat capacity of some molten alkali nitrates and their mixtures. Source: [12]

Heat capacities and viscosities in dependence on temperature are shown in Figure 2. These quantities can be tailored by adding nanoparticles, as listed in Table 1. Nevertheless, nanoparticles have an ambivalent effect. On the one hand, they increase heat capacity, but on the other, they increase viscosity and thus increase the tendency towards laminar flow.

Table 1 An overview of rheological measurements of HTFs based on nitrates. Source: [8, 14-17]

HTF composition	Modification	Method	Temperature interval	Results	
$NaNO_3$-$NaNO_2$-KNO_3 (Hitec), $Ca(NO_3)_2$-$NaNO_3$-KNO_3, $LiNO_3$-$NaNO_3$-KNO_3, $Ca(NO_3)_2$-$LiNO_3$-KNO_3		rotational rheometer, DSC/DTA	230-397 °C (Hitec), 192-432 °C ($CaNO_3)_3$-$LiNO_3$-KNO_3), 145-372 °C (others)	updating databases	[14]
eutectic nitrates ($NaNO_3$-KNO_3,$LiNO_3$-$NaNO_3$-KNO_3,$LiNO_3$-$NaNO_3$-KNO_3-$Ca(NO_3)_2$	0.5 wt.% a 1 wt.% SiO_2 (10-20 nm)	rotational rheometer, DSC/DTA	250-500 °C	increase in specific heat and viscosity	[8]
$NaNO_3$-KNO_3	$Ca(NO_3)_2$	rotational rheometer, DSC/DTA	250-500 °C	increase in specific heat and viscosity	[15]
$NaNO_3$-KNO_3 (60/40) – solar salt	0.1 wt.% CuO (29 nm)	rotational rheometer, DSC/DTA	250-500 °C	increase in specific heat and viscosity	[16]
$NaNO_3$-KNO_3 (60/40) – solar salt	0.5, 1 a 1.5 wt.% SiO_2 (7 nm), Al_2O_3 (50 nm)	rotational rheometer, DSC/DTA	250-400 °C	increase in specific heat and viscosity	[17]

5. CONCLUSION

This work focuses on heat transfer fluids, mainly nitrate melts. Emphasis has been placed on their preparation and the methodology of their measurements, especially the measurement of rheological properties. It can be anticipated that once objective obstacles are removed, this topic will be addressed from a practical standpoint.

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EXPERIMENTAL AND THEORETICAL STUDY OF PHASE TRANSITION TEMPERATURES OF Fe-C-Cr-Ni ALLOYS

EXPERIMENTÁLNÍ A TEORETICKÉ STUDIUM TEPLOT FAZOVÝCH TRANSFORMACÍ SLITIN NA BÁZI Fe-C-Cr-Ni

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Abstract

Steels are commonly used metallic materials, that's why higher requirements are imposed on their properties. Thermodynamical and thermophysical properties are one of the most important quantities of materials, which are needed for understanding behaviour of materials under defined conditions. The paper is dedicated to the study of alloys based on Fe-C-Cr-Ni. Studies alloys contained carbon in a range of 0.344 – 0.382 wt. %, chromium 0.010 – 1.040 wt. % and nickel 0.001 – 1.084 wt. %. Phase transition temperatures, such as temperatures of α→γ phase transition, depending on the composition, were determined. Experimental data were obtained using SETSYS 18$_{TM}$ and NETZSCH DIL 402 Expedis Supreme devices and theoretical data were obtained using calculations in SW Thermo-Calc. This paper is relevant because there are no enough of accurate experimental data, which can be used for a simulation of metallurgical processes and for technological purpose. The aims of the paper were obtaining of new experimental data and discussing and comparing obtained data with theoretical ones.

Key words: *Fe-C-Cr-Ni alloys, phase transition temperatures, α→γ, DTA, dilatometry, SW Thermo-Calc*

1. INTRODUCTION

Alloys based on Fe are widely used in all sectors of modern production [1-2]. Many authors investigate various grades of steels. There is still insufficient data of these systems in the available literature [3]. Specific heats, phase transformations temperatures, enthalpy, entropy, Gibbs energy and other properties are the main material data for the thermodynamic and thermophysical description of materials, depending on composition of alloys and other factors [4]. Phase transformations temperatures were obtained using thermal analysis methods, such as differential thermal analysis (DTA) and dilatometry.

Performed study presents experimental data of phase transformations temperatures of laboratory prepared Fe-C-Cr-Ni alloys. These data were compared and discussed with results calculated using one of the most powerful software package for thermodynamic calculations Thermo-Calc.

2. EXPERIMENT

2.1 Sample characterization

The studied alloys contained carbon in a range of 0.344 – 0.382 wt. %, chromium 0.010 – 1.040 wt. % and nickel 0.001 – 1.084 wt. % and other minor elements presented in the Table 1. For DTA analysis the samples had the shape of a cylinder with a diameter 3.5 mm, height 3 mm and sample weight was 190 ± 5 mg. As for dilatometry, the samples had the shape of a cylinder as well with a diameter 6.3 mm, height 10 mm and a weight was 2450 ± 10 mg. The samples were polished and cleaned in acetone using ultrasound.

Table 1 Chemical composition of alloys /wt. %. Source: own

Alloy	C	Cr	Ni	Al	Cu	Co	W
A	**0.344**	**0.924**	**0.001**	**0.010**	**0.007**	**0.013**	**0.045**
B	**0.382**	**0.010**	**1.084**	**0.010**	**0.014**	**0.001**	**0.001**
C	**0.360**	**1.040**	**1.080**	**0.004**	**0.012**	-	-

2.2 Differential thermal analysis and experimental conditions

Figure 1 SETSYS 18$_{TM.}$ Source: own.

Experimental data depending on the composition of alloys were obtained using SETSYS 18$_{TM}$. The measurements were carried out in the atmosphere of argon with purity 6N to protect the samples against oxidation. Temperature calibration was done using Ag for all samples. An empty corundum crucible was as a reference sample. The heating rate was 10 °C/min. Experimental data of phase transformations were obtained by DTA method (a dynamic thermal analysis method in which the temperature effects of the examined samples are monitored during its continuous linear heating or cooling) for a studied alloys A, B and C.

2.3 Dilatometry and experimental conditions

Temperatures of phase transformations of studied alloys A, B and C were obtained by dilatometry (an experimental method that allows the study of length changes of the investigated material due to physical or chemical processes) using a NETZSCH DIL 402 Expedis Supreme device. The measurements were carried out in the atmosphere of argon with purity 6N and the heating rate was 10 °C/min.

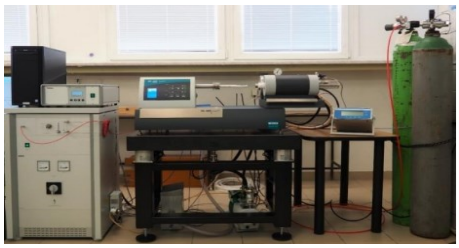

Figure 2 NETZSCH DIL 402 Expedis Supreme. Source: own.

2.4. Results and discussions

Obtained experimental and theoretical values of start and end of α→γ phase transition are presented in the Table 2 and Figure 3 and 4.

Table 2 Obtained experimental and theoretical temperature values. Source: own.

	DTA	DIL	TC
sample A			
Tα→γ s (°C)	768	757	745
Tα→γ e (°C)	818	823	793
sample B			
Tα→γ s (°C)	726	717	701
Tα→γ e (°C)	794	792	769
sample C			
Tα→γ s (°C)	750	743	719
Tα→γ e (°C)	795	781	766

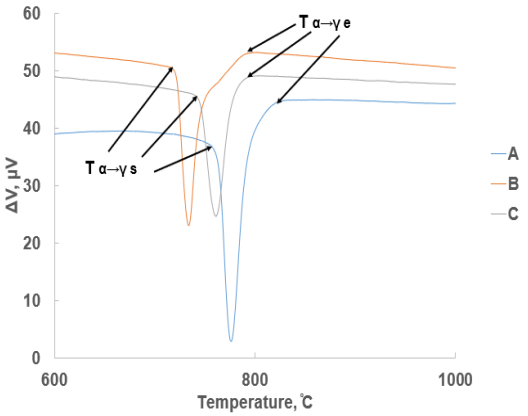

Figure 3 Obtained DTA curves, α→γ phase transition temperatures. Source: own.

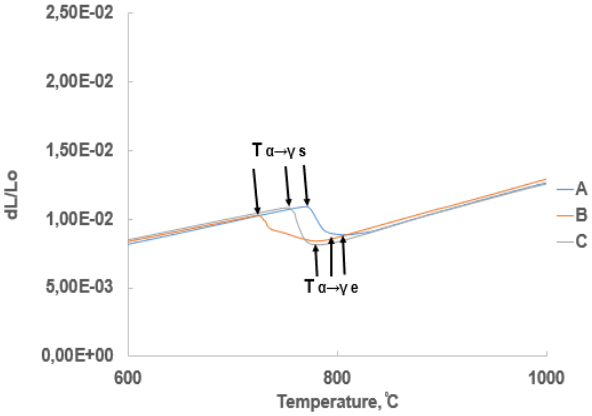

Figure 4 Obtained DIL curves, α→γ phase transition temperatures. Source: own.

As for phase transformations temperatures depending on the content of alloys, experimental values were detected from DTA and DIL curves and are presented and marked in the Table 2. Theoretical values of phase transformations temperatures were obtained by SW Thermo-Calc (temperatures are presented and marked in the Table 2 as well) and compared with experimental values. The start and end of α →γ transformation are marked as $T_{\alpha\rightarrow\gamma,s}$ and $T_{\alpha\rightarrow\gamma,e}$.

From the Table 2 and Figure 3 and 4 we can see, that phase transformations temperatures depend on the content of alloys. With increasing of content of chromium in studied alloys A and B $T_{\alpha\rightarrow\gamma,s}$ and $T_{\alpha\rightarrow\gamma,e}$ increase as well and with increasing of content of nickel in alloys A and B $T_{\alpha\rightarrow\gamma,s}$ and $T_{\alpha\rightarrow\gamma,e}$ decrease. Results obtained usins DTA, dilatometry and SW Thermo-Calc have the same trend. As for alloy C, content includes major elements – nickel and chromium. $T_{\alpha\rightarrow\gamma,s}$ obtained using DTA, dilatometry and SW Thermo-Calc have the same trend: $T_{\alpha\rightarrow\gamma,s}$ are lower than $T_{\alpha\rightarrow\gamma,s}$ of alloy A and higher then $T_{\alpha\rightarrow\gamma,s}$ of alloy B. As for $T_{\alpha\rightarrow\gamma,e}$, results obtained using dilatometry and SW Thermo-Calc have the same trend ($T_{\alpha\rightarrow\gamma,e}$ are lower than $T_{\alpha\rightarrow\gamma,e}$ of alloys A and B), which does not match with results obtained using DTA.

$T_{\alpha\rightarrow\gamma,s}$ and $T_{\alpha\rightarrow\gamma,e}$ have big difference between teoretical and experimental values, because it is more difficult to determine it by thermal analysis methods. The differences between the experimental and theoretically determined values for alloy A are from 12 °C to 23 °C for $T_{\alpha\rightarrow\gamma,s}$ and from 25 °C to 30 °C for $T_{\alpha\rightarrow\gamma,e}$, for alloy B are from 16 °C to 25 °C for $T_{\alpha\rightarrow\gamma,s}$ and from 23 °C to 25 °C for $T_{\alpha\rightarrow\gamma,e}$, for alloy C are from 24 °C to 31 °C for $T_{\alpha\rightarrow\gamma,s}$ and from 15 ° C to 29 °C for $T_{\alpha\rightarrow\gamma,e}$.

3. CONCLUSION

In the presented work phase transformations temperatures of three alloys based on iron, nickel, carbon and chromium were studied. Experimental values of phase transformations temperatures were detected by DTA and Dilatometry (experimental curves) and compared with theoretical values calculated by use SW Thermo-Calc. With increasing of content of nickel and chromium in studied alloys A and B $T_{\alpha\rightarrow\gamma,s}$ and $T_{\alpha\rightarrow\gamma,e}$ increase as well. As for alloy C, experimental and theoretical results of $T_{\alpha\rightarrow\gamma,s}$ have same trend and obtained results of $T_{\alpha\rightarrow\gamma,s}$ using dilatometry and SW Thermo-Calc have same trend, which does not match with results obtained using DTA. $T_{\alpha\rightarrow\gamma,s}$ and $T_{\alpha\rightarrow\gamma,e}$ have big difference between teoretical and experimental values, because it is more difficult to determine it by thermal analysis methods. New original experimental data were obtained for studies alloys, which can be used for a simulation of metallurgical processes and for technological purpose.

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Studijní program:

Procesní inženýrství

Obor:

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CONTINUOUS FLOW CHEMISTRY AND PHOTOCHEMISTRY INMANUFACTURING OF ACTIVE PHARMACEUTICAL INGREDIENTS
KONTINUÁLNÍ PRŮTOČNÁ CHEMIE A FOTOCHEMIE PŘI VÝROBĚ AKTIVNÍCH FARMACEUTICKÝCH LÁTEK

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Abstract

An active pharmaceutical ingredient is any substance in a pharmaceutical product that is biologically active. These ingredients need to meet the strict limits considered of not only the chemical purity. The continuous flow methodology either with combination with photochemistry can be useful tools to meet these standards. This review shows some main directions in the field of the active pharmaceutical ingredient preparation using continuous flow chemistry and photochemistry with comparison study on Ibuprofen synthesis.

Key words: *Active pharmaceutical ingredients, Flow chemistry, Photochemistry*

1. INTRODUCTION

In recent years, there has been an explosion of use of flow chemistry and photochemistry in organic synthesis. Flow chemistry allows the continuous synthesis of the target compound under controlled and mild conditions [1, 2]. The continuous flow technology also enables easy coupling of individual reaction steps without the need of isolation ad purification of intermediates [3, 4]. There are advantages over batch methods for example in heat transfer, better mixing, efficiency and safety [1]. Flow reactors are devices where chemical reactions are performed in narrow channels involving a very high surface area to volume ratio which provides very efficient rates of mass and heat transfer [2].

Using light to accelerate a chemical reaction is one of the most promising opportunities to access new chemical transformations in a more effective and sustainable way [3]. However, developing photochemistry, especially at the industrial scale, where significant productivity is required, continues
to be a challenge [8, 9].

While the perceived benefits of using flow chemistry vary across the different stages of the pharmaceutical industry, it has become a high-impact tool when applied appropriately. Flow chemistry has become popular tool across the pharmaceutical industry, with a majority companies having invested into this technology. Major pharmaceutical companies and contract manufacturing organizations have made a sustained investment in flow chemistry in continuous processing. In many cases having entire manufacturing plants dedicated to this technology [4]. A more recent trend, however, is to implement flow chemistry in a drug discovery setting [11, 12].

2. COMPARISON OF FLOW AND PHOTOCHEMICAL APPROACH TO IBUPROFEN SYNTHESIS

For illustration, we wish to compare continuous flow synthesis and flow-photochemical rearrangement of the high volume drug Ibuprofen. Ibuprofen (*iso*-butylphenyl propionic acid) is sold over the counter and annual production is estimated to surpass 9.8 kilotons [5]. Since its discovery in the early 1960's several routes have been reported [6] also including two recent flow approaches by McQuade [7] and Jamison [8] which both use Friedel-Crafts acylation and one flow-photochemistry approach from Baxendale [9] utilizing photo-Favorskii re-arrangement.

For the comparison reasons, the newest flow approach (see Figure 1) was chosen together with flow-photochemistry process (see Figure 2).

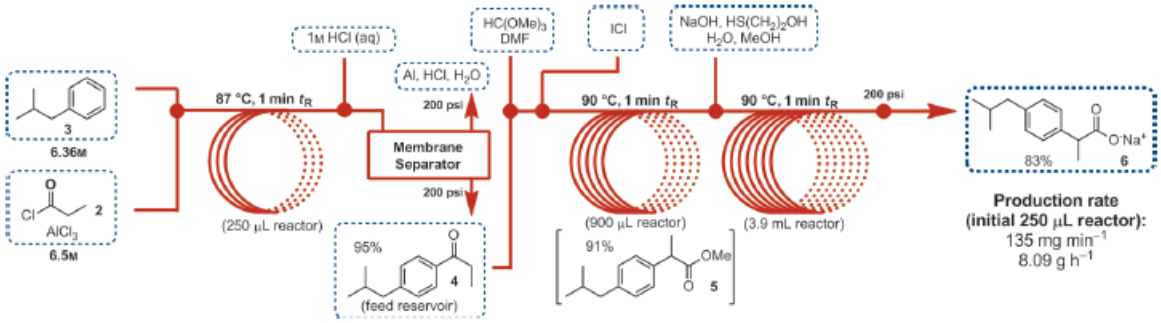

Figure 1 Scheme of the three-minute Ibuprofen synthesis from Jamison. Source: [8]

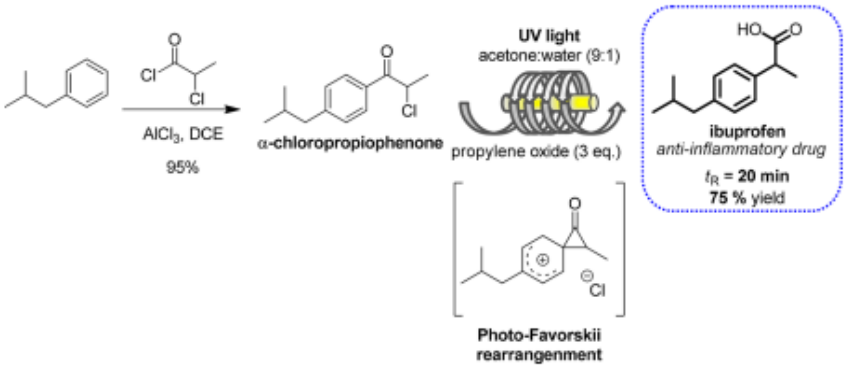

Figure 2 Scheme of the photo-flow approach to access Ibuprofen via Photo-Favorskii rearrangement from Baxendale. Source: [9]

In this comparison (see Table 1), flow approach in synthesis of Ibuprofen provides better results considered of an hourly output (8.09 vs. 0.52 g/h), overall yield (83 vs. 76 %) of the material, total residence time for the synthesis (3 vs. 20 minutes) and economical point of view (2 822 vs. 5 917 USD/kg). The prices for this calculation include only costs of reagents and solvents. The twice higher price for photochemical approach is mostly caused by an expensive 2-chloropropionyl chloride (1 030 USD/kg). If reagents were purchased in bulk, prices could be lower. The operating and acquisition costs were not taken into account. This does not mean, that flow approach must be better in all the cases, but for Ibuprofen synthesis is better. What can be said is, that these two procedures provide better results than a batch in most cases.

Table 1 Comparison of flow and photochemical approach to Ibuprofen synthesis.
Source: own.

	Advantages	Disadvantages	Yield (%)	Total cost (USD/kg)*
Flow approach	- Fast (total t_R = 3 minutes) - High-throughput (8.09 g/h) - Handles dangerous and corrosive reagents - Available and inexpensive reagents	- Reaction system prone to clogging - Double pumping system required	83	2 822
Photochemistry approach (micro-flow)	- Photo-reactor compatible with existing flow-system - Allows a real time analysis when linked to photo-spectrometer - Commercially available system with various light filters	- Low productivity (520 mg/h) - Heat generated by the lamp	76	5 917

* prices for the calculation adopted from commercial supplier Sigma Aldrich

3. CONCLUSION

The advantages of flow and photochemistry in flow technology have been demonstrated. Flow synthesis helps to overcome the limitations that would have been imposed by conducting an analogous synthesis in batch. These limitations can be for example minimizing of the safety hazards by avoiding of neither accumulation or isolation of hazardous intermediates. The flow technology can overcome the purity issues and others.

When flow methodology combined with photochemistry, which means utilization of irradiation of the reaction mixture either with or without the presence of the photocatalyst. The irradiation can be performed by low, medium or high pressure lamps and nowadays more often by LED sources which show high monochromaticity and high intensity of the light source. Both of these methods show greater advantages against batch procedure considered of purity, yield and duration time for the reaction.

Photochemistry has recently witnessed a remarkable increase of attention from researchers. The first reason is the use of continuous-flow reactors, which gives a great degree of operational flexibility in the handling of such photochemical reactions. The second reason is, that reactions could be carried out in a highly selective and mild fashion (room temperature, visible light or under an avoidance of toxic chemicals). In this context, the combination of flow and photochemistry is an excellent approach that over recent years has been employed successfully.

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DISTRIBUTION OF TRACE ELEMENTS IN MAGNETIC AND NON – MAGNETIC FRACTIONS AFTER COAL COMBUSTION

DISTRIBUCE STOPOVÝCH PRVKŮ V MAGNETICKÝCH A NEMAGNETICKÝCH FRAKCÍCH PO SPALOVÁNÍ UHLÍ

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Abstract

The paper valuates the possibility of bottom ash utilization as a waste material after being subjected to particle-size and magnetic separation. The aim of the paper is to monitor the distribution an association of trace elements with major elements in magnetic and non-magnetic fractions and to determine their enrichment/depletion in order to facilitate technological utilization.

Key words: *Bottom ash, coal, magnetic separation, distribution of elements, trace elements*

1. INTRODUCTION

Current research trends deal with the issue of waste treatment and recovery. Global coal combustion production is more than 1.2 billion tons, which is double in the last 5 years [1].

Over the centuries, the development of processes and equipment for efficient and ecological energy conversion has seen a turning point. One way of energy conversion / combustion is fluidized bed combustion. It is a specialized coal combustion process in which solid particles are suspended in the inlet air streams to achieve a more efficient chemical reaction and heat transfer. One of the main advantages of FBC is that it allows the combustion of many unconventional fuels that would not otherwise be possible to burn. In addition, this type of combustion produces very low NOx and SO_2 emissions [2]. The solid residue from this type of incineration is ash, which is divided into fly ash (FCA) and bottom coal ash (BCA).

CBA has applications in the field of engineering, it also pays considerable attention due to its potential application, including the replacement of aggregates, concrete products, embankments and reclamation work. CBA contains iron and other rare and toxic elements that can complicate / prevent its further use. Therefore, the chemical properties must be studied for possible technological applications [3-5].

In this work, the BCA was investigated and the distribution of the studied elements after dry magnetic separation in vibrofluidized state state was monitored.

2. MATERIALS AND METHODS

Bottom coal ash (BCA) studied in this work originates from atmospheric circulating fluidised bed power station where bituminous coal was combusted with (dry) desulphurization additive at approximate temperature of 850 °C.

The samples of BCA were dried at 105 °C for 2 hours. The dried samples were subjected to sieve analysis on sieve machine Fritsch Analysette 3, where three size fractions were subsequently selected: F1 (16.73 %) was <0.2 mm, F2 (60.59 %) was 0.2-0.4 mm and F3 (22.68 %) >0.4 mm. The resulting three fractions were subjected to dry magnetic separation in a vibrofluid state on an experimental separator with a tearing force of 21 kg (application of vibrofluidization allows the transition from thin film separation to volume separation, which in turn increases the selectivity of the process).

The resulting magnetic fractions (MF) and non-magnetic fractions (NMF) and their chemical composition were investigated by X-ray fluorescence spectrometry on an ARL PERFORM X 420 spectrometer (Rh-X-ray tube with max. power 4200 W, 2 detectors, 4 collimators, 9 measuring crystals, Be-window 50 µm, X 420).

3. RESULTS AND DISCUSION

Chemical analysis (Table 1) shows that MF of BA contains valuable metal components such as iron and aluminium, while the dominant component of NMM is CaO. The data in the table also show the content of trace elements of individual fractions after magnetic separation.

TABLE 1 CHEMICAL COMPOSITION OF THE SELECTED MAJOR ELEMENTS AND TRACE ELEMENTS IN MAGNETIC AND NON-MAGNETIC FRACTIONS AFTER DRY MAGNETIC SEPARATION OF BCA. SOURCE: (OWN)

Studied elements	Particle size					
	<0.2 mm		0.2-0.4 mm		>0.4 mm	
	MF1	NMF1	MF2	NMF2	MF3	NMF3
Fe_2O_3 (%)	60.36	2.42	62.82	2.82	70.37	3.45
CaO (%)	13.99	63.62	13.24	61.48	8.96	45.02
Al_2O_3 (%)	6.73	2.51	6.87	4.02	5.16	12.1
Ni (ppm)	320	46	156	64	108	48
Cu (ppm)	169	20	96	19	49	29
Zn (ppm)	443	48	465	80	476	152
Rb (ppm)	27	11	21	18	21	55
Sr (ppm)	239	280	231	301	179	300
Y(ppm)	25	11	29	15	25	19
Zr (ppm)	125	70	141	104	112	159
Nb (ppm)	17	4	22	14	13	26
Ba (ppm)	297	133	238	131	111	216
V (ppm)	142	118	163	139	126	131

ENRICHMENT FACTOR

An enrichment factor (EF) was calculated to make it easier to evaluate the overall distribution trends of the target elements. Enrichment factor in magnetic fractions related to corresponding non-magnetic fractions were calculated according to formula:

$$EF_{(i)} = \frac{w_i(\text{magnetic fraction})}{w_i(\text{non-magnetic fraction})} \quad (1)$$

where w_i values are weight fractions of the *i*-th element (or its oxide) in magnetic or non-magnetic ash fraction. The EF are summarized in Table 2.

TABLE 2 ENRICHMENT FACTORS OF THE STUDIED ELEMENTS IN MAGNETIC FRACTIONS. SOURCE: (OWN)

Studied elements	Particle size		
	<0.2 mm	0.2–0.4 mm	>0.4 mm
Fe_2O_3	24.94	22.28	20.40
CaO	0.22	0.22	0.20
Al_2O_3	2.68	1.71	0.43
Ni	6.96	2.44	2.25
Cu	8.45	5.05	1.69
Zn	9.23	5.81	3.13
Rb	2.45	1.17	0.38
Sr	0.85	0.77	0.60
Y	2.27	1.93	1.32
Zr	1.79	1.36	0.70
Nb	4.25	1.57	0.50

Ba	2.23	1.82	0.51
V	1.20	1.17	0.96

Enrichment factors (calculated according to Eq. 1) are plotted in Figure 1. The enrichment factor for the iron content is not plotted in the graph due to readability bias.

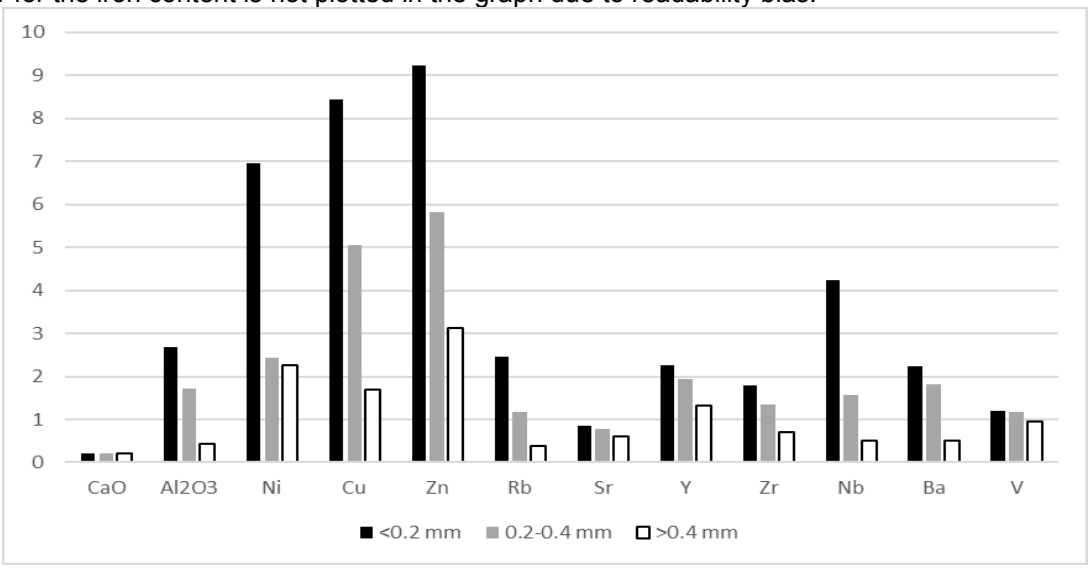

Figure 1 Enrichment factors of studied major and trace elements in magnetic fractions (vs. nonmagnetic fractions)**.** Source: (own)

CORRELATIONS BETWEEN CONCENTRATIONS OF THE TARGET ELEMENTS

Table 3 Correlation matrix calculated from the concentrations of the target elements in 6 fractions (statistically significant values are highlighted in bold)**. Source:** (own)

	Fe_2O_3	CaO	Al_2O_3	Zn	Cu	Ni	Rb	Sr	Y	Zr	Nb	Ba
Fe_2O_3	1	**-0.969**	0.001	**0.986**	0.699	0.683	-0.178	**-0.924**	**0.898**	0.253	0.174	0.333
CaO		1	-0.244	**-0.994**	-0.710	-0.675	-0.069	**0.864**	**-0.953**	-0.465	-0.380	-0.446
Al_2O_3			1	0.160	0.150	0.064	**0.967**	0.161	0.365	**0.925**	**0.907**	0.541
Zn				1	0.724	0.694	0.024	**0.875**	**0.953**	0.408	0.330	0.429
Cu					1	**0.987**	0.005	-0.430	0.688	0.314	0.269	**0.833**
Ni						1	-0.054	-0.432	0.629	0.226	0.182	0.766
Rb							1	0.286	0.158	**0.818**	0.802	0.411
Sr								1	-0.719	-0.028	0.069	0.010
Y									1	0.632	0.578	0.538
Zr										1	**0.991**	0.608
Nb											1	0.597
Ba												1

The correlation calculations are used frequently when predicting the content and distribution of elements in coals or combustion residues and for the assessment of their environmental toxicity. To obtain information on the relationships and associations of selected elements, a correlation table was calculated (see Table 3). Critical value of the correlation coefficient in this case (for 6 measured values, α = 0.05, and two-tailed probability) is R = 0.811. Statistically significant values for Zn are with Fe_2O_3 (R = 0.986), the negative correlation coefficient is between the content of CaO and Zn (R = -0.994), which indicates a strong inverse relationship. The correlation coefficient for Zn and Al_2O_3 is R = 0.160, which indicates an unlikely association. A significant value of the correlation coefficient Sr is to CaO (R = 0.864), which indicates a significant association. In contrast, the association of Sr with Fe_2O_3 or Al_2O_3 is negative or none (R = -0.924 and R = 0.161). The only value of the association for Al_2O_3 is the relation to Zr and Nb (R = 0.925 and R = 0.907), where on the contrary the majority components of CaO and Fe_2O_3 have a negative or none.

The most interesting relationships are plotted also Figure 2 – they are Fe_2O_3-Zn (black line) and CaO-Zn (orange line), b) Fe_2O_3-Sr (black line) and CaO-Sr (orange line), c) Fe_2O_3-Y (black line) and CaO-Y (orange line), d) Al_2O_3-Zr (black line) and Al_2O_3-Nb (orange line).

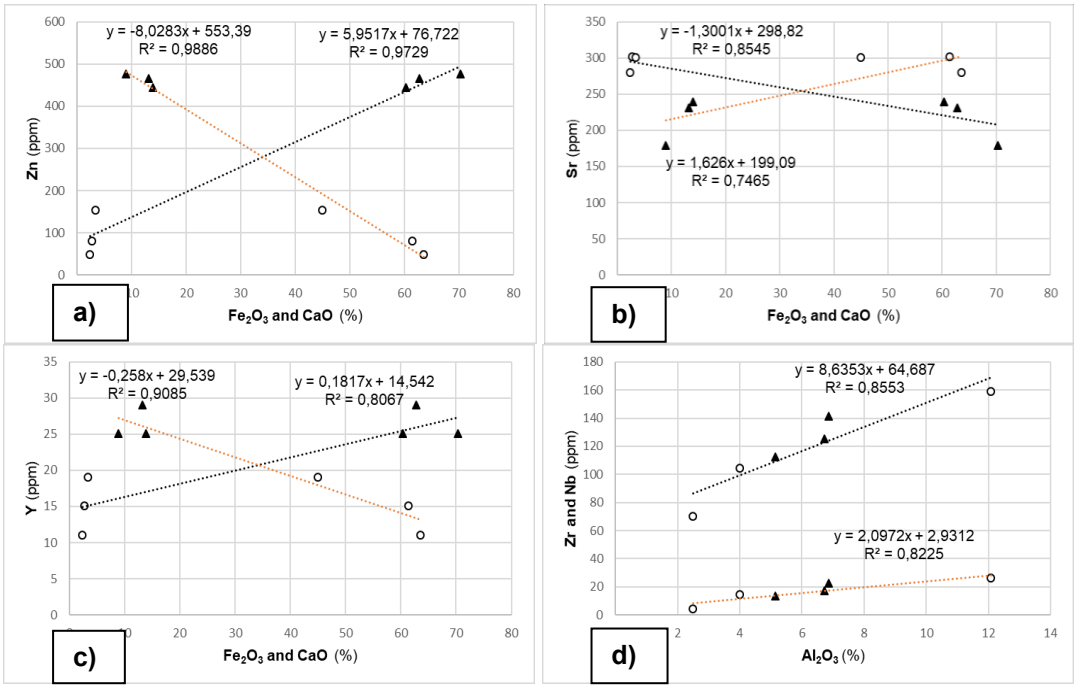

Figure 2 Relationship between the concentrations of a) Fe_2O_3-Zn and CaO-Zn, b) Fe_2O_3-Sr and CaO-Sr, c) Fe_2O_3-Y and CaO-Y, d) Al_2O_3-Zr and Al_2O_3-Nb (black triangles are used for magnetic fractions and white circles for non-magnetic fractions)**. Source:** (own)

4. CONCLUSION

In this study, samples with characteristic BCA particle size subjected to dry magnetic separation in the vibrofluid state were presented. The high content of Fe_2O_3 in the magnetic versus non-magnetic fractions indicates that the chosen type of dry magnetic separation is very effective. The Fe_2O_3 content in the separated fractions depends on the chemical composition of the coal entering the combustion. The strong Zn-Fe_2O_3 association indicates joint mode of occurrence of these two elements in the coal, probably in pyrite or other sulphides/disulphides. Sr has a high association with CaO, the content of which is determined by the desulphurisation additive (lime). The elements Zr and Nb show a strong positive correlation with Al_2O_3, which could correspond with their occurrence in the aluminosilicate minerals.

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EFFECT OF THERMAL EXFOLIATION OF G-C_3N_4 ON ITS PROPERTIES

VLIV TEPELNÉ EXFOLIACE NA VLASTNOSTI G-C3N4

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Abstract

In this paper, an effect of thermal exfoliation on some properties of graphitic carbon nitride (g-C_3N_4) is studied. Four exfoliated samples of g-C_3N_4 were prepared for different times of exfoliation. These samples were characterized, and their photocatalytic activity was tested on the degradation of phenol. The aim of this paper is to find out how do the properties of graphitic carbon nitride change as a result of exfoliation.

Key words:

Graphitic carbon nitride, exfoliation, nanosheets.

1. INTRODUCTION

Nanosheets attract considerable attention due to their unique structural and physicochemical properties [1]. Since the discovery of two-dimensional crystalline graphene, which has many interesting properties and possible applications, great efforts have been made to synthesize nanosheets with the structure of a single atomic layer and from different materials [2], [3]. Exfoliation of bulk layered materials forming their nanosheets has improved electrical properties, increased specific surface area and new possibilities for applications in electronics, energy storage and the use of solar energy have emerged [4], [5].

2. EXPERIMENTAL

Bulk graphitic carbon nitride was prepared by a simple heating of 5 g of melamine in a muffle furnace at 550 °C for 4 hours with the heating rate of 3 °C/min. Prepared material was then cooled down out of the furnace to an ambient temperature. After cooling down, the synthetized material was ground in a laboratory mill into a fine powder and labelled as CN.

Exfoliated materials were prepared from the bulk material labelled as CN by a thermal exfoliation. Small amount of CN material (0.5 g) was equally distributed on a ceramic plate and heated in a muffle furnace at 500 °C for 1, 2, 3 and 4 hours with heating rate of 10 °C/min and then cooled down out of furnace to an ambient temperature. The obtained materials were labelled as CN 1, CN 2, CN 3 and CN 4, respectively.

The prepared materials were characterized using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), specific surface area (SSA) measurement, UV/Vis diffuse reflectance spectrometry (DRS), elemental analysis and the photocatalytic decomposition of phenol.

3. RESULTS AND DISCUSSION

The structures of the prepared materials were studied by means of XRD, as demonstrated in Figure 1. The two diffraction peaks of low intensity were found at 2θ at around 15 and 31 degrees, which correspond to the (100) and (002) diffractions. These diffractions were assigned to the hexagonal phase of graphitic carbon nitride. The less intensive (100) diffraction corresponded to in-plane ordering of connected heptazine units and the more intensive one (002) corresponded to interlayer stacking of heptazine planes [6]. The decrease of intensity of both diffractions was observed and is connected to the time of exfoliation [7]. The structure of the CN materials was also studied using FTIR

spectrometry, displayed in Figure 1. Two typical regions for graphitic carbon nitride, A and B, were observed. The bands in the region A were associated with the stretching vibrations of N-H bonds and bands in the region B with the stretching vibrations of C-N and C=N bonds of heterocyclic rings. The narrow bands in the C region were associated with the breathing mode of triazine units. The spectral peak around 3500 cm^{-1} were explained by the stretching vibrations of –OH groups. The FTIR spectra of all CN materials were typical for graphitic carbon nitride [8]. The diffuse reflectance spectra of the prepared materials were recorded and obtained data were transformed using the Schuster-Kubelka-Munk equation:

$$F(R_\infty) = \frac{(1-R_\infty)^2}{2R_\infty} \quad (1)$$

where
R_∞ - diffuse reflectance from a semi-infinite layer.

The UV-Vis DRS spectra were recorded to observe light absorption properties (Figure 2) and mainly to determine the optical band gap energies of the exfoliated CN materials. The optical band gap (further only band gap) energies (E_g) (see Figure 2) were changing in the range from 2.69 eV to 2.77 eV which is smaller range than reported by other researchers [9]. They were determined using the well-known Tauc method:

$$\varepsilon h\nu = C(h\nu - E_g)^p \quad (2)$$

where
ε - the molar extinction coefficient,
hv - the energy of incident photons,
E_g - the band gap energy,
C - a constant,
p - the power depending on the type of electron transition: p = 2 was used in this study.

The elemental composition of the prepared CN materials was summarized in Table 1. The elemental analysis was used for the determination of C, H and N. The content of oxygen was calculated up to 100%. The remarkable increase of the oxygen content and hydrogen were associated with the oxidation of the CN structures which caused bonding of -OH and =O groups to the edges of graphitic carbon nitride [10]. The SSA measurement showed that time of the thermal exfoliation is important for the size of the specific surface area. The SSA values increased in order CN < CN 1 < CN 2 < CN 3 < CN4, numerically 14 m^2/g, 58 m^2/g, 90 m^2/g, 142 m^2/g and 200 m^2/g.

The photocatalytic activity of the CN materials was tested using phenol in the concentration of 30 mg/L. Each suspension prepared for the photocatalytic degradation contained 90 mg of CN material and 150 mL of the model phenol solution. Before the photocatalytic degradation, each mixture was stirred in dark for 60 minutes to reach adsorption-desorption equilibrium and then it was irradiated with a LED source (420 nm, intensity of 13.4 mW/cm^2) for 120 minutes and the reaction suspension temperatures were kept at 20 °C. Aliquots of 2 mL were taken in regular intervals and filtered using syringe filters Chromafil GF/RC-20/25 with pore size 0.2-1 μm. For the determination of phenol, 1 mL of the degraded phenol solution and 9 mL of distilled water were put in a beaker, 4 mL of 5% solution of Na_2CO_3 was added and mixed. Then, 4 mL of a diazotized solution of 4-nitroaniline was added, mixed and after 15 minutes an absorbance was measured at 470 nm. The diazotized colourless solution
of 4-nitroaniline was prepared by adding 8-10 drops of saturated $NaNO_3$ solution to a 40 mL of 5 mmol/L 4-nitroaniline dissolved in diluted HCl solution (1:9). The photocatalytic performance of CN materials increased in order CN, CN 1, CN 2, CN 3 and CN4, see Figure 3. Photocatalytic efficiency was enhanced due to enlarged SSA and =O and -OH groups anchored the edges of the structure [11].

Table 1 Elemental composition of prepared materials. Source: (own)

Samples	C (w.%)	H (w.%)	N (w.%)	O (w.%)	Molar ratio C:N
CN	34.70	1.94	61.60	1.76	0.657
CN 1	33.90	2.25	60.50	3.35	0.654
CN 2	33.60	2.27	60.00	4.13	0.653
CN 3	33.60	2.24	59.90	4.26	0.654

CN 4	33.60	2.37	60.00	4.03	0.653

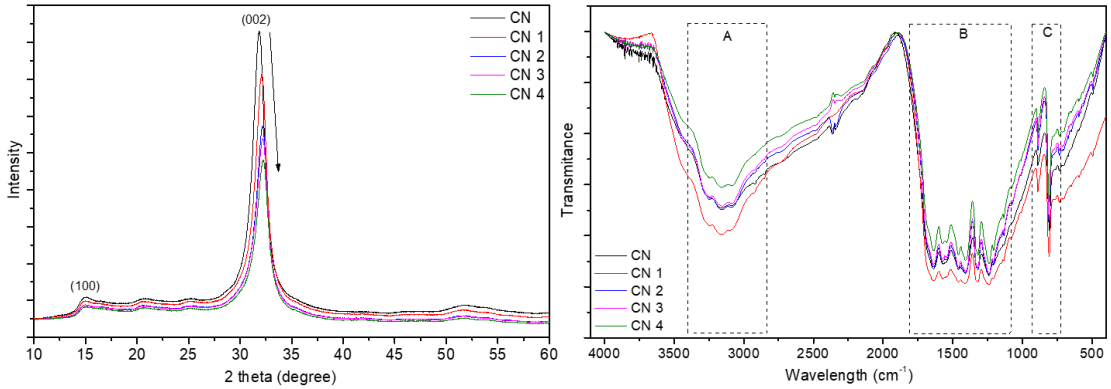

Figure 1 XRD patterns (left) and FTIR spectra of prepared materials (right).

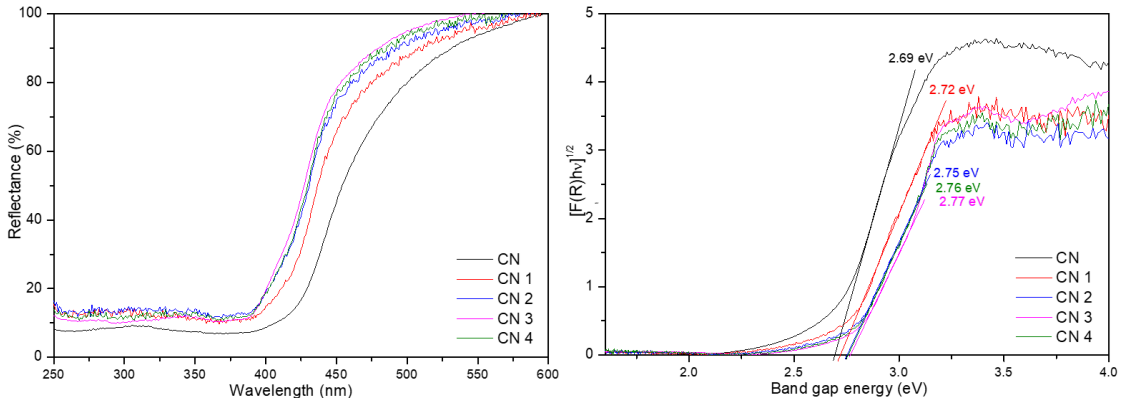

Figure 2 DRS spectra (left) and calculated Tauc plot for indirect band gap (right).

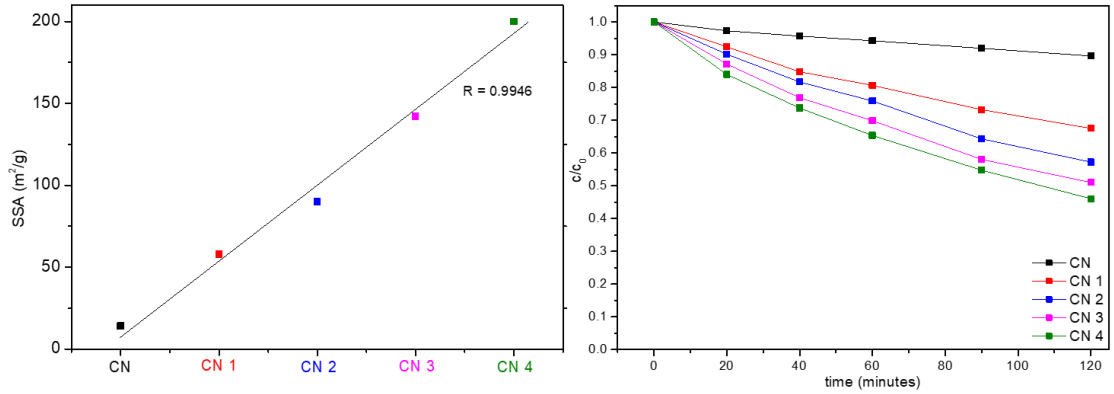

Figure 3 Specific surface area dependence on exfoliation time (left) and photocatalytic degradation of phenol (right). Source: (own)

4. CONCLUSION

Four exfoliated samples were prepared from bulk graphitic carbon nitride using the thermal exfoliation at 500 °C. The specific surface area of samples increased with longer exposure to the high temperature from 14 to 200 m^2/g. The band gap energies of the CN materials also increased with longer exposure to the high temperature in the air atmosphere in order 2.69 eV, 2.72 eV, 2.75 eV, 2,76 eV and 2.77 eV for samples CN, CN 1, CN 2, CN 4 and CN 3. The elemental analysis of the prepared materials revealed that with longer exposure to a high temperature, content of oxygen and hydrogen

increased due to thermal oxidation of material associated with bonding of =O and -OH groups at the edges
of nanosheets and structure itself. The decreasing intensity of the XRD patters indicated the formation of nanosheets and the lower number of stacked layers and as a result of the exfoliation of g-C_3N_4. The FTIR spectra of all the CN materials showed the two characteristic band regions associated with the breathing mode of triazine units and the spectral peak around 3500 cm^{-1} which was explained by the stretching vibrations of -OH groups. The photocatalytic activity of the prepared materials was tested using the phenol degradation. The photocatalytic efficiency increased in order CN < CN 1 < CN 2 < CN 3 < CN4 which corelates with their increasing SSA. The materials with the longest exposure to the high temperature was the most efficient and had the largest specific surface area.

In summary, the thermal exfoliation of graphitic carbon nitride broke down the initial structure to smaller fragments and nanosheets thereby it remarkably enlarged the specific surface area depending on the time of thermal exposure. These smaller fragments having =O and -OH groups bonded to the edges became more hydrophilic which also increased the photocatalytic performance due to a better dispersion. The exfoliated g-C_3N_4 materials are promising photocatalysts thanks to simple preparation without the need for complicated procedure using acids, basis, and hydrothermal procedures. In further research, the photocatalytic decomposition using exfoliated bulk semiconducting materials toward persistent pesticides and antiepileptic drugs will be studied.

ACKNOWLEDGEMENT

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BIOGAS PURIFICATION USING CONDENSING WATER MEMBRANE

ČIŠTĚNÍ BIOPLYNU POMOCÍ KONDENZUJÍCÍ VODNÍ MEMBRÁNY

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Abstract

Recently, the purification of a raw biogas has attracted a great attention from the researchers. The possibility of effective waste utilization for renewable biofuel production has enormous ecological and economic benefits. In this paper, a water-swollen thin film composite membrane for effective separation of CO_2 and H_2S from methane in biogas is presented. The hydrophilic polyamide reverse osmosis membrane covered with water coming as condensate from the biogas acts as a thin selective separation layer through which water-soluble compounds as CO_2 and H_2S can be separated from methane. The biogas saturated with the water vapor was brought into a contact with the spiral wound membrane in order to preserve the selective skin layer. Under these conditions, the retentate stream containing 94.4 vol % of biomethane was obtained.

Key words:

Biogas, purification, biomethan, membranes.

1. INTRODUCTION

It is generally accepted that world's resources of fossil fuels would be depleted during the several forthcoming decades. The search for alternative renewable sources of the energy is one of the most important task of current investigation [1]. Biogas, which is produced by anaerobic digestion of animal and plant biomass and other organic waste, is therefore an ideal renewable energy source. The obtained biomethane can be compressed as CNG (compressed natural gas) [2].

2. MATERIALS AND METHODS

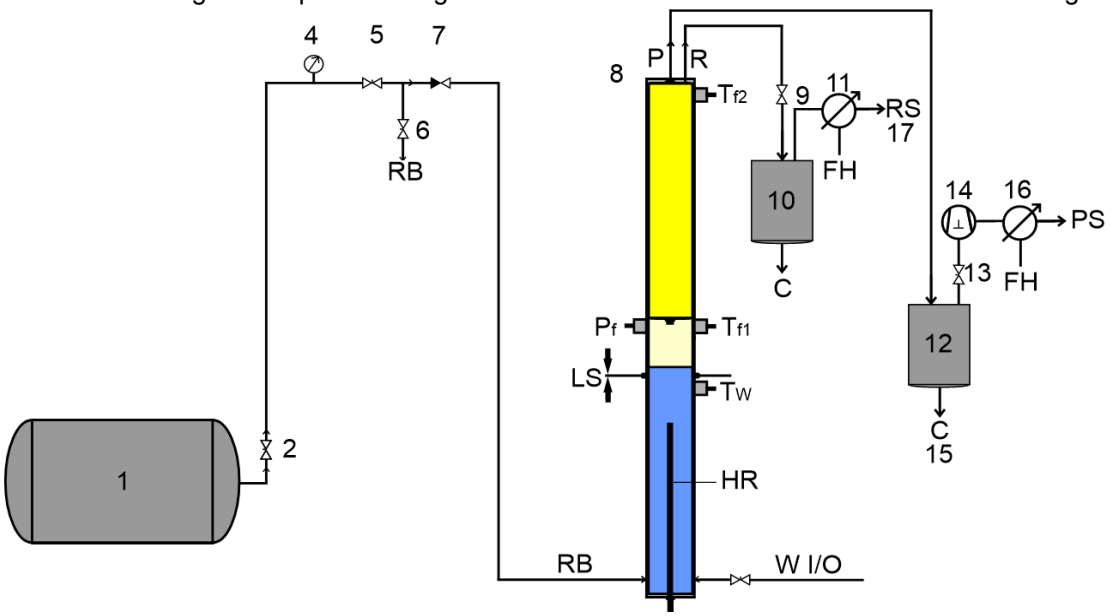
In this research, a laboratory apparatus for biogas purification was designed. This apparatus was assembled, tested for high pressure, and then the first biogas cleaning test was performed. The goal was to reduce the content of CO_2 and H_2S in biogas and obtain the purest possible biomethane (more than 95 vol. % if possible) by means of membrane separation.

A method based on a water vapor condensing on a hydrophilic gas-permeable substrate using a DUPONT DOW FILMTECTM XLE-2521 spiral wound membrane filter designed for desalination of brackish water was used. Water vapor is present in biogas from all sources. In all purification technologies, the water vapor has to be removed before performing other steps to avoid complication during purification process [3]. However, our proposed technology based on the membrane separation process can utilize the water vapor during the purification stage. In reality, the water condensing on the thin swollen layer of the hydrophilic polyamide membrane acts as a separation barrier that keeps apart CO_2 and H_2S from the main component of interest, the methane. This is caused by their different solubility in water [4,5].

The apparatus was composed almost exclusively of stainless steel (AISI 304, AISI 316 L, AISI 316 Ti), using tubes with an outer diameter of 6 mm, inner diameter of 3 mm and Swagelok-type fittings. A diagram of the apparatus is shown in Figure 1. The apparatus was kept assembled for several months. It was regularly tested for gas tightness up to an overpressure of 7 bar and further modified between individual days of measurements. Dozens of apparatus configurations were tested. They differed from each other in several parameters, like the dimension of the pipe containing the spiral wound filter, the location of the hot water tank for increased humidification of biogas, the positions and types of valves and pressure regulators, and the (not always used) filter cooling system. Figure 2 shows the scheme of the apparatus achieving the best results. The humidification chamber

was placed into the tube directly under the filter and was heated to 90 °C. The filter was exposed to an operating temperature of up to 75 °C at its bottom and approximately 40 °C at its top.

A control / display / recording software based on the LOXONE automation system was created to control the raw biogas inlet pressure regulator and the humidification chamber electric heating rod.



(1) Biogas storage tank; **(2)** Pressure control valve; **(3)** Condensate reservoir; **(4)** Manometer gauge; **(5)** Valve for quick inlet blocking; **(6)** Sampling valve; **(7)** Backflow pressure valve; **(8)** Filter vessel; **(9)** Retentate flow setting valve; **(10)** Condensate collector; **(11)** Retentate flow meter; **(12)** Condensate collector; **(13)** Valve; **(14)** Vacuum pump; **(15)** Permeate flow meter; **(16)** Permeate sampling valve; **(17)** Retentate sampling valve; **(C)** Condensate; **(RB)** Raw biogas; **(P)** Permeate; **(R)** Retentate; **(FH)** Fume hood; **(PS)** Permeate sampling; **(RS)** Retentate sampling; **(LS)** Level sensor; **($W_{I/O}$)** Water input/output; **(T_W)** Temperature of water; **(T_{f1})** Temperature lower end of filter; **(T_{f2})** Temperature upper end of filter; **(P_f)** Pressure low end of the filter; **(HR)** Heating rod

Figure 1 Scheme of biogas purification apparatus. Source: (own)

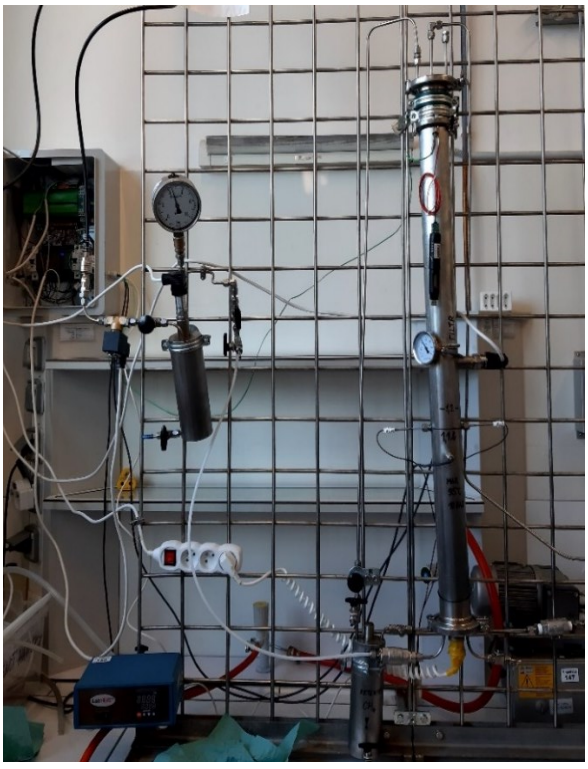


Figure 2 Photo of biogas purification apparatus. Source: (own)

3. CONCLUSION

The experimental data obtained from the biogas purification using one spiral-wound membrane filtration module were analyzed to determine conditions needed for the highest selectivity (for the highest CH_4 content in the retentate stream) and for the highest CH_4 yield (for the highest CO_2 removal efficiency, lowest methane losses in the permeate stream).

The CH_4 content in the retentate is the key parameter of the cleaning process, because it is decisive for the further use of biomethane and is defined in the legislation In order to be able to supply the treated biomethane to the natural gas network, it is necessary that the methane content is always greater than **95 %**. If used to power an agricultural machinery, a lower methane content would be sufficient (80-90 % CH_4). The highest CH_4 content in the retentate was measured when the needle valve used to reduce the retentate stream was set to minimum flow, at inlet biogas pressure of 2.6 bar. This highest CH_4 content was 94.4 vol. %. The result was later repeated as 94.0 % CH_4 at 5.0 bar. Further adjustments would make it easy to get above 95 % CH_4. The corresponding yield of methane was only 24.5 %.

The highest volumetric yield of CH_4 from biogas to retentate (69 %) was achieved in the first measurement at 4.95 bar, when the retentate needle valve was considerably open. This caused a high flow of retentate at the outlet of the filter, while the CH_4 content in the retentate was still relatively high (85.7 vol. %). Generally, methane yield higher than 45 % at approximately 90 vol. % CH_4 in the retentate was easily accessible with this single-stage filtration. The results of all measurements are given in Table1.

Table 1 The results of biogas purification. Source: (own)

	Pinput	Yield	CH_4			CO_2			O_2			N_2 + rest			H_2O vapor			H_2			H_2S		
	CH_4		B	R	P	B	R	P	B	R	P	B	R	P	B	R	P	B	R	P	B	R	P
	Bar	%	vol. %															ppm					
1	4.95	69.0	52.1	85.7	27.8	43.7	8.70	69.0	0.7	0.7	0.6	2.5	2.6	2.5	1.0	2.3	0.1	250	150	322	10	11	9
2	4.95	53.8	52.1	86.9	35.6	43.7	7.50	60.9	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.4	250	135	305	10	10	10
3	4.95	54.9	52.1	88.3	34.8	43.7	6.10	61.7	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.4	250	100	322	10	10	10
4	4.60	58.5	52.1	92.2	32.3	43.7	2.20	64.2	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.4	250	30	359	10	3	13
5	3.00	30.9	52.1	93.5	43.5	43.7	0.90	52.6	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.7	250	15	299	10	3	11
6	3.00	30.7	52.1	93.7	43.5	43.7	0.70	52.5	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.7	250	19	298	10	3	11
7	3.00	31.3	52.1	93.7	43.3	43.7	0.70	52.8	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.7	250	48	293	10	5	11
8	3.00	31.8	52.1	93.9	43.1	43.7	0.50	53.0	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.7	250	2	303	10	7	11
9	2.80	23.2	52.1	93.9	45.9	43.7	0.50	50.1	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.8	250	10	286	10	3	11
10	2.60	24.6	52.1	94.4	45.5	43.7	0.50	50.5	0.7	0.6	0.7	2.5	2.3	2.6	1.0	2.3	0.8	250	3	289	10	3	11
11	1.15	19.5	52.1	93.7	47.1	43.7	0.70	48.9	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.8	250	2	280	10	2	11
12	1.12	19.7	52.1	93.7	47.0	43.7	0.70	49.0	0.7	0.7	0.7	2.5	2.6	2.5	1.0	2.3	0.8	250	3	280	10	2	11
1	5.95	45.4	49.8	88.7	36.4	40.3	0.40	53.9	1.9	1.8	1.9	7.0	6.8	7.1	1.0	2.3	0.6	800	40	1060	30	5	39
2	5.95	47.7	49.8	93.1	34.9	40.3	0.30	54.0	1.9	0.9	2.2	7.0	3.4	8.2	1.0	2.3	0.6	800	30	1063	30	1	40
3	5.95	42.4	49.8	93.6	37.0	40.3	0.30	51.9	1.9	0.8	2.2	7.0	3.0	8.1	1.0	2.3	0.6	800	30	1024	30	1	38
4	5.95	46.5	49.8	93.7	35.3	40.3	0.20	53.5	1.9	0.8	2.2	7.0	3.0	8.3	1.0	2.3	0.6	800	30	1053	30	0	40
5	5.95	44.4	49.8	93.7	36.2	40.3	0.20	52.7	1.9	0.8	2.2	7.0	3.0	8.2	1.0	2.3	0.6	800	20	1040	30	1	39
6	5.95	44.7	49.8	93.7	36.1	40.3	0.20	52.8	1.9	0.8	2.2	7.0	3.0	8.2	1.0	2.3	0.6	800	21	1043	30	1	39
7	5.95	43.5	49.8	93.7	36.5	40.3	0.20	52.4	1.9	0.8	2.2	7.0	3.0	8.2	1.0	2.3	0.6	800	20	1035	30	0	39
8	5.00	44.2	49.8	88.7	36.9	40.3	4.20	52.2	1.9	1.0	2.1	7.0	3.8	8.1	1.0	2.3	0.6	800	200	998	30	2	39
9	5.00	46.4	49.8	91.6	35.7	40.3	1.80	53.3	1.9	0.9	2.2	7.0	3.4	8.2	1.0	2.3	0.6	800	100	1035	30	1	40
10	5.00	24.5	49.8	94.0	43.2	40.3	0.40	46.3	1.9	0.7	2.0	7.0	2.6	7.6	1.0	2.3	0.8	800	20	916	30	1	34
11	5.00	26.4	49.8	93.7	42.6	40.3	0.20	46.8	1.9	0.8	2.0	7.0	3.0	7.6	1.0	2.3	0.8	800	15	928	30	5	34
12	5.00	29.5	49.8	93.0	41.6	40.3	0.90	47.7	1.9	0.8	2.0	7.0	3.0	7.7	1.0	2.3	0.8	800	15	947	30	1	35
13	4.50	26.7	49.8	90.8	42.7	40.3	0.20	47.2	1.9	1.4	1.9	7.0	5.3	7.3	1.0	2.3	0.8	800	15	935	30	0	35
14	4.50	26.5	49.8	93.3	42.6	40.3	0.10	46.9	1.9	0.9	2.0	7.0	3.4	7.6	1.0	2.3	0.8	800	10	930	30	0	35
15	4.50	27.2	49.8	93.3	42.3	40.3	0.10	47.1	1.9	0.9	2.0	7.0	3.4	7.6	1.0	2.3	0.8	800	10	934	30	0	35
16	4.50	30.2	49.8	92.8	41.4	40.3	0.10	48.1	1.9	1.0	2.0	7.0	3.8	7.6	1.0	2.3	0.8	800	6	953	30	0	36
17	4.50	26.2	49.8	90.9	42.9	40.3	0.10	47.0	1.9	1.4	1.9	7.0	5.3	7.3	1.0	2.3	0.8	800	10	932	30	0	35
18	4.50	29.9	49.8	91.9	41.6	40.3	0.10	48.1	1.9	1.2	2.0	7.0	4.5	7.5	1.0	2.3	0.8	800	15	951	30	1	36
19	4.50	26.2	49.8	91.4	42.8	40.3	0.10	47.0	1.9	1.3	1.9	7.0	4.9	7.3	1.0	2.3	0.8	800	10	932	30	0	35
20	4.00	16.6	49.8	89.0	45.7	40.3	0.10	44.4	1.9	1.8	1.9	7.0	6.8	7.0	1.0	2.3	0.9	800	5	881	30	1	33
21	4.00	14.9	49.8	89.0	46.2	40.3	0.10	44.0	1.9	1.8	1.9	7.0	6.8	7.0	1.0	2.3	0.9	800	3	872	30	0	33
22	4.00	16.0	49.8	92.8	45.7	40.3	0.10	44.1	1.9	1.0	1.9	7.0	3.8	7.3	1.0	2.3	0.9	800	10	874	30	1	33
23	4.00	15.4	49.8	90.5	46.0	40.3	0.10	44.0	1.9	1.5	1.9	7.0	5.7	7.1	1.0	2.3	0.9	800	8	873	30	1	33

Presented work shows an innovative approach to the relatively inexpensive production of biomethane from agricultural, sewage-sludge or even landfill biogas. In our single stage method, the condensing water on the thin swollen layer of the composite hydrophilic membrane promotes the formation of a very thin selective water layer. The significant difference in solubility and permeability of methane and the raw biogas impurities (carbon dioxide, hydrogen sulfide) going through the water layer causes the effective CO_2/CH_4 separation and the recovery of high-purity biomethane.

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Studijní program:

Chemické a enviromentální inženýrství

VUV AND UV/H_2O_2 ADVANCED OXIDATION PROCESSES FOR PHOTOCHEMICAL TREATMENT OF VOCs FROM WASTE GASES IN THE PILOT PLANT UNIT

VUV A UV/H_2O_2 POKROČILÉ OXIDAČNÍ PROCESY PRO FOTOCHEMICKÉ ODBOURÁVÁNÍ TĚKAVÝCH ORGANICKÝCH LÁTEK Z ODPADNÍCH PLYNŮ V POLOPROVOZNÍM ZAŘÍZENÍ

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Abstract

This paper describes the degradation of volatile organic compounds (VOCs) from the waste gas in the pilot plant unit. The light-driven advanced oxidation processes – photolytic, photooxidation and photochemical methods are used. The aim of this study is to assess the removal effectiveness of the pilot plant unit on the model contaminants (styrene, xylenes, and their mixtures), and to monitor and describe the changes in the characteristics of the water phase during the experiments. At the concentration of 50 ppmv of solvents in the airstream and with the airflow rate of 100 $m^3 \cdot h^{-1}$ were the conversions 74, 65, 54 and 48 % for mixtures of styrene: xylenes = 1:0, 7:3, 3:7 and 0:1, respectively.

Key words:

Advanced oxidation processes, styrene, xylene, hydroxyl radical.

1. INTRODUCTION

Nowadays, environmental issues are widely discussed throughout the whole society. One of the main problems is air pollution, especially by fine particulate matter ($PM_{2,5}$), nitrogen oxides (NO_x), and volatile organic compounds (VOCs). Increased morbidity and mortality due to exposure to VOCs in the air are well known. Harmful health effects such as suppression of host defenses, increased cancer risk, exacerbation of many types of pulmonary and cardiovascular diseases, and premature mortality are often described [1]. Furthermore, ground-level ozone, as the most concerning secondary pollutant, is produced by the reaction of NOx and VOCs in the lower atmosphere, especially with sunlight and oxidants [2].

Important methods, which can be used for unyielding VOCs removal from waste air and water are Advanced oxidation processes (AOPs). These processes were first studied and described by the American scientist W.H. Glaze in the 80's of the 20th century [3].

AOPs use the production of highly reactive radicals (especially hydroxyl radicals), which attack pollutant molecules and oxidatively decompose them into simple inorganic compounds (mineralization). Complete mineralization as a result of the AOP method provides a huge advantage over other decontamination non-destructive methods, in which water or air is cleaned, but contaminants accumulate in condensate separators, on adsorbents, filters, membranes, sludge, etc. AOPs can be used e.g. as the last decontamination step in many applications, where conventional methods of waste air and water purification are not sufficient or disadvantageous.

A continuous-flow photochemical pilot plant unit was used in this study. This unit is approaching the utilization in a real industrial application and the scale can be enlarged as needed. The unit consists of a photolytic/photooxidation reactor, *dry-VUV_{185}/UV_{254}*, and a photochemical *aqueous-UV_{254}/H_2O_2* reactor, respectively, to eliminate VOCs (solvents) from waste gas. The suggested two-step unit utilizes the advantages of both AOP's systems.

As model VOC pollutants were used styrene, xylenes, and their mixtures. This study aims to describe the removal efficiency of solvent mixtures in the suggested two-step unit.

2. MATERIALS AND METHODS

The experiments were performed in two step pilot plant unit (see Figure 1):

- *The first step* is a **dry photolytic/photooxidation reactor** containing:
  - 16 VUV_{185nm}/UV_{254nm} lamps (80 W)
- *The second step* is a **wet photochemical scrubber** containing:
  - 15 UV_{254nm} lamps (75 W) in the middle, showering part
  - 8 UV_{254nm} lamps (80 W) in the tank with H_2O_2 solution
  - 3 UV_{254nm} lamps (200 W) in the external tubular reactor

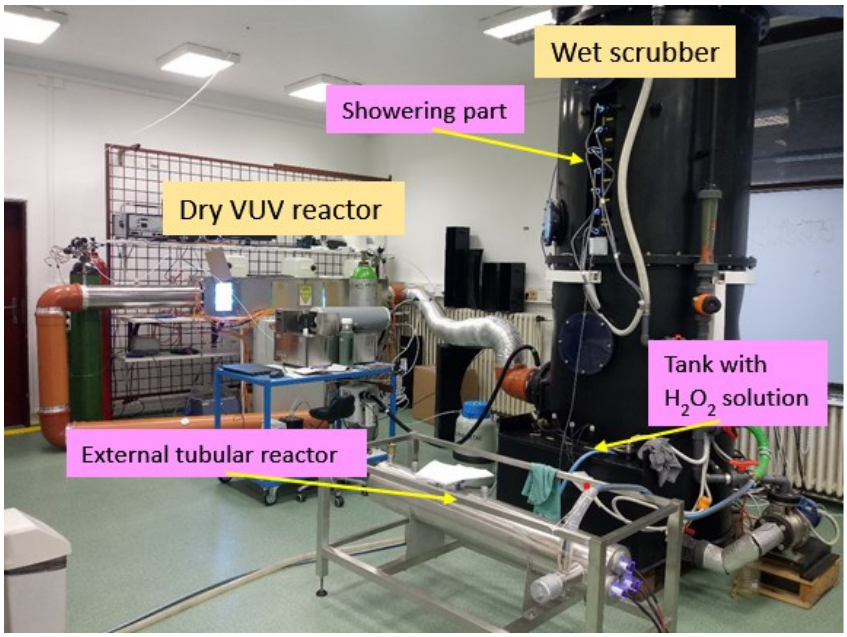

Figure 1 Two steps pilot plant unit. Source: (own)

The airstream was enriched by the solvent vapors, using small part of the air which was purged through liquid solvent.. The solvent vapors at the concentration of 50 ppmv in the airstream were led through the reactors with the air flow rate of 100 $m^3 \cdot h^{-1}$. Different solvents were used: pure styrene, xylenes mixture, and the mixture of the xylenes: styrene in ratios 7:3 and 3:7.

The solvent vapors concentration was measured online by a portable total hydrocarbon analyzer (FID 2010T, Testa GmbH). The air samples were taken from sampling points (behind the first and behind the second step) with a gas-tight syringe and were analyzed on a gas chromatograph with a flame ionization detector (8890 GC System, Agilent Technologies Inc.). Water samples were regularly taken from the scrubber and analyzed on the total carbon analyzer ($Formacs^{HT-I}$, Skalar Ltd.). The pH of the water samples was measured using a pH-meter (Multi 3420, WTW) with pH-probe (SenTix 940-3, Xylem Inc.). Intermediates and products of the degradation were determined in selected water samples with gas chromatograph with quadrupole mass selective detector (GC 7890 + MSD 5975, Agilent) and ion chromatograph (Eco IC, Metrohm). The airflow rate was monitored by flow meter Testo 435-4.

Conversion of xylene/styrene was chosen as a determining value for the effectiveness of the solvent vapors degradation according to the Eqs. (1) and (2):

$$X = \frac{n_{0,k} - n_k}{n_{0,k}} \quad (1)$$

$$X = \frac{c_{0,k} - c_k}{c_{0,k}} \qquad V = const. \quad (2)$$

where X is the degree of conversion (-), $n_{0,k}$ is the initial substance amount of solvent vapors (mol), n is the solvent vapors substance amount (mol), c_0 is the initial concentration of solvent vapors (ppmv) and c is the solvent vapors concentration at the set time (ppmv).

3. RESULTS AND DISCUSION

In the first step of the unit – in the photolytic/photooxidation reactor (dry-VUV_{185}/UV_{254}), xylene and styrene can undergo direct photolytic degradation by UV irradiation, but the rate of these reactions is much lower than the rate of photo-induced oxidation reactions [4]. These compounds are primarily oxidized by ozone (generated by UV) and radicals formed from atmospheric oxygen and water vapor after VUV irradiation, especially by hydroxyl radicals [5].

The lamps in this reactor are producing strong UV irradiation, which decomposes oxygen molecules in the air into oxygen atoms. Ozone is then formed from the oxygen atom and oxygen molecule [6]. Ozone is able to oxidize present pollutants and also is photolytically decomposed to produce electronically excited singlet oxygen atom which reacts with a water molecule to yield two hydroxyl radicals •OH [7].

Another important source of •OH is water (humidity) photolysis under 190 nm. Hydrogen atom (or hydroperoxyl radical $\bullet HO_2$, which also occurs in water photolysis in the presence of O_2) is then able to react with ozone to form next •OH [8].

Hydroxyl radicals are the most powerful nonselective oxidants. Styrene and xylene are primarily oxidized by hydroxyl radicals because photooxidation by •OH with the rate constant (in cm^3 $molecule^{-1}$ s^{-1}) in the order of magnitude 10^{-12} is much faster than the photooxidation by O_3 with the rate constant in the order of magnitude 10^{-17} for styrene and 10^{-22} for xylene [9].

After passing through the first step *(dry-VUV_{185}/UV_{254}),* part of organic vapor is already mineralized, part is oxidized into degradation intermediates and part stays unchanged. Then, **in the second step of the unit** (*aqueous-UV_{254}/H_2O_2*), the intermediates and solvents are absorbed into the aqueous phase and primarily oxidized by radicals formed from H_2O_2 after UV_{254} irradiation [10] or further oxidized in the gas phase through the UV_{254} irradiation in the scrubber. Photolytic degradation intermediates (benzaldehyde) of solvents are often much more soluble in water than solvents themselves, so they should be more easily absorbed into the water and mineralized in the second step. Furthermore, ozone formed in the first step, which would not be consumed for solvent degradation, would be absorbed into the H_2O_2 solution in the second step, where it would be partly utilized for the next solvent oxidation and also partly removed.

UV irradiation (λ = 254 nm) produced by the lamps in the photochemical reactor (wet scrubber) decomposes H_2O_2 yielding 2 •OH radicals. Homolytic cleavage is the most commonly accepted mechanism of H_2O_2 photolysis [11].

In Figure 2 is shown average conversion of styrene, xylene, or their mixture at the different concentration ratios. Is clearly visible, that with increasing styrene content is also increasing the total average conversion. Xylenes are more resistant to •OH attack than styrene, because of their absence of reactive double bond in the substituent group. Because the activation energies for hydrogen abstraction are commonly much higher than those for radical addition [12], the preferred reaction mechanism of styrene with •OH is a radical addition on the ethenyl double bond [13]. Vice versa •OH addition to the aromatic ring is preferred in the reaction of •OH and xylenes at around room temperature [9, 13].

In Figure 3 are presented the changes in total carbon concentration and pH of the water phase during the experiments. Intermediates formed in the first step (primarily benzaldehyde) were dissolved in the hydrogen peroxide solution and further oxidized into less harmful simple organic compounds, especially acids (acetic, formic, lactic, oxalic), ethanol, methanol, acetone, CO_2, and water, which was confirmed by GC-MS and ion chromatography. This is in the agreement with the observed rapid decline in pH of the hydrogen peroxide solution and increase of carbon concentration.

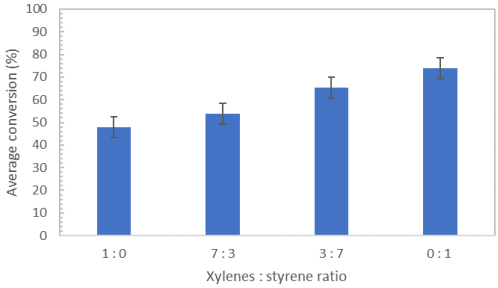

Figure 2 Average conversion of styrene, xylene or their mixture at the different concentration ratios. Source: (own)

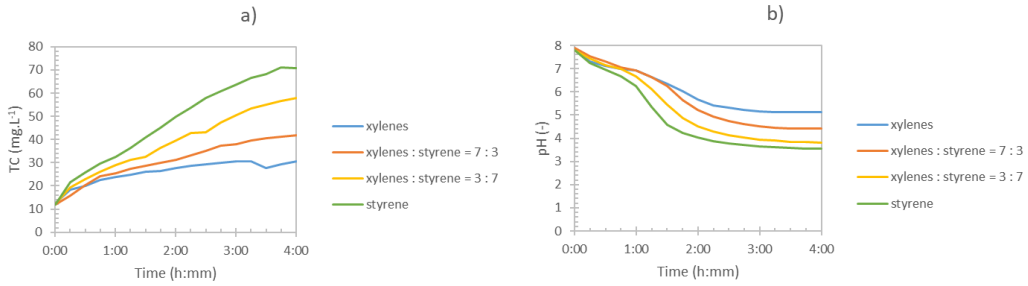

Figure 3 Changes in water phase characteristics during the experiments: a) Total carbon concentration, b) pH. Source: (own)

4. CONCLUSION

In this study was assessed the removal effectiveness of the pilot plant unit on the model contaminants – styrene, xylenes, and their mixture. As the efficiency indicator was chosen the degree of conversion. At the concentration of 50 ppmv of solvents in the airstream and with the airflow rate of 100 $m^3 \cdot h^{-1}$ were the conversions 74, 65, 54 and 48 % for mixtures of styrene: xylenes = 1:0, 7:3, 3:7 and 0:1, respectively. Total carbon concentration in the water phase increased because of forming simple organic compounds and CO_2. The pH of the water phase decreased with the presence of simple organic acids.

There are many further research possibilities, for example, study of kinetics and the mechanism of the reactions occurring in the reactors.

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Studijní program:

Nanotechnologie

ANTIMICROBIAL NANOFIBROUS MATS PRODUCED FROM HYDROPHOBIZED HYALURONAN

ANTIMIKROBIÁLNÍ NANOVLÁKENNÉ VRSTVY Z HYDROFOBIZOVANÉHO HYALURONANU

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Abstract

The paper presents electrospinning and characterization of nanofibrous mats based on hydrophobized hyaluronan with incorporated antiseptics. The aim of the paper is to describe the preparation of these nanofibrous mats by electrospinning, and their properties important for the possible application, such as morphology, yield, encapsulation efficiency of antiseptics and their release rate, antimicrobial efficiency and cell viability.

Key words: *lauroyl hyaluronan, nanofiber, electrospinning, octenidine, triclosan*

1. INTRODUCTION

Electrospinning (ES) enables incorporation of active pharmaceutical ingredients (API) into polymer nanofibers, which enhance the biological properties of nanofibrous mats; these incorporated API can, for example, protect wounds against bacterial infection and enhance the healing process [1]. However, an important aspect is also the biological effect of the polymers themselves, as many medical devices require presence at the site of action for days or longer. It is advantageous to use a polymer which will not only be a carrier but also exhibits a suitable biological activity. A number of natural polymers show biological activity, for instance hyaluronic acid plays a crucial role in the wound healing processes. Hyaluronic acid (HA) is a natural biopolymer that occurs naturally in the body and is involved in all phases of the wound healing process [2], and external application of HA promotes this natural process. However, unmodified HA is strongly hydrophilic. HA dissolves in contact with water and forms a gel; HA nanofibrous mats dissolve immediately, and any incorporated substances are released. In the field of electrospinning, this problem is usually overcome by using the covalent cross-linking of HA [3–5]. Cross-linking always requires an extra step in the production process, some of which is difficult to transfer from the laboratory environment to production. On the other hand native HA could be modified with hydrophobic side chains [6–8]. This approach enables a production of nanofibrous materials by a simple one-step process. Yet HA modified this way is rarely used for electrospinning, so far thin films were prepared for medical purposes [9] or various fibrous materials [10, 11]. In this paper, preparation of nanofibrous mats from hydrophobized hyaluronan – lauroyl hyaluronan (L-HA) is described. L-HA was prepared by esterifying OH groups with a symmetric lauric acid anhydride [8]. In previous research was reported that L-HA is biodegradable material, safe for implantation into mammal organisms [12]. Chosen parameters of the electrospinning process allowed us to incorporate two antiseptic agents – octenidine dihydrochloride (OCT) and triclosan (TRI) with a high encapsulation efficiency.

2. EXPERIMENTAL, RESULTS AND DISCUSSION

The electrospinning solutions consisted of L-HA and poly(ethylene) oxide (PEO, 400 kDa) dissolved in isopropanol (IPA) and distilled water (DW, 3:2 w/w). The concentration of all solutions was 3 wt%. The ratio of L-HA:PEO was 9:1. Various concentrations of octenidine dihydrochloride (0.5 wt% and 2 wt%) and triclosan (2 wt% and 5 wt%) were used. If OCT or TRI was added to the solution, the amount of PEO was reduced by the same amount. All solutions were stirred for 12 hours at room temperature before being used for electrospinning. The polymer solutions were electrospun using

a 4SPIN® LAB device (Contipro a.s., Czech Republic). A linear needleless multi-jet spinning nozzle was used as the emitter and a rotating cylinder was used as the collector. The distance between the emitter and the collector was set to 18 cm; other parameters were set as follows: accelerating voltage of 54 kV, solution feed rate of 400 µL/min, airflow of 20–30 L/min. Temperature and humidity were maintained at 24–27 °C and below 30 %. Each nanofibrous mat was electrospun for 60 minutes. Self-supporting nanofiber materials which can be handled comfortably were prepared.

Figure 1 shows SEM image of a nanofibrous mat without API as well as SEM images of nanofibrous mats with various contents of OCT or TRI. Fiber diameter of L-HA was 659 ± 228 nm, that decreased to 350–370 nm after the incorporation of the APIs (Table 1). No residual IPA was detected using GC-MS in any of the prepared materials, which means the electrostatic spinning process was correctly optimized.

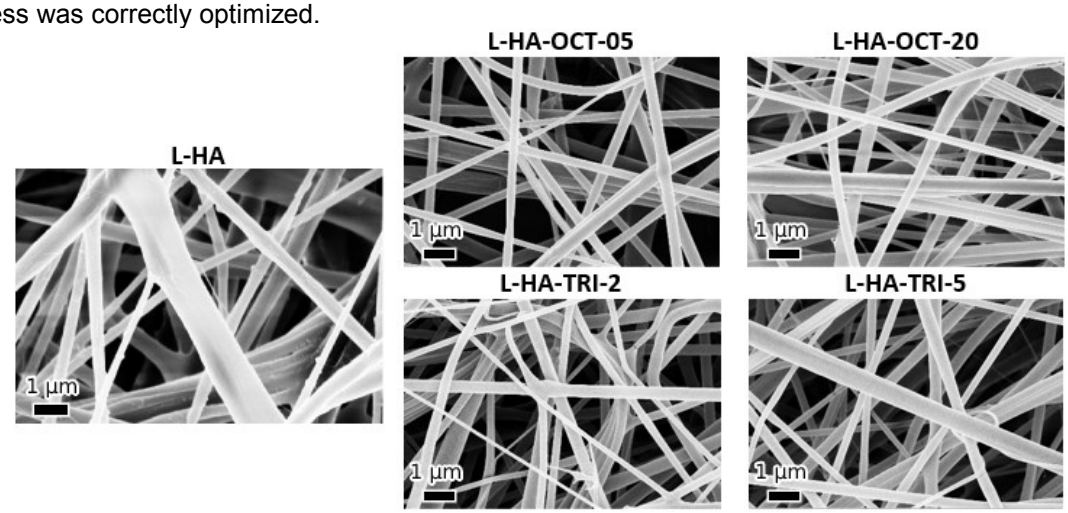

Figure 1 SEM images (magnification of 10,000×) of the prepared nanofibrous mats. Source: (own)

The data in Table 1 show encapsulation efficiencies higher than 90% were achieved for both APIs. On a macroscopic scale, both APIs were distributed throughout the nanofibrous mats homogeneously; deviations between the individual samples taken from the nanofibrous mats were no higher than 0.04 wt%.

Table 1 Fiber diameter, yield, and encapsulation efficiency of prepared mats. Encapsulation efficiencies calculated from hypothetical API content and real API content (determined by HPLC). Source: (own)

Sample	Fiber diameter (nm)	Yield (g/m^2)	Hypothetical API content (wt%)	Real API content (wt%)	Encapsulation efficiency (%)
L-HA	659 ± 228	9.79 ± 0.87	-	-	-
L-HA-OCT-05	366 ± 104	7.86 ± 0.21	0.5	0.46 ± 0.01	92
L-HA-OCT-20	347 ± 153	7.87 ± 0.17	2	1.97 ± 0.02	99
L-HA-TRI-2	351 ± 147	7.71 ± 0.55	2	2.06 ± 0.01	103
L-HA-TRI-5	371 ± 162	8.03 ± 0.09	5	5.01 ± 0.04	100

Numerous biomedical applications that employ nanofibrous materials require these materials to maintain their integrity for at least several hours and to release the incorporated drugs gradually. The behavior of the prepared nanofibrous mats was studied in PBS under *in vitro* conditions to determine their swelling behavior and evaluate their integrity after immersion. None of the nanofibrous materials retained its nanofibrous structure – after merely 1 hour, the mats had become film-like with irregularly scattered pores; however, the materials retained their integrity and did not fall apart. The swelling capacity ranged between 1,000 and 1,200 % in 24 hours. The high swelling capacity allows to manage an excess of exudate in a potential wound healing application.

The release of the APIs from the nanofibrous materials was studied with a batch release method using a dialysis membrane. PBS (pH 7.4) was used as the medium. The amounts of OCT released from L-HA-OCT were minimal (below the detection limit of HPLC). This was probably caused by the affinity of OCT to negatively charged components, and since the backbone of L-HA was made of sodium hyaluronate, which has a strong negative charge [13], the cationic OCT [14] became bound

to it. Materials containing TRI released the API gradually. In total, 14% and 30% of the TRI contained in the L-HA-TRI-2 and L-HA-TRI-5, respectively, was released over the course of 72 hours (Figure 2). Predominantly the TRI distributed on the surface of the fibers was released into the medium, and the rest of the API was bound inside the nanofibers. Therefore, the greater percentage of TRI released from the L-HA-TRI-5 sample suggests that a greater amount of the TRI was distributed on the surface of the nanofibers than in the case of the L-HA-TRI-2. In both cases, more TRI would be released with the degradation of polymer matrix.

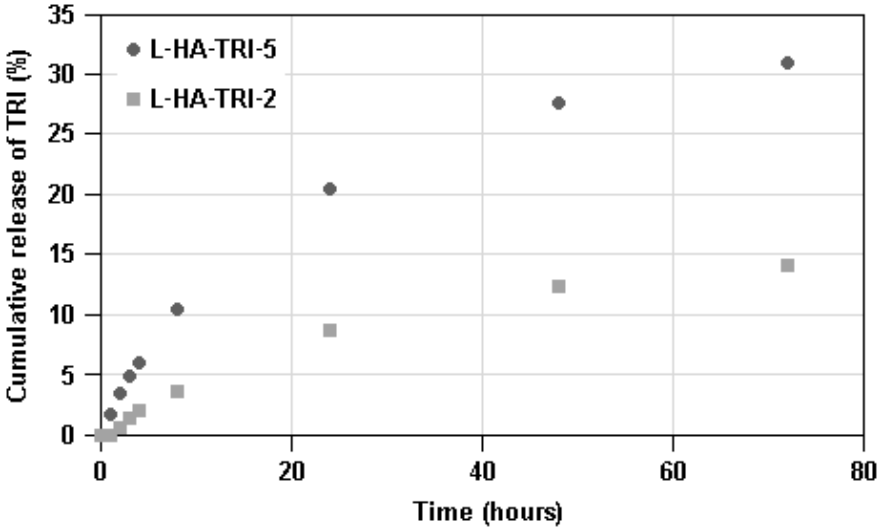

Figure 2 Cumulative release of TRI. Source: (own)

The antimicrobial activity was tested using disc diffusion method, the tested strains include *S. aureus*, *E. coli*, and *C. albicans*). The L-HA-OCT-05 material was not proven to have any antimicrobial activity against any of the tested strains, while the nanofibrous material with the higher content of OCT (2 wt%) exhibited an inhibition zone against *S. aureus*. Materials containing TRI in both concentrations exhibited inhibition zones against all tested strains, with the highest size against *S. aureus*.

Materials intended for use as API carriers in biomedical applications should exhibit no adverse biological activity, including cytotoxicity. Thus, the influence of nanofibrous mats' extracts on 3T3 mouse fibroblasts was studied. Extracts of L-HA nanofibrous mats slightly increased cell viability. Lauric acid is known to modulate cell energy metabolism [15] and the slight increase in viability could, therefore, have been caused by the presence of solubilized lauric acid chains. After considering error, the viabilities of 3T3 fibroblasts exposed to extracts of L-HA-OCT mats were comparable to the viabilities of 3T3 cells exposed to L-HA extracts regardless of the content of OCT. OCT was probably not released into the extracts in sufficient amounts to produce a cytotoxic effect. The L-HA-TRI nanofibers produced cytotoxic effects because greater amounts of TRI were present in the prepared nanofibrous mats, and because greater amounts of TRI were released from the nanofibrous mats. The inhibition of cell viability was dependent on the content of TRI as the L-HA-TRI-5 extract displayed a significantly higher degree of cytotoxicity than the L-HA-TRI-2 extract. Cell viability increased with increasing degree of dilution and eventually reached values comparable to L-HA.

3. CONCLUSION

Using electrostatic spinning, nanofibrous mats from a hydrophobized derivative of hyaluronic acid with incorporated antiseptic agents – octenidine dihydrochloride and triclosan were prepared. Unlike previous published studies, no toxic solvents or cross-linking agents were used for the production. Chosen process parameters enabled incorporation of both antiseptics with very high efficiency, homogeneous distribution of APIs throughout the mats was achieved.

Prepared nanofibrous mats were self-supporting and retained its good mechanical properties even in the wet state. Even though the release of APIs was highly dependent on their properties (water solubility etc.) and their interaction with used polymers, the nanofibrous materials exhibited antimicrobial activity. The chosen hyaluronan derivative slightly promotes cell viability, thus the toxicity was directly dependent on the antiseptic content and its release. If all the mentioned parameters are

considered, these materials could be used e.g., in the field of drug delivery systems or as wound healing dressings.

ACKNOWLEDGEMENT

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HYDROTHERMAL AND MICROWAVE-ASSISTED SYNTHESIS OF NANO-ZnS AND THEIR PHOTOCATALYTIC ACTIVITY

HYDROTERMÁLNÍ A MIKROVLNAMI-ASISTOVANÁ SYNTÉZA NANO-ZnS A JEHO FOTOKATALITICKÁ AKTIVITA

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Abstract

In this study, nanostructured ZnS was successfully prepared by hydrothermal and microwave-assisted synthesis using zinc chloride and sodium sulfide as precursors. This nanomaterial is very promising in the term of pollutant degradation and its antibacterial activity. FTIR spectroscopy, Raman microspectroscopy, scanning electron microscopy, and X-ray powder diffraction analyses were used for the thorough characterization of the prepared samples which was completed with the photocatalytic efficiency by the decomposition of organic azo dye Acid Orange 7 under UV irradiation.

Key words:

ZnS, hydrothermal synthesis, microwave-assisted synthesis, photocatalytic activity.

1. INTRODUCTION

Nanostructured materials have attracted much attention due to their unique properties that are different from bulk materials. Zinc sulfide (ZnS) is a semiconductor with wide band gap (~3.6 eV) [1]. This is one of the reasons why ZnS has been used for the light emitting diodes, flat panel displays, electroluminescent, and infrared devices [1]. Nanoparticles ZnS have also a great potential in antibacterial application due to the large surface to volume ratio in comparison with bulk ones. Antibacterial effects of ZnS nanoparticles (2-4 nm) against some pathogen bacteria (*Pseudomonas aeruginosa, Actinomycet, Salmonella typhi*) have been observed [2]. In this paper, we report a rapid microwave-assisted method compared with hydrothermal synthesis for simple preparation of nanostructured ZnS synthesized from sodium sulfide (Na_2S) and zinc chloride ($ZnCl_2$). Main principle of both methods is based on solution heating, which causes particle reduction. In comparison to hydrothermal synthesis, the microwave-assisted synthesis is much faster, cleaner, energy efficient, and more economical [3]. Photocatalytic activity is a commonly investigated function of semiconductor nanostructures and determines the ability of the material to decompose other molecules (organic substances, environmental pollutants etc.).

2. MATERIALS AND METHODS

Preparation process of hydrothermal synthesis was optimized [4], and the microwave synthesis parameters were chosen according to previous studies [5,6,7]. A solution of $ZnCl_2$ (0.5 M) and solution of Na_2S (1 M) were combined, and later the formed solution was diluted with distilled water. Total volume of the solution was 200 ml. The obtained solution was heated in a microwave oven (SENCOR, 700W) operating at 50 % power. The heating time in the microwave was 30 minutes, the solution was stirred and temperature was measured after every 10 minutes. The same preparation of solution was applied to hydrothermal synthesis. Solution was heated (up to 100 °C) and stirred on a magnetic stirrer (Heidolph, MR Hei-Standard) for 3.5 hours. Precipitates were separated from solution by centrifugation and washed repeatedly with water. Prepared samples were designated as ZnS_H (hydrothermal synthesis) and ZnS_M (microwave-assisted synthesis).

SEM analysis was performed using JEOL JSM-7610Fplus microscope. Samples were coated by thin layer (20 nm) of Pt to make surface conductive, and to prevent charge accumulation. GWYDDION software was used to determine particle sizes. XRPD patterns were recorded (range

5-80 °2θ) in reflection mode in symmetrical Bragg-Brentano arrangement using Bruker D8 Advance diffractometer equipped with fast position sensitive detector VÅNTEC 1. Radiation CoKα was used (λ = 0.1789 nm). Sizes of ZnS crystallites were calculated from the most intensive reflection, i.e., ZnS (111), using Scherrer equation [8]:

$$L_c = \frac{K \cdot \lambda}{\beta \cdot \cos\theta} \quad (1)$$

where:
K – dimensionless shape factor (0.9)
λ – radiation wavelength (nm)
β – full width at half maximum (FWHM) of the ZnS (111) reflection (°2θ)
θ – position of the ZnS (111) reflection (°2θ).

FTIR spectra in the range of 400 – 4 000 cm^{-1} were recorded by Nicolet 6 700 - Thermo Fisher Scientific with diamond ATR crystal (spectral resolution 4 cm^{-1}, 32 scans). The measured data were processed by the OMNIC software. Raman spectra were acquired on Smart Raman System XploRA^{TM} in the range of 120 – 1 200 cm^{-1}. Laser (785 nm) was reduced to 50 % of the initial intensity. Grating with 600 grooves/mm and objective with magnification 50x were used. The acquisition time was set to 10 s with 10 times repetition. Photocatalytic activity (PA) was tested as follows. For each sample, two suspensions containing Acid Orange 7 (AO7) aqueous solution (V_{AO7} = $5 \cdot 10^{-3}$ dm^3, $c_{AO7} = 6.259 \cdot 10^{-4}$ mol/dm^3), 50 ml of demineralized water, and 50 mg of the sample were stirred for 1 h in the dark to obtain the adsorption equilibrium. One suspension was further stirred under UV irradiation (λ = 254 nm) for 1 h, the second one (control) was stored in the dark. Discoloration was evaluated using CINTRA 303 UV-VIS spectrometer according to the equation:

$$PA\ (\%) = \left(1 - \left(\frac{A_i}{A_c}\right)\right) \cdot 100 \quad (2)$$

where:
A_i – intensity of AO7 absorption maximum (480 nm) for irradiated suspension
A_c – intensity of AO7 absorption maximum (480 nm) for control suspension.

3. RESULTS AND DISCUSION

SEM images of ZnS_H and ZnS_M samples (see Figure 1) show high degree of agglomeration. In both samples, the sizes of agglomerates are in micrometer range. However, sizes of the observed particles vary. While agglomerates in ZnS_H sample contain small round shaped (nano)particles having size in the range of 50 - 200 nm, agglomerates in ZnS_M sample consist of (nano)particles having size < 150 nm. EDS spectra showed the presence of Zn, S, and Na elements in both samples, only in the selected spectrum of the ZnS_M sample (see Figure 1) Zn band overlaps Na band. Occurrence of Pt and C elements is associated with sample preparation for the SEM analysis. Oxygen may indicate the atmospheric water on the surface of particles.

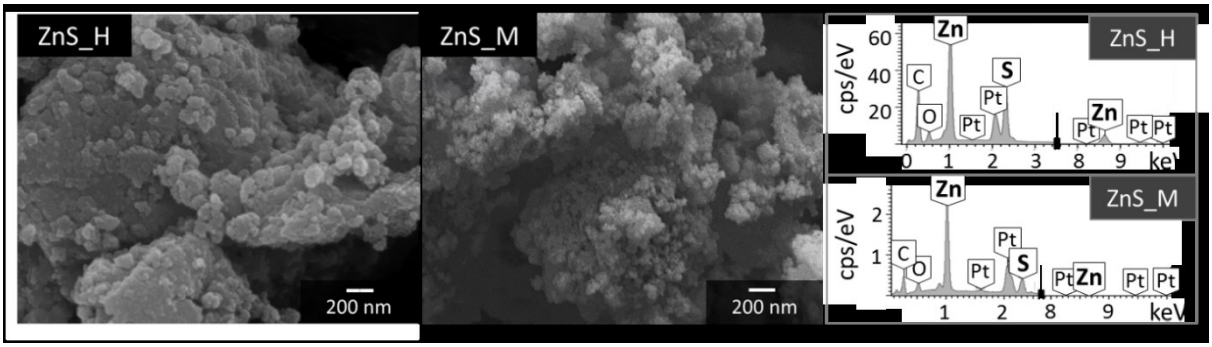

Figure 1 SEM images and EDS spectra of synthesized ZnS_H and ZnS_M samples. Source: (own)

XRPD analysis (see Figure 2) revealed that both ZnS_M and ZnS_H samples contain the same ZnS phase: the cubic phase sphalerite (PDF no. 005-0566). Width of the reflections

indicates a low degree of crystallinity. FWHM value for the ZnS_H and ZnS_M sample are 2.894° and 2.824°, respectively. L_c values, calculated according to the equation (1), are similar for both samples, 3.33 nm (ZnS_H sample) and 3.41 nm (ZnS_M sample). Apart from ZnS, the XRPD analysis did not show the presence of any other phases.

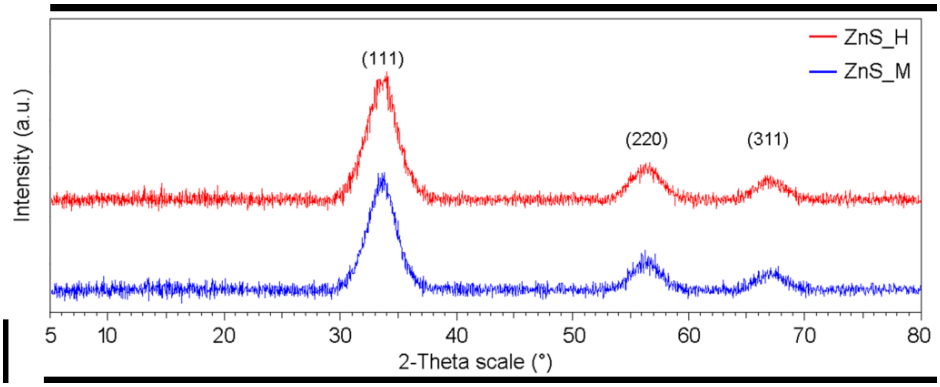

Figure 2 XRPD patterns of synthesized ZnS_M and ZnS_H samples. Source: (own)

Measured FTIR spectra are shown in Figure 3, and it is clearly evident that both samples have similar band position. Thus, the different preparation methods lead to the same composition of the sample, which is in agreement with XRPD results. The most intensive bands at ~3 230 cm^{-1} and ~1 629 cm^{-1} correspond to the stretching and bending vibration of –OH, respectively. The presence of –OH groups indicates the absorbed water, originating from atmospheric humidity, on the surface of nanostructured ZnS. Based on the data from literature, the obtained spectra correspond to the ZnS spectra, and the Zn-S bond can be observed at positions ~1 111 cm^{-1}, ~977 cm^{-1}, and ~635 cm^{-1} [9,10].

Raman spectra for both ZnS_M and ZnS_H samples are shown in Figure 3. Similarly, to the results of XRPD and FTIR analyses, Raman spectra reveal that both ways of preparation lead to the same ZnS phase as the spectra has similar shape and band positions. According to the bands appearance and bands positions, the ZnS cubic phase, i.e. sphalerite, is confirmed due to the presence of bands at 276 cm^{-1} and 352 cm^{-1}, which corresponds to the transverse and longitudinal optical zone center phonons of the cubic ZnS sphalerite phase [11]. The shape of the Raman spectra (see Figure 3) is partially caused by the amorphous-like structure of the ZnS and partially by the nano-sized particles of the synthetized ZnS [12].

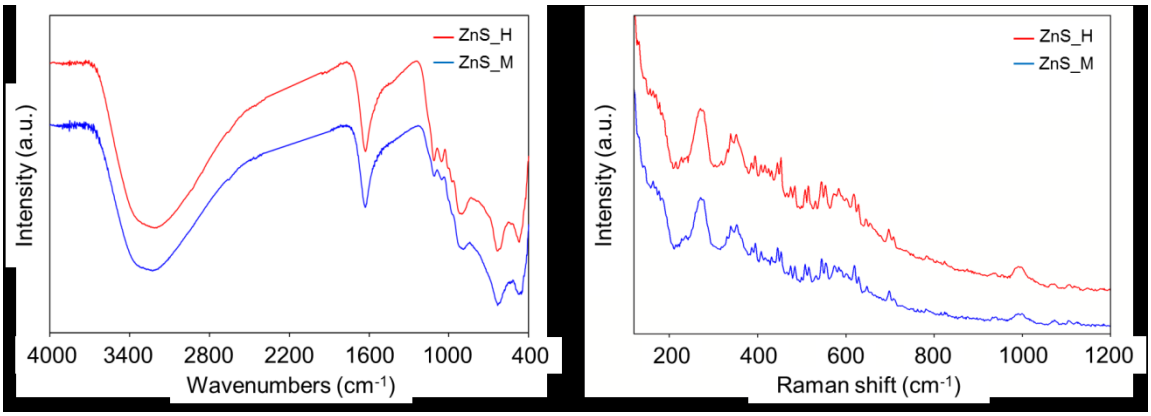

Figure 3 FTIR (left) and Raman spectra (right) of synthesized ZnS_M a ZnS_H samples. Source: (own)

ZnS samples prepared by hydrothermal and microwave synthesis do not show a significant difference in photocatalytic activity. Although no change in the color of the AO7 solution was visually observed during the first half of the total duration (1 h) of the experiment, the resulting PA values for both ZnS_H and ZnS_M samples were very satisfactory. PA values, calculated according to the equation (2), are 99.27% (ZnS_H) and 98.06% (ZnS_M). The photocatalytic efficiency of both ZnS_H and ZnS_M samples can therefore be considered very good.

4. CONCLUSION

Hydrothermal and microwave synthesis led to the successful synthesis of photocatalytically active nano-ZnS. The ZnS nanoparticles are not separate; the resulting ZnS_H and ZnS_M samples consist of nanostructured agglomerates. While SEM analysis showed slight morphological differences between the samples, XRPD, FTIR, and Raman analyzes consistently confirmed cubic (sphalerite) ZnS phase in both samples and revealed no significant differences between them. Both samples show high photocatalytic activity. After 1 h of UV irradiation, more than 99% (ZnS_H) and more than 98% (ZnS_M) of the AO7 dye was degraded. The microwave synthesis is faster and more energy efficient than the hydrothermal synthesis. Microwave radiation ensuring uniform heating of the reaction mixture makes the microwave synthesis a promising method for preparing larger amount of this highly efficient ZnS photocatalyst in water and wastewater treatment. Further research aims to refine the optimization of the preparation process and to find the most efficient synthesis conditions. Therefore, three different n_{Zn}/n_S ratios (1:1, 1.5:1, 2:1) and six different reactions times were tested, and the samples will be characterized to optimize the nano-ZnS synthesis and find most economically friendly photocatalytic nano-ZnS material.

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INFLUENCE OF PVDF NANOFIBER STRUCTURE ON CeO_2 NANOPARTICLE ANCHORAGE

VLIV STRUKTURY NANOVLÁKNA PVDF NA UKOTVENÍ NANOČÁSTICE CeO_2

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Abstract

The influence of polyvinylidene fluoride (PVDF) forming flat platelet-like crystallites on PVDF nanofibers (NFs) morphology is investigated. Crystallographic plane forming the dominant flat surface of the NFs is used for surface modification with catalytically active CeO_2 nanoparticles (NPs). The aim of this paper is to investigate the type and the intensity of interactions between PVDF NFs and CeO_2 NPs using molecular modeling.

Key words: *polyvinylidene fluoride; CeO_2; nanofiber; morphology; molecular modeling*

1. INTRODUCTION

Much attention is currently being paid to electrospinning and the influence of its parameters on the properties of nanofibers (NFs) [1], especially those made of polyvinylidene fluoride (PVDF) [2]. Electrostatic spinning leads to a specific microstructure of NFs. The effect of PVDF chains ordering and nanofiber morphology was shown [3]. Also the effect of layered crystal structure forming stripe-like NFs with a tendency to longitudinally twist into hollow tubes was recently described for polyacrylonitrile [4]. The stripe-like morphology can also affect the chemical modification, especially the adhesion of metal oxide nanoparticles (NPs) when the flat NFs surface corresponds to specific crystallographic plane. In this work, this effect was studied via molecular modeling on PVDF surfaces and photoactive cerium oxide (CeO_2) NPs. [5]. In order to achieve high photoactivity, CeO_2 NPs must anchor to the dominant flat surface of PVDF NFs. The fulfillment of this condition was investigated by force field calculations in Biovia Materials Studio 7.0 software.

2. MATERIALS AND METHODS

The real PVDF NF membrane functionalized with CeO_2 NPs was prepared by electrostatic spinning using the NS 1WS500U instrument (Nanospider laboratory device from Elmarco, The Czech Republic) and analyzed by scanning electron microscope FEI Nova NanoSEM 450 (FEI, Brno, The Czech Republic) at the Jan Evangelista Purkyně University (Ústí nad Labem, The Czech Republic).

Since electrospun PVDF NFs crystalize in β-PVDF phase, the PVDF unit cell was built as orthorhombic, space group Cm2m, with cell parameters: a = 8.58 Å, b = 4.91 Å, and c = 2.56 Å [6]. Distinctly layered ordering of chains in the β-PVDF structure is shown in Figure 1a. Periodic models of PVDF(100), PVDF(010), and PVDF(0-10) surfaces were created by cleaving the structure along corresponding (hkl) planes (Figure 1a), enlarged to ~ 100 × 100 Å and finished by addition of vacuum slab (height of 400 Å). The CeO_2 cubic unit cell (a = 5.411 Å; [7]) was cleaved along (100), (110), (111), and (211) planes (Figure 1b). Through these planes, the CeO_2 NPs models ($Ce_{198}O_{396}$) were adjacent to PVDF surfaces. In the case of alternate occupation of (hkl) planes only by Ce atoms or only by O atoms, both variants were prepared and distinguished by Ce or O (i.e. (111)Ce, (111)O, (100)Ce, and (100)O; Figure 1b).

Eighteen initial NP/surface models were prepared by placing each of the six CeO_2 NPs on each of the three PVDF surfaces. The NPs were oriented with the base parallel to a given PVDF surface. Five variants of each initial NP/surface model were built, so a total of ninety models were studied. Geometry optimization of each model was performed in MS/Forcite module. Atoms were

parameterized and their charges were assigned by COMPASS force field [8], which was verified for use on models containing either CeO_2 NP or PVDF [9-12].

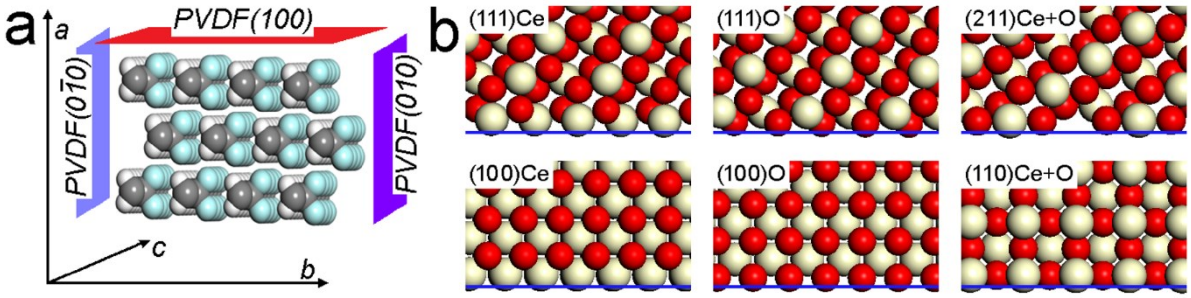

Figure 1 (a) Layered ordering of chains in the β-PVDF crystal structure with marked positions of three main planes parallel to the c axis, i.e. parallel to the carbon backbone of the chains. (b) Side views of CeO_2 periodic structure cleaved along (hkl) planes (111), (211), (100), and (110). The planes and atoms in them (forming the base of the NP adjacent to the PVDF surface) are marked with a blue line. Alternating Ce and O atoms are demonstrated for (111) and (100) planes. Both Ce+O atoms in one (110) or one (211) plane are clearly seen. Atom color legend: grey – C, light blue – F, white – H, red – O, yellow – Ce. Source: (own)

The Smart algorithm, as implemented in the MS, with $5 \cdot 10^5$ steps was used. Convergence thresholds for energy, force, and displacement were $1 \cdot 10^{-4}$ kcal·mol^{-1}, $5 \cdot 10^{-3}$ kcal·mol^{-1}·Å^{-1}, and $5 \cdot 10^{-5}$ Å, respectively. Cell parameters were not optimized. For each optimized model, interaction energy (E_{int}; kcal/mol) was calculated from potential energies (E_p) using the following equation

$$E_{int} = E_{p1} - E_{p2} - E_{p3} \quad (1)$$

where:
E_{p1} – E_p of a whole model (kcal/mol),
E_{p2} – E_p of a PVDF surface (kcal/mol),
E_{p3} – E_p of a CeO_2 NP (kcal/mol).

Interaction energy values were related to 1 nm^2 and denoted as E_{int}/S (kcal/mol/nm^2). The lower the E_{int}/S value, the stronger the interaction between CeO_2 NP and PVDF surface.

3. RESULTS AND DISCUSION

Molecular modeling has shown the possibility of CeO_2 NPs anchoring on the surface of PVDF nanofibers. Negative E_{int}/S values were obtained for all examined CeO_2 planes on all examined PVDF planes (Table 1). Interactions between CeO_2 NPs and planes PVDF(100) and PVDF(010) are comparable, and stronger compared to the interactions between CeO_2 NPs and PVDF(0-10) plane (Table 1). This is due to the fact, that PVDF(100) and PVDF(010) contains contact atoms F providing strong hydrogen bonds with Ce atoms of the NP, because of the highest difference in electronegativity values (χF-χCe = 2.86 [13]) within the possible interacting atomic pairs. For other interacting atomic pairs, the differences in electronegativity values are as follows: χH-χCe = 1.08, χF-χO = 0.54 and χO-χH = 1.24 [13]. Contact atoms of the PVDF(0-10) plane are hydrogens. Therefore, interaction with the oxygen atoms belonging to the NP structure is stronger than the interaction with the cerium atoms (χO-χH = 1.24 > χH-χCe = 1.08).

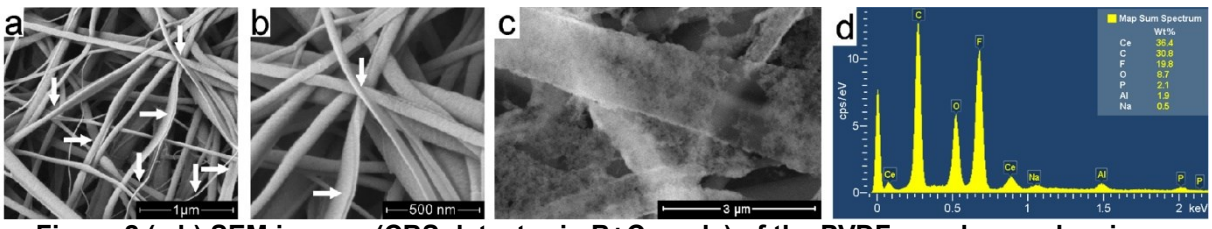

Figure 2 (a,b) SEM images (CBS detector in B+C mode) of the PVDF membrane showing a stripe-like morphology of the nanofibers. Narrower edge compared to the dominant flat surface and the longitudinal folding of nanofibers is indicated by vertical and horizontal white arrows, respectively. (c) SEM image (TLD detector in SE mode) of the CeO_2 NPs/PVDF samples. (c) EDS analysis of the CeO_2 NPs/PVDF sample. Source: (own)

Concerning the morphology of PVDF nanofibers (Figure 2), it can be stated that the dominant surface is the layered PVDF(100) plane (Figure 1a), while the available area of the other two PVDF planes is significantly smaller. In addition, in the case of longitudinal folding of the nanofibers (Figure 2), the resulting edges are also formed by the PVDF(100) plane. The anchoring of CeO_2 NPs to PVDF nanofibers is therefore controlled mainly by the interaction between CeO_2 NPs and PVDF(100) plane. The remaining two planes do not play much of a role in the real sample, neither the strongly interacting PVDF(010) plane nor the weakly interacting PVDF(0-10) plane.

CeO_2 NPs having a crystallographic orientation (211) exhibit the weakest interaction with each of the PVDF planes (Table 1). However, in the case of the dominant PVDF(100) plane, none of the remaining three CeO_2 planes (111), (110), and (100) is significantly preferred (Table 1), and CeO_2 NPs may therefore exhibit all of these crystallographic orientations in the CeO_2 NPs/PVDF sample.

Table 1 E_{int}/S (kcal/mol/nm^2) values for each of the four CeO_2 planes adjacent to ach of the three PVDF planes. In the case of CeO_2 planes (111) and (100), E_{int}/S values are provided for both types of adjacent atoms, and also the average of both E_{int}/S values is provided in the last column. The E_{int}/S values for planes (110) and (211) are provided in column Ce+O. Source: (own)

PVDF adjacent planes	CeO_2 adjacent planes	adjacent atoms			average E_{int}
		Ce	O	Ce+O	
(100)	(111)	-2619±62	-2297±65	-	-2458±181
	(100)	-2479±62	-2441±155	-	-2460±120
	(110)	-	-	-2412±139	-
	(211)	-	-	-1 687±27	-
(010)	(111)	-3073±92	-2285±93	-	-2679±405
	(100)	-2868±92	-1731±143	-	-2300±581
	(110)	-	-	-2234±71	-
	(211)	-	-	-1732±53	-
(0-10)	(111)	-1792±130	-1806±68	-	-1799±104
	(100)	-1584±132	-2467±49	-	-2025±453
	(110)	-	-	-1928±86	-
	(211)	-	-	-1485±61	-

This result is promising because these CeO_2 planes are useful for their catalytic activity. High reactivity of (110) and (100) planes for CO oxidation was reported by Tana et al. [14]. Planes (110) and (100) are typical of the surface of CeO_2 nanorods, while in the case of CeO_2 nanoparticles, the surface is dominated by the (111) plane. This plane is the most energetically stable, and thus shows weaker catalytic properties than the other two, yet its catalytic efficiency has been demonstrated in hydrolysis [15]. Photocatalytic properties have also been demonstrated in the reduction of CO_2 at the CeO2 planes (110) and (100) [16] and in the production of hydrogen at the (111) plane [17].

Finding that CeO_2 NPs on the dominant β-PVDF(100) surface can preferentially exhibit these crystallographic orientations thus provides the possibility of various practical applications of the CeO_2 NPs/PVDF membrane.

4. CONCLUSION

The PVDF membrane was surface modified with CeO_2 NPs. Molecular modeling using a force field was used to compare the non-bond interactions of CeO_2 and PVDF structures for different mutual crystallographic orientations. The molecular modeling revealed that the β-PVDF(100) plane forming the dominant flat surface of the nanofibers is suitable for anchoring CeO_2 NPs. The interaction energies found for this plane are comparable to the interaction energies found for the β-PVDF(010) plane. Weaker interactions with CeO_2 were found for the β-PVDF(0-10) plane. Both β-PVDF(010) and β-PVDF(0-10) planes forming the edges of the flat nanofibers represent a significantly smaller surface area compared to the dominant β-PVDF(100) plane. Moreover, due to the longitudinal folding of the nanofibers, these planes come into contact, making them even less accessible for CeO_2 NPs. The interaction energy between CeO_2 and the β-PVDF(100) plane is thus the most important factor influencing the surface modification of the nanofibers by the CeO_2 NPs. The results of molecular modeling suggest that surface modification of PVDF nanofibers with CeO_2 NPs is possible. Molecular modeling revealed that CeO_2 NPs on the dominant β-PVDF(100) surface can preferentially exhibit the following three crystallographic orientations: (100), (110), (111). This is a promising result because these three CeO_2 planes are catalytically active.

The CeO_2 NPs/PVDF membrane is a type of material useful in applications that require a nanostructured polymeric carrier surface-modified with catalytically active NPs with suitable crystallographic orientations. The molecular modeling method described in this study is not limited to CeO_2 NPs and PVDF nanofibers – it can be used to study interactions and preferred crystallographic orientations of different NPs on different nanofibers.

ACKNOWLEDGEMENT

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Studijní program:

Materiálové vědy a inženýrství

OPTIMALIZATION OF MAGNETIC SEPARATION PROCESS FOR IRON RECOVERY FROM SLAGS

OPTIMALIZACE PROCESU MAGNETICKÉ SEPARACE PRO ZÍSKÁNÍ ŽELEZA ZE STRUSEK

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Abstract

A huge amount of slag is produced as a byproduct, and the steel slag usually has been dumped in a landfill site and the steel slag has been considered as an industrial waste. However, the steel slag contains valuable resources such as iron, copper, manganese, and magnesium. The target of the current work is to investigate the possibility of iron recovery from steel furnace slag (FS) by wet magnetic separation. In this work, the heat treatment of the FS was tested with the aim to transform wustite (FeO) into magnetite (Fe_3O_4) and thus to improve the magnetic separation efficiency.

Key words:

Metallurgical slags, magnetic separation, iron recovery.

1. INTRODUCTION

With the continuous development of steel making industry, the increasing yield of by products has gained great concern. Disposal of the slags, which are in fact the source of the valuable minerals, became difficult as a result of more stringent environmental regulations and thus the searching of the suitable methods for the separation of their components are highly demanding. The slags originating during cast iron and steel production can be divided into three main categories: blast furnace (BF) slags, steel furnace slags (FS) and ladle slags (LS) [1, 2].

Generally, 0.10-0.15 t of steel slag is produced during 1 t of steel output [3]. For years, the appropriate treatment or utilization of steel slag has become an essential issue for modern steel industry. For liquid steel slag with high viscosity, a substantial amount of liquid steel, typically 7 - 10 wt%, will be retained in steel slag during the slag separation from molten steel [4]. In addition, owing to the presence of iron oxides such as FeO, Fe_2O_3, Fe_3O_4 calcium ferrite ($2CaO \cdot Fe_2O_3$), and Fe, Mn, Mg oxides [5], the total iron content in steel slag could reach 14-30 wt%. In steel slag, the main mineral phases are metallic iron, $2CaO \cdot SiO_2$, $2CaO \cdot Fe_2O_3$, and wüstite (FeO).

The transformation of FeO to Fe_3O_4 a α-Fe occurs in the temperature range of 570 – 1370 °C. To suppress the backward phase transition of the originated phases, the fast rate of the cooling below 570°C is essential. This process should increase the content of magnetic phases in the slag. Transformation is dependent on the degree of undercooling below the eutectoid temperature [6]. Magnetic separation has proved to be an optimal method to separate and recover iron from steel slag [7]. Especially wet magnetic separation method is used to separate the metallic iron particles form the slag powder [8, 9].

In this work, we studied the the possibility of increasing the wet magnetic separation recovery of the magnetic part of FS by its thermal treatment aimed to increase the portion of the magnetic fraction. The chemical composition of the obtained magnetic and non-magnetic fractions was characterized using X-ray fluorescence spectroscopy, phase composition was studied using X-ray diffraction method.

2. MATERIALS AND METHODS

2.1. Studied materials

Steel furnace slag (FS), originated during steel making process was studied and its chemical composition is shown in Table 1. Calcium oxide, followed by SiO_2 are the dominant components of this slag as evident from Table 1. Slag contains a significant amount of iron (in Table 1 expressed as Fe_2O_3).

Table 1 Chemical compositions of original slags (wt.%)

Samples	Components						
	MgO	Al_2O_3	SiO_2	CaO	SO_3	MnO	Fe_2O_3
FS	3.57	1.53	9.40	47.93	0.14	4.38	**29.7**

In order to liberate the metallic iron from the slags, the received slag was stepwise crushed by a jaw crusher (Brio s.r.o., Czech Republic) followed by the vibration milling (Testchem, Poland). A jaw crusher with a feeding size smaller than 80 mm and discharging size smaller than 15 mm was employed in the primary crushing of slag in order to adjust the particle size of slags prior the milling with vibration mill. The vibration mill with a feeding size smaller than 5 mm and discharging size of > 0.020 mm, was employed in the further crushing. The mild slags were then classified by a sieve with aperture size 100 micron. Subsequently, a portion of the slag (FS_800) was put into an alumina crucible and heated to 800 °C in a muffle furnace for 1 h with a heating rate of 10 °C/min.

2.2. Wet magnetic separation experiments

Experiments were carried out using a glass beaker on which a belt with neodymium magnets was placed on its outside wall. Typically, about 5 g of the slag was put into a glass beaker and mixed with 300 mL of water. The obtained suspension was then stirred 5 min using Mechanical Overhead Stirrer (Heidolph Model RZR 2041) operated at 250 RPM in order to homogenise the suspension. A belt of neodymium magnets was then placed on the outer wall of the glass beaker and the suspension was next stirred for 10 minutes. During this process, most of the strongly magnetic particles presented in slag adhered to the glass wall, and the nonmagnetic materials fell onto a bottom part of the beaker. Subsequently, the non-magnetic fraction was separated by the filtration. Finally, after removing of the belt with magnets, the magnetic fraction felt to the bottom of the beaker and small amount of the water was added. After that the magnetic fraction was separated by filtration. Both, magnetic and non-magnetic fractions were dried at 70 °C and weighed.

2.3. Characterization of the slags

Chemical composition of the original slags and individual fraction of the slags obtained during magnetic separation was performed on wave dispersive X-ray fluorescence spectrometer Supermini 200 (Rigaku, Japan) equipped with Pd tube (200W) and scintillation counter and F-PC detector.

Phase composition of the samples was studied using Theta/2Theta X-ray diffractometer MiniFlex600 (Rigaku, Japan) equipped with Co tube (600W) and D/teX Ultra detector. Samples pressed in rotational holders were analysed in reflection mode.

3.RESULTS AND DISCUSSION

The yields of the magnetic fractions obtained by wet procedure for both FS and FS_800 is shown in Table 2.

Table 2 Yield of magnetic fractions for wet separation procedure

Samples	Magnetic fraction (%)
FS	26
FS_800	69

The yield of the magnetic fraction of the original FS slag was 26 %, in the case of heat-treated slag FS_800 the yield increased to 69 % (Table 2). As evident, the yield of the magnetic phase increased due to the heat treatment of the slag. The chemical composition of the magnetic (M) and non-magnetic (NM) fractions for both slags is shown in Table 3.

Table 3 Chemical compositions of magnetic (M) and non-magnetic (NM) part for wet magnetic separation (wt.%)

Samples	Fraction	Components						
		MgO	Al_2O_3	SiO_2	CaO	SO_3	MnO	Fe_2O_3
FS	M	3.79	0.95	5.21	32.85	0.13	6.73	**46.17**
	NM	2.92	1.33	8.62	47.65	0.25	4.37	**29.32**
FS_800	M	5.33	1.19	7.95	35.41	0.10	6.11	**40.34**
	NM	2.92	2.07	12.89	54.10	0.22	2.89	**21.96**

Comparing the data in Table 3 with the chemical composition of the original slags (Table 2) the enrichment of the magnetic fraction by Fe_2O_3 at the level around 40 wt.% in the case of both slags is clearly observable. The amount of Fe_2O_3 in non-magnetic fractions of both slags demonstrates there is still reasonable amount of iron containing phases which should be separated. X-ray diffraction patterns of original slag, heat - treated slag and magnetic and non-magnetic fractions obtained from FS_800 slag are shown in Figure 1. The most intensive diffraction lines for identified major iron containing phases are magnetite (Fe_3O_4) and wüstite (FeO) as documented in Figure 1.

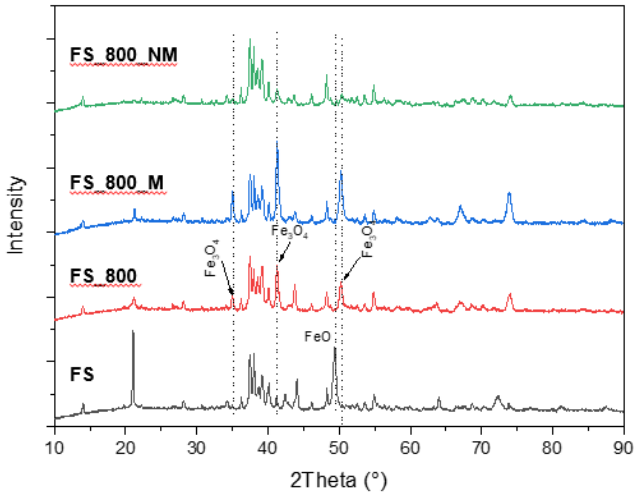

Figure 1 XRD patterns of original FS sample, heat - treated sample FS_800 and magnetic (FS_800_M) and non-magnetic (FS_800_NM) fractions obtained from FS_800 sample

X-ray diffraction patterns demonstrates the effect of thermal treatment on the transformation of FeO. During the heat treatment of the FS sample the intensity of the diffraction lines of the wustite (FeO) decreased, on the other hand, the intensity of the diffraction lines of magnetite (Fe_3O_4) increased as a result of FeO oxidation process. Figure 1 also shows a more significant increase in the intensity of Fe_3O_4 diffraction lines in the FS_800_M magnetic fraction. In contrast, the non-magnetic fraction FS_800_NM shows reduced intensity of the diffraction lines. Although the results in Table 3 show lower enrichment of magnetic fraction by Fe_2O_3 in the case of thermally treated slag, the yield of magnetic fraction is significantly higher (more than two times) in comparison to non-calcined slag (Table 2) and thus higher amount of iron is recovered.

3. CONCLUSION

The use of wet magnetic separation in the case of the FS sample resulted in the isolation of 29 wt.% of the magnetic fraction enriched with 16 wt.% Fe_2O_3 compared to the original sample. Heat treatment of this sample increased the gain of magnetic fraction to 69 wt.% by weight and increased the Fe_2O_3 content by 10 wt.% compared to the original sample. The results showed the potential of the thermal treatment of the slag for the separation process of magnetic fraction, whereas by this procedure, higher amount of iron could be recovered.

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Studijní program:

Řízení průmyslových systémů

USE OF THE NEUROGENETIC ALGORITHM FOR THE CREATION OF A TECHNICAL-ECONOMIC MODEL FOR THE RELIABILITY OF INDUSTRIAL EQUIPMENT TO SUPPORT MAINTENANCE MANAGEMENT

VYUŽITÍ NEURO-GENETICKÉHO ALGORITMU PRO TVORBU TECHNICKO-EKONOMICKÉHO MODELU SPOLEHLIVOSTI PRŮMYSLOVÉHO ZAŘÍZENÍ PRO PODPORU ŘÍZENÍ ÚDRŽBY

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Abstract

The paper deals with the issue of maintenance of technical systems in order to find the ideal system of care for production equipment and technological units. Finding this optimal state is often not without the implementation of the organization of changes, new concepts and technologies that can change the overall view and approach to savings, but also to draw attention to possible risks in the future. One of the possible new approaches to this issue, which is addressed in this article, is to create a technical-economic model of reliability of industrial equipment to support maintenance management, based on a neurogenetic system.

Key words:

maintenance, costs, technical device, optimization, neurogenetic system.

1. INTRODUCTION

Maintenance is a partial work process of each production process. All maintenance activities and measures aim to ensure the highest productivity of the production process by maximizing the use of machinery and equipment.

Many manufacturing companies use increasingly complex production equipment and technologies to expand or change production to quickly adapt to immediate customer requirements and needs. As the complexity of all machines and equipment around us grows, the approach to their care (maintenance) changes accordingly, so does the complexity of the relationships (models) that describe the reliability of the equipment. The current issue of maintenance is to find the ideal system of care for production equipment and technological units. Finding this optimal state is often not without the implementation of the organization of changes, new concepts and technologies that can change the overall view and approach to savings, but also to draw attention to possible risks in the future.

Price is always a key argument for customer decisions and effective cost reductions are currently affecting the world. Maintenance costs make up a large part of the operating costs of most manufacturing companies. Maintenance is often considered an economic burden that only consumes considerable funds and does not create any on its own.

The most important activity in the management of production facilities is efficient maintenance, as the share of maintenance costs in some types of industry can reach up to 40% of the company's turnover or up to 15% of production costs per product [1].

The basic resources available for maintenance and maintenance are, and will be for a long time [2]:

- human resources - labor costs,
- materials and spare parts - all consumed material or spare parts used to repair or restore buildings,
- infrastructure - workplaces used for maintenance and overhauls, of tools, equipment for ensuring maintenance and of transport and lifting equipment,
- information resources - required to manage, perform and ensure maintenance,
- financial resources - for financial coverage and maintenance.

2. MODEL FOR OPTIMIZATION

If we want to solve any optimization task, it must be based on a purpose function that characterizes the problem. However, the creation of this purpose function requires a great deal of knowledge of the issues addressed, including the specifics of the environment.

In the case of optimizing the preventive maintenance interval, this means finding such a moment, such a value of the diagnostic signal (usage time, operating time, operating parameter, structural parameter, cost indicator), when the performed recovery (provided that the object "lived" at this moment) ensures achieving minimum average unit costs for the operation and renovation of the building over its entire useful life [3].

The problem in solving most optimizations is to ensure a sufficient amount of data from this area, ie. both technical and economic in nature. Most data of an economic nature are very sensitive or the company does not have such data available.

As part of testing the technical and economic model of reliability of industrial equipment to support maintenance management, which solves the main problems - lack of data and the creation of a dedicated function and finding the optimal time to perform maintenance, the use of Monte Carlo was combined with a neurogenetic system. The core of the model was a neurogenetic system to support process control using the capabilities of a neural network and the optimization capabilities of a genetic (evolutionary) algorithm solving a global optimization problem. The structure diagram of the neurogenetic system is shown in Figure 1.

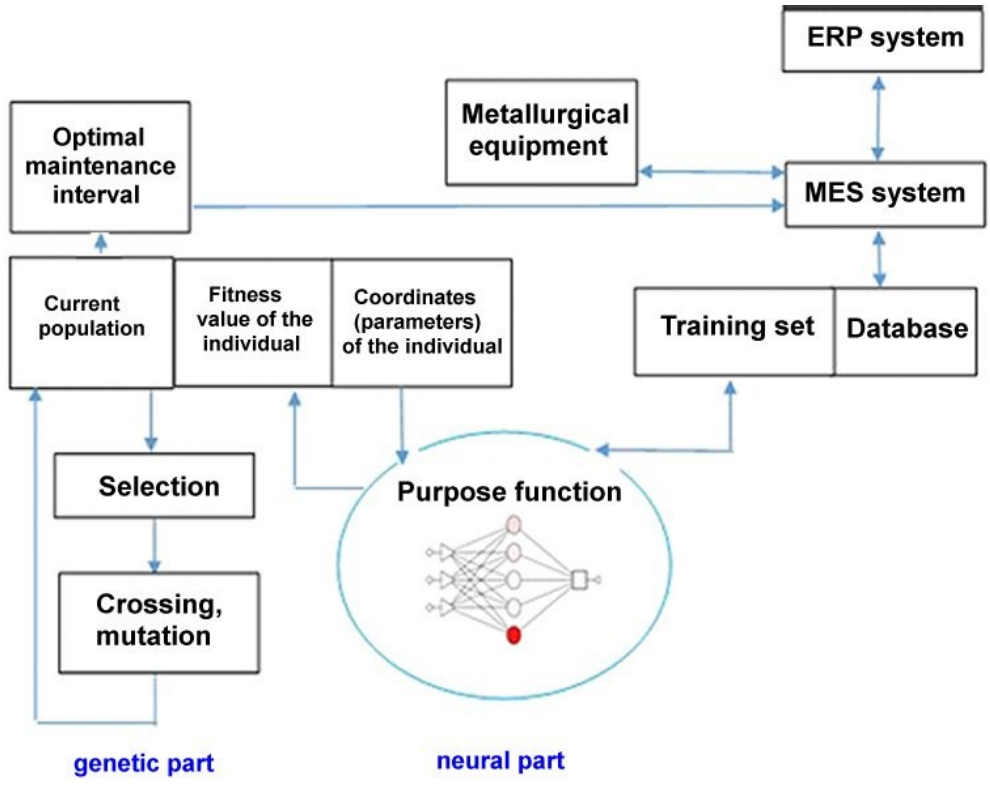

Figure 1 Neurogenetic / evolutionary system. Source: (own).

The source of data for the neurogenetic system of maintenance interval optimization was a sample of economic and operational maintenance data from the literature [3] and for the training set the rest of the data were generated using the Monte Carlo method. Based on the input parameters of the training set, a suitable neural network topology and its parameters were determined using the STATISTICA 7.1 software system.

The input variables for further processing in the STATISTICA software were the following variables:

1 - Prom1 - operating times until fault
2 - Prom2 - distribution function,
3 - Prom3 - average operating time to preventive maintenance,
4 - Prom4 - preventive maintenance costs
5 - Prom5 - losses due to maintenance after failure
6 - Prom6 - unit costs for preventive periodic maintenance

20 basic values were used for the input variable (Prom1), according to which other values were subsequently generated for column 1. Variables No. 2, 3 and 6 were calculated. Variables 4 and 5 were taken for this model case from the publication [2].

Data: Tabulka1.sta* (10s krát 48ř)

	1 Prom1	2 Prom2	3 Prom3	4 Prom4	5 Prom5	6 Prom6	7 Prom7	8 Prom8
1	1319	0,013848	1315,253	300000	900000	237,5691		
2	1988	0,06794	1959,962	300000	900000	184,2616		
3	2170,496	0,094702	2127,562	300000	900000	181,0672		
4	2329,148	0,123148	2268,832	300000	900000	181,0769		
5	2421,644	0,142077	2348,961	300000	900000	182,1524		
6	2423,307	0,142433	2350,385	300000	900000	182,1785		
7	2553,641	0,172157	2460,074	300000	900000	184,9298		
8	2749,003	0,223299	2616,615	300000	900000	191,4569		
9	2758,673	0,226032	2624,095	300000	900000	191,8485		
10	3009,667	0,303199	2808,435	300000	900000	203,9851		
11	3019	0,306285	2814,905	300000	900000	204,5031		
12	3025	0,308277	2819,049	300000	900000	204,8384		
13	3172	0,35882	2916,753	300000	900000	213,5724		
14	3183	0,362726	2923,762	300000	900000	214,2629		
15	3229,058	0,379251	2952,638	300000	900000	217,2045		
16	3290,961	0,401855	2990,239	300000	900000	221,2763		
17	3295	0,403344	2992,644	300000	900000	221,5464		
18	3330	0,416316	3013,229	300000	900000	223,9074		
19	3374,314	0,432899	3038,638	300000	900000	226,9469		
20	3379,824	0,434973	3041,746	300000	900000	227,3284		
21	3395,042	0,440711	3050,271	300000	900000	228,3862		
22	3399	0,442206	3052,474	300000	900000	228,6623		
23	3407	0,445232	3056,908	300000	900000	229,2214		
24	3460	0,465381	3085,676	300000	900000	232,9613		
25	3492,025	0,47763	3102,541	300000	900000	235,2482		
26	3590	0,515326	3151,702	300000	900000	242,3432		
27	3595	0,517255	3154,112	300000	900000	242,7084		
28	3676,536	0,548706	3192,062	300000	900000	248,6905		
29	3696,441	0,556371	3200,94	300000	900000	250,1558		
30	3718,889	0,565001	3210,77	300000	900000	251,8092		
31	3725	0,567348	3213,412	300000	900000	252,2594		
32	3863	0,61982	3269,324	300000	900000	262,3901		

Fig. 2 Training set. Source: (own)

From the results of the neural network training, it was selected as the best network - network No. 7 (RBF 3: 3-5-1: 1) as shown in Fig. 3 - left part.

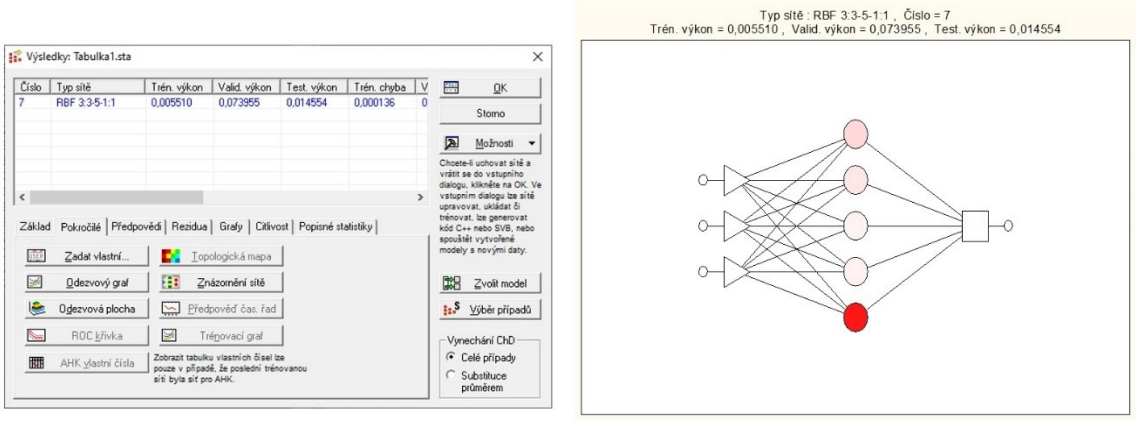

Fig. 3 Creation of network No. 7 and graphic representation of the neural network structure.
Source: (own)

A graphical representation of the topology of the selected neural network can be seen in Figure 3 on the right. The structure of the selected neural network consists of three inputs, which continue into three neurons in the first layer, five neurons in the second (hidden) layer and one neuron at the output, with the result being one value.

This experiment verified the ability of the neural network to learn data and provide relevant solutions even when entering a larger amount of data. Subsequently, the achieved results of the neural network with STATISTICA software could be transferred to the interface of the C ++ programming language and subsequently to MS Excel. Based on the source code, a purpose-built function would be defined in MS Excel and the evolutionary part offered by this software would be added using the Solver tool. This proved the ability to create a system on real data and solve maintenance issues.

3. CONCLUSION

The so-called combined approach is used for the proposed technical and economic model to support maintenance management, which means that not only artificial intelligence methods are used to solve a certain problem, but a connection with some other method, the Monte Carlo method for this model. The output of the proposed model is an updated optimal interval for any technical object. The novelty of the solution lies in the fact that the technical-economic purpose function will be used for optimization, which is implemented using a neural network, so the proposed purpose function is not general, but is always implemented for a specific device and takes into account all its specifics.

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CHAT BOT FOR IMPROVING HUMAN RESOURCE MANAGEMENT

CHAT BOT PRO VYLEPŠENÍ ŘÍZENÍ LIDSKÝCH ZDROJŮ

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Abstract

The paper presents the basic reasons for the introduction of chatbots in human resources (HR) and recruitment. The purpose of the paper is to assess the influence of artificial intelligence of chatbots on the recruitment process. The study is completely based on secondary sources like articles and websites are used to present the current paper. The aim of the study is to identify chatbots impact across the recruitment process.

Key words:

Chat Bot, artificial intelligence, human, resources, management.

1. INTRODUCTION

The human resources (HR) of any organization are very important in building and growing a company by employing efficient and competent employees. In order for each company to achieve its long-term socio-economic goals, it should ensure the satisfaction of human resources. In recent years, HR services have unified with information technology (IT) in the form of human resource information system (HRIS), enterprise resource planning (ERP), human resource analysis, data mining, etc. Artificial intelligence (AI) has become an evolving technology in technological progress an area of business practices that helps an organization increase. With the advent of chatbots in HR, one of the main areas in AI and natural language processing, organizations have become more focused on AI. Bot is considered an effective communication system that can be used between employees and customers to perform some communication-oriented processes in the organization without any human intervention. Artificial intelligence technology simplifies solving complex problems. Chatbots not only influence the organization's decision-making process, but also facilitate a better understanding of AI among employees within the organization. To verify the usefulness of chatbots in a human resource management system, it is necessary to capture the functionality of chatbots in real time. In this work, an overview of chatbots in HRM, often called HR-robots, is studied to emphasize the usefulness in real time with respect to relevant challenges such as cost factor, complex business domains, limited response, etc. [1].

The acceptance of chatbots for service optimization is expanding. Most companies focus on external interactions with consumers, specifically customer support. However, these same companies should benefit greatly from automating internal processes that will bring value to the company and its employees [2].

Regardless of the size of the company, but even more so in larger companies, chatbot is a great solution for optimizing answers to frequently asked questions that are easy to program. Chatbot can be considered as a manual that collects all relevant information. It can answer and clarify all doubts of potential employees. Responds immediately.

When thinking about the tasks themselves, human resources experts manage the entire human part of society. He works primarily in a company-employee relationship, managing all professionals, from hiring to retaining talent. At the same time, they implement favorable environments that, among other things, strengthen the motivation and creation of employees.

2. HR CHATBOTS USE CASES

Some advantages of chatbots in the field of human resources management include [2]:

- **24/7 availability:** Whether it is the applicant's status or the remaining days of vacation, the chatbot serves candidates and employees around the clock, without waiting time.
- **Repeat query automation:** With the implementation of chatbots, it is possible to use human resources efficiently. Frequent and recurring questions will be handled by a chatbot or even a voice assistant.
- **Increased level of interaction with potential applicants:** Chatbots communicate with its applicants from the beginning actively and automatically guide them throughout the application process.
- **Increase HR team productivity:** Employees can focus on more complex tasks with HR chatbots to increase team productivity in internal and external processes.
- **Efficient data collection:** Communication AI assistants not only interact with candidates or employees but can also collect important data and integrate it into existing systems when needed.
- **Cost reduction:** Thanks to the efficient use of resources and the automation of the right process points, chatbots save not only time but also costs.
- **Higher satisfaction of employees and candidates:** Freeing employees from unpleasant tasks and improving the interaction between the company and candidates - with right implementation naturally comes higher satisfaction.

The aim in the next part is to study the impact of AI chatbots in the recruitment process. More specifically, this study addresses AI chatbots, the importance across the functions of the recruitment process [3]:

- **Simplification of the first phase:**

Current chatbots can do a lot. They can interpret resumes and ask for explanations Through individual communication with candidates one-on-one, instant messaging conversations on platforms such as Facebook Messenger and text messaging, chatbots can gain some information about the applicant's experience, answer common questions and collect a wide range of data and ask for human choice analysis.

- **Getting the right data at the right time:**

All organizations that would like to update the candidate database every day, respond more quickly to clients, and build long-term relationships with candidates can deploy a chatboat attached to the database to update it regularly. Companies can verify information about their database, which is a key influence. Thanks to individual and automated discussions, companies can restore applicants' accessibility, their current position, mobility or even new certification.

- **Qualifying candidates:**

Chatbots can filter suitable candidates from unsuitable ones by asking candidates questions about skills, qualifications and past experience, which can be an otherwise tedious and time-consuming task for recruiters. He can then effectively classify and qualify the entire group of candidates in terms of the required criteria of the organization.

- **Attracting more qualified job seekers:**

Companies are aggressively forwarding e-mails to their database to get more job seekers, but the success rate is not as high as expected. With chatbot on messaging applications, companies can draw into a database of applicants and push them to the right place at the right time. Applicants can easily log in via chatbot. It is not necessary to log in or go through the lengthy application process to go to the website. Jobseekers receive job offers in their messaging applications rather than via e-mail. At that point, they can request them without having to go to another application or website.

- **Increased number of applications:**

Using an automated recruitment chatbot on Facebook Messenger, any potential candidate could be asked to sign up for job alerts and provide them with their Facebook profile information, as well as show them vacancies, application process information or even job videos. The possibility of submitting an application by the applicant increases the number of folds if they are involved directly from the place of initial interest, because they already had contact and established a relationship with the company.

- **Question and Answer (FQA):**

Companies can use chatbots to answer frequently asked questions by recognizing the keywords provided by the applicant. It is crucial that the answers are clear and informative, which will allow the applicant to quickly gain knowledge and clear understanding, which will lead to the applicant's satisfaction.

- **Reactions to unsuccessful candidates:**

To remain competitive, a company must attract the best talent and qualified professionals. Companies can only be successful in this if they are considered to be someone who treats people with respect. With a large number of applications for one job position, it is practically impossible for recruiters to personally reject everyone, and therefore chatbots become the most suitable option. Chatbots can respond to applicants as soon as a decision is made. Applicants can recognize this type of speed and at the same time do not develop any negative feeling towards the organization, because they do not go through the anxieties of the waiting time.

- **Application for applicants for screening:**

Chatbots can start a conversation with candidates as soon as they apply for a company job. Chatbots can ask many questions when communicating with them. Questions can range from questions about work experience where they previously worked, areas of interest, etc. When this process is over, the applicant will assess the relevance of the vacancy. The decision is made by the recruitment chatbot based on the conversation that took place, the restoration of details and the assessment of the job requirement, if the candidate is most suitable for the job.

- **Evaluate the experience of recruiting candidates:**

Companies need to be aware of how candidates feel about their recruitment experience. By getting feedback, it is possible to build a strong relationship, and this can differentiate a company from the competition To increase the retention rate, it is important to ask applicants how they feel. Chatbots can help monitor candidates' feedback after interviews and gain an in-depth look at how companies build bonds with people in the talent pool and are also useful in recruitment strategy.

- **Interview with candidates:**

Scheduling an interview with a candidate is another time consuming task. Intellectual chatbots have access to a recruiter's calendar to check if they are available, and then schedule a date and time for that candidate.

- **Improve candidates on board:**

The very first step for a candidate is to join the organization, which is also a long and crucial process. To make the process smoother, organizations can deploy a chatbot that delivers important information to newly hired employees at the right time.

- **Experience with the candidate:**

With the opening of a new job, a large number of applicants will be attracted in large numbers, which can be a big task for a person. This means that the chatbot can advocate a faster response and speed up the process. In order for the uproar to arise, recruiters should, if necessary, change their recruitment strategy and increase the interest of candidates. The time it takes candidates to send resumes and recruiters should reduce them. Chatbots can quickly return to candidates, so candidates and recruiters are happy on this front.

With the right approach, companies can find a more natural process from job search to conversation. Experience is extremely important in today's marketing recruitment. The path of the candidates must be easy, direct and pleasant, and this must be ensured by the talent acquisition leader. Recruitment chatbots can connect with candidates in a conversational business and also answer the recruitment FAQ, a limit that prevents many applicants from applying. With web chat recruitment, such as career chat, applicants can study the organization and draw recruiters in live agent and computer modes.

- **Feedback on the candidate's experience:**

Structured questions that accompany predefined answers will help with real-time feedback.Instead of using forms, applicants can have access to a dynamic interactive chat interface to share their views. At the point of improvement, it is possible to ask employers questions to candidates, such as "where do you think we need to improve" to understand areas for improvement. Candidates' feedback could be shared with recruiters in order to take the necessary actions to improve any imperfections to best meet human capital needs.

- **Building a relationship:**

Correspondence is important throughout the recruitment process. This applies to the HR department as well as to job seekers. The information accessible through chatbots makes it a simple and natural methodology. Chatbots are powered by instructions. Chatbot will submit a decision inquiry and ensure that the discussion is reasonable.

- **An employer brand building tool:**

Employer branding helps a company excel if it has a chatbot on the company's work page. Although many organizations are excellent at building content branding employers and publishing this content on their career site, but unfortunately it does not see many candidates. Using chatbots it is very possible to send automatic messages to current subscribers with the latest blog posts, videos, etc. on multiple posting platforms messages. By providing a personality to a recruitment chatbot, some companies take their brand to the next level. Companies also ensure that the culture and values of organizations are well aligned with chatbot and its interactions and promote the employer's brand by ensuring regularity of messaging during the recruitment process.

3. CONCLUSION

Human resource management plays a central role in business. Technological progress in this department therefore has a huge impact on the entire organizational structure. The successful implementation of innovative technologies in HR will have a positive impact on the rest of the company.

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RELATIONSHIP BETWEEN INDUSTRY 4.0 AND HUMAN RESOURCES

VZÁJEMNÝ VZTAH PRŮMYSLU 4.0 A LIDSKÝCH ZDROJŮ

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Abstract

The main goal of this article will be to summarize the literary research of Czech and foreign literature on the topic of the relationship between Industry 4.0 and human resources. Within human capital, the areas of labor market, computer literacy and education were selected. In the individual chapters, the operation of Industry 4.0 on selected areas of human resources will be described in detail. It should be noted that in this case it is a mutual action, therefore Industry 4.0 has an impact on human resources as well as human resources on Industry 4.0, because one could not exist without the other.

Key words

Industry 4.0, human resources, education, computer skills, labor market.

1. INTRODUCTION

Industrial production has undergone several periods of change from the beginnings of the use of steam energy to the automation of processes through the use of information technology. The coming era, called Industry 4.0, covers the entire value chain from raw materials to end use to business and support functions (eg supply chain, sales). Industry 4.0 is creating new principles, such as: increased connectivity, production virtualization, processes by linking sensor data (from monitoring physical processes) to models, decentralized decision-making, the ability to collect and analyze data in real time, increased service orientation, and more.

Thus, Industry 4.0 will create opportunities for new business models, solution offerings and new products. As industrial companies will have to consider implementing elements of Industry 4.0 in the future, not only to maintain a competitive advantage, they will also have to face a number of challenges posed by this change. These challenges will take many forms, likely to involve the integration of new IT capabilities, the impact of exponentially growing amounts of sensor data, distribution networks, data security, and the impact on human resources in the enterprise.

2. INDUSTRY 4.0

The Czech Republic is a country with one of the longest industrial history ever. It is also the wish of all that it will continue to maintain its competitiveness on a global scale in the future. Therefore, it is crucial for her to take the challenge of P4.0 correctly and use it to her advantage and for the benefit of future generations. The Czech industry is undergoing a transformation caused by the introduction of information technologies, cyber-physical systems and artificial intelligence systems into production and services. The impact of these changes is so fundamental that there is talk of a fourth industrial revolution, collectively referred to as Industry 4.0. The essence of P4.0 is the connection of the virtual cybernetic world with the physical world, which brings with it interaction with the whole society, ie with the social world [1].

The premise of P4.0 is that individual aspects of physical life will have their own legacy in the cyber world, where they will have their own and unique IP. In this context, there is talk of the Internet of Things (IoT). This is followed by the Internet of Services (IoS), which manages the activities of IoT things. In the event that humans and robots communicate together, an interface needs to be put in place to create an Internet of People (IoP) [2].

3. HUMAN RESOURCES

Under the term human resources, it can be imagined a strategic, comprehensive and logically connected unit of people who work in the company individually or collectively and contribute to achieving the company's goals. Human resource management is defined as the targeted development of a company by providing qualified, motivated and dedicated employees who are interested in participating in the running of the company and thus create a competitive advantage [3].
Basic objectives of human resources management [4]:

- fulfillment of the company's strategic goals,
- creating an environment for increasing work performance,
- providing qualified and motivated employees,
- maintaining positive working relationships, between employees and between employees and management,
- adherence to an ethical approach to employee management.

The most common personnel activities in the field of human resources management include [5]:

- job creation and analysis,
- personnel planning,
- recruitment, selection and hiring of employees,
- employee evaluation,
- placement and termination of employment,
- remuneration,
- education and development,
- work relationship,
- employee care and benefits,
- internal communication.

4. LABOR MARKET

P4.0 and its influence into everyday life will lead to the need to change the content of the required qualifications, as well as the labor market in general. The entire organizational structures of companies as well as the required professions can change. Employees will need to acquire new knowledge in order to work with new technologies. What real impact this will have on the employment rate is likely to be seen, because at the moment the introduction of automation in the company tends to solve the problem of shortage of skilled labor. Once this gap is covered and businesses replace the work of existing employees, there will be a need to change labor market, social and training policies to help businesses and people and reduce their economic and social impact. Several studies have already been carried out which are listing the jobs at risk of digitization the most and the least.
Jobs most at risk from digitization:

- Officials for the processing of figures,
- general administrative staff,
- drivers of cars and motorcycles (except trucks).

Jobs least endangered by digitization:

- Managers in retail and wholesale,
- doctors (except dentists),
- specialized nurses and midwives [6].

Overall, the Czech manufacturing industry employs a large number of people compared to the rest of Europe, which is a positive factor due to P4.0 (23 % in 2018) of the total number of employees. Within the manufacturing sector, more employees are concentrated in low-tech industries. The growing demand for knowledge and skills of the workforce is reflected in an increasing share of tertiary educated people. This is especially the young population. This trend is common to all countries on the European continent. The share of skilled workers in tertiary-educated workers in industry is shown in Figure 1., where the legend outside the figure shows the values (in %), while over 59 %, such as the Nordic countries, indicates the fact that tertiary-skilled professions work mainly tertiary-educated workers. people. While a country such as Romania (less than 28 %) has only 24 % tertiary-educated workers in their skilled professions. The Czech Republic gained 40 % in this 2019 survey, so almost every second employee is tertiary educated. This provides an opportunity for the employment of the technically capable emerging generation in the future, at the expense of the resignation of predominantly secondary school-educated practitioners [6].

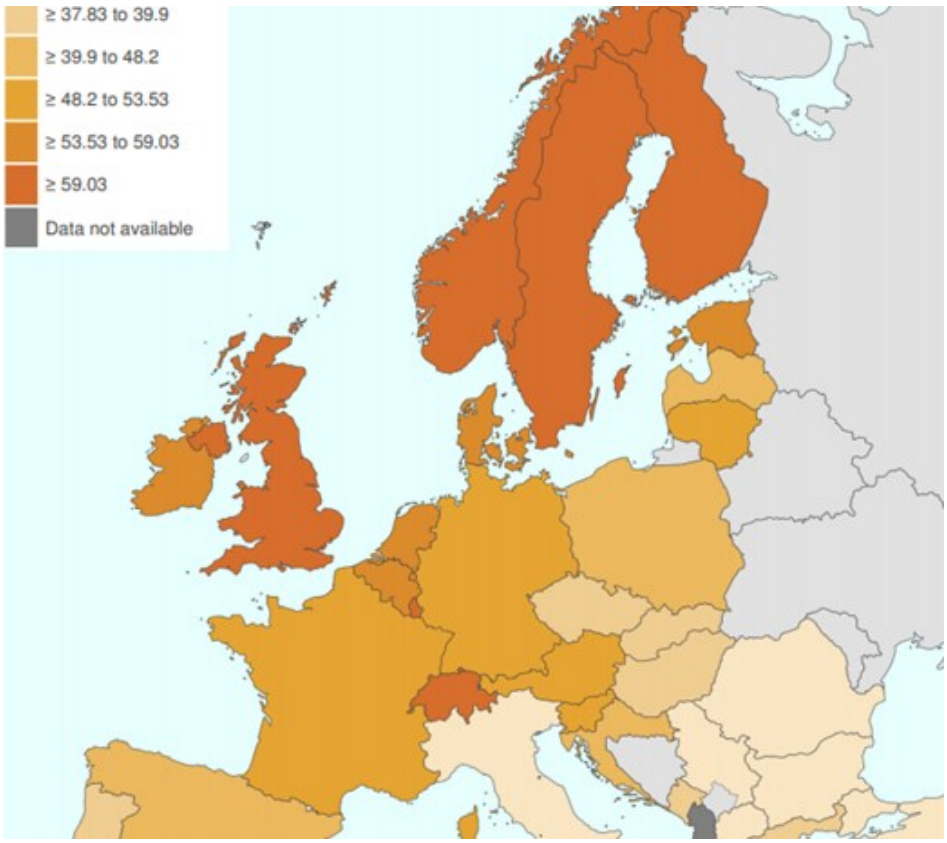

Figure 1 Proportion of qualification-intensive professions and tertiary educated in industry. Source: [7]

5. COMPUTER LITERACY OF POPULATION AND EDUCATION

General computer literacy, formal or informal education in the population is also an important prerequisite for the advent of new technologies. Computer literacy is affected by the availability of an Internet connection, its quality and the availability of Internet services. As far as systematic education is concerned, it will not only be a matter of introducing subjects that relate to the latest technologies, but a kind of interdisciplinary education across disciplines. Among the general knowledge that graduates should not lack in the future are the ability to work with information, create system concepts, understand the application of analysis and synthesis, solve problems, mathematical and logical skills along with so-called soft skills such as independence, responsibility, ethical behavior, flexibility. All these listed abilities and skills should have not only graduates of technical fields, but all students of tertiary education. This basis should be followed by information on the overall functioning of the Internet, its benefits, but also pitfalls (meaning in the context of cyber security), the development of new technologies and P4.0 tools. The reason why all graduates should have this knowledge is that the elements of P4.0 will penetrate into all spheres of life and not only professional ones in the coming years. Graduates of technical fields will then have an extension of knowledge in the form of detailed technical implementation of individual technologies [6].

Czech universities are generally prepared for teaching about P4.0, but the necessary strategically developed curriculum and entire fields of study are lacking. A few study programs under P4.0 are already working, but many more are needed in the future. As well as existing fields of study such as law, economics, etc., they will need to add their curriculum with this issue. It is also important to involve university students as much as possible in internships in companies, so that they can obtain practical information and, after graduation, be able to move smoothly into the operation of the company without lengthy adaptation processes. The possibility for current employees is also the possibility of retraining. These could take the form of lifelong learning at universities or within companies themselves. The overall popularization of technology and technical disciplines is also currently needed, as without students or applicants, changes will be very difficult to make.

According to research [8], the number of graduates has increased slightly since 2010, and it can be assumed that this trend will continue, which is positive given P4.0. Regarding the use of computers, in the age group 16-24 in the Czech Republic almost everyone came into contact (97 %).

In the age group 16-74 it is 78 %, which is also a relatively decent result compared to other countries. Another part of the research dealt with computer literacy in such a way that it determined the individual tasks on the computer (from the simplest to the most complex) and people answered whether they performed them successfully on the computer. The data show that, in general, the age category 16-24 is better than category 16-74, but this is a trend mentioned in almost all the countries. As for the individual operations, it copied and moved the component 89 % in the younger category, 60 % in the wider category, which corresponds to the overall average. As the tasks become more difficult, we lag behind the overall average more and more, so that only 10 % of the younger category (average 20 %) and 5 % of the broader category (average 10) wrote a computer program by almost half.

6. CONCLUSION

This article examined the relationship between Industry 4.0 and human resources. The areas of the labor market, computer literacy of the population and education were selected as key for the needs of the article. As far as the labor market environment is concerned, the entire organizational structures of companies as well as the required professions may change. Employees will need to acquire new knowledge in order to work with new technologies. Likewise, companies will need to respond to changes within the company in order to manage their human resources efficiently and use Industry 4.0 as a competitive advantage. In particular, the areas of performance management, training and recruitment will be problematic. According to research [7, 8], it follows that the Czech Republic does not lag behind the rest of Europe in terms of computer literacy. The room for improvement is the training of the older population, which is not as good at computer tasks as a generation younger. In the field of education, in the future it is a matter of developing strategically elaborated curricula, from which fields with interdisciplinary overlap will emerge.

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EVALUATION OF ENTERPRISE READINESS FOR INDUSTRY 4.0 IMPLEMENTATION

HODNOCENÍ PŘIPRAVENOSTI FIREM NA ZAVEDENÍ PRŮMYSLU 4.0

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Abstract

The paper presents an introduction to the upcoming Industry 4.0 approach and focuses on evaluation of companies' readiness for its implementation. The relation between Industry 4.0 implementation and Lean Manufacturing is highlighted. The aim of the paper is to map an existing literature background and describe the main characteristics of the proposed evaluation model.

Key words:

Industry 4.0 implementation, readiness for Industry 4.0, evaluation model, Lean Manufacturing.

1. INTRODUCTION

The process management is a way of enterprise management focused on efficient implementation, description, optimization and continuous improvement of internal and external company processes leading to an achievement of business objectives and operational excellence. In this way, an organization can achieve better flexibility against development dynamics of a market and be more flexible to customer requirements. Advantages of process management are e.g. transparent and effective process design, reducing process times, an organizational structure supporting right functioning of processes, significant cost saving, flexibility or continuous improvement [1].

Lean Manufacturing is a widely used process management approach based on increasing production productivity and effectivity by reducing complexity and costs by eliminating main wastes (defects, overproduction, waiting, transportation, inventory, motion, extra-processing and non-utilized talent) [2]. Lean Manufacturing arose from Toyota Production System in Japan.

Nowadays, we are in a phase of the fourth industrial revolution called Industry 4.0. Industry 4.0 is a designation for manufacturing approach based on an utilization of cyber-physical systems and related automation and digitalization leading to production customization and personalization [3]. What is the state of its implementation in enterprises? Are companies ready for its implementation? This paper aims to define main readiness areas, focus on relation between Lean Manufacturing and the readiness and describe the main characteristics of the evaluation model.

This will lead to complete Industry 4.0 implementation model based on the readiness evaluation which will be part of further research. It should help enterprises to make an assessment of their current Industry 4.0 implementation readiness enabling to strengthen found bottlenecks and select the most efficient way of the implementation.

2. LITERATURE REVIEW OF READINESS FOR INDUSTRY 4.0 IMPLEMENTATION

This chapter maps the main aspects of the readiness for Industry 4.0 implementation. The previous research showed there is a strong relation between the readiness for Industry 4.0 implementation and already implemented Lean Manufacturing. But it is not the only aspect.

Hurta and Noskievicova (2021) found 44 sources including the topic of connection between the readiness for Industry 4.0 implementation and agile manufacturing approaches (mainly Lean Manufacturing). [4] The main authors focusing this topic are:

- Lichtblau et al. (2015) created an evaluation model of the readiness for Industry 4.0 implementation including an assessment of strategy and organization, smart factory, smart operations, smart products, data driven services and staff. The evaluation stands on 26 questions and 3 company characteristics (a sector, a number of employees and an annual turnover). The evaluation sorts companies to outsiders, beginners, intermediates, experienced, experts and top performers according to their level of the readiness. To measure readiness, criteria were defined for each area and have to be met to move up to the next readiness level. The evaluation was done through an online survey. The survey design was based on two-phase methodology. The first phase determined Industry 4.0 friendly companies and the second phase was focused on them.
- Schumacher et al. (2016) built their own model of Industry 4.0 implementation readiness and maturity based on a revision of already existing models. They enriched technologically focused models by organization aspects. Their model focuses on the readiness in areas of product, customers, operations, technology, strategy, leadership, governance, company culture and staff. They proposed an empirically grounded model divided into 9 dimensions with 62 items assessing the Industry 4.0 maturity. Evaluation of maturity was conducted by using a survey consisting of one closed-ended question per item. Each question contained an answer to a Likert-scale reaching from 1- “not distinct” to 5- “very distinct”. The total maturity level resulted from calculating the weighted average of all maturity items within its related dimension. The weighting factor equals the average importance.
- Ustundag and Cevikcan (2018) did a summarization of existing information related to maturity and readiness for Industry 4.0 implementation models including difference between them and proposed their own model. It includes 13 evaluation areas which are grouped into 3 dimensions. The dimensions are Smart products and services, Smart business processes and Strategy and Organization. Each area is graded with related survey questions by 0–3 points. After all, calculated points of all areas are grouped under dimensions and sub-dimensions in order to identify overall maturity levels to Absence, Existence, Survival and Maturity categories.
- Sharma and Gandhi (2018) see the main aspects of the readiness evaluation in maturity level of Lean Manufacturing implementation which provides a significant frame for Industry 4.0 implementation, a level of a national cybernetics economy measured by a number of installed robots per 10.000 employees, or maturity level of IT network security.
- Vita et al. (2018) mention that the main aspect of successful implementation of Industry 4.0 is properly established Lean Manufacturing. They enclosed a summarization of existing evaluation models for Lean Manufacturing maturity level as well as Industry 4.0 maturity level and constructed a model of their integration. They used a survey method. Then, data were analysed through SEM analysis and general statistics methods.
- Prinz et al. (2018), Satoglu et al. (2018), Sony (2018) and others perceive Lean Manufacturing implementation level as the main factor for Industry 4.0 implementation readiness.
- Muizzullah et al. (2019) made a model for Industry 4.0 implementation standing on a readiness of companies in fields of Lean Manufacturing, HR and productivity, technology, finance and interaction with customers. They used Actor Analysis and Casual Loop Diagram leading to a conceptual System Diagram.
- Ebrahimi et al. (2019) focus on modelling the readiness for Industry 4.0 in a frame of transition from World Class Manufacturing based on 5 main pillars – workplace organization, costs, maintenance, quality control, logistics and customer services.
- Rossini et al. (2019) issued a study of 108 European companies implementing Industry 4.0 which confirmed that the proper implementation of Lean Manufacturing increases the readiness of companies for Industry 4.0.
- Tortorella et al. (2019) were investigating the relation between Industry 4.0 implementation and Lean Manufacturing across 147 Brazilian companies. It resulted to findings about existing relation between a company size, a length of Lean Manufacturing utility period and influences of process and product technologies on a company performance. They used a survey method divided to three related lean practice areas and two Industry 4.0 technology areas and safety, delivery, quality, productivity and inventory performance indicators. The model was grounded on the contingency theory, multivariate data analyses were performed.
- Kolla (2019) summarized existing methods of evaluations of Lean Manufacturing implementation, Industry 4.0 implementation and their integration.
- Grufman and Lyons (2020) upgraded the Lichtblau´s IMPULS model of the Industry 4.0 implementation readiness to make it applicable in conditions of small and medium enterprises. They used a survey approach and utilized a literature review with grounded theory approach.

Based on the literature review, this topic seems to have a sufficient literature background for further research activities. A gap of the existing research is seen in diversity of the current approaches. The researched data are often gained from different kinds of national economies and the approach to the readiness for Industry 4.0 evaluation is not united.

3. EVALUATION MODEL OF READINESS FOR INDUSTRY 4.0 IMPLEMENTATION

The current methods of the evaluation are based mainly on questions asked to representatives of an evaluated subject and then they are evaluated by coefficients and statistically processed. Therefore, the evaluation can be influenced by a subjectivity of a questioned person. To avoid that, it is recommended to ask questions as unequivocally as possible.

The most of authors focus on the readiness evaluation in a frame of concrete economy (Brazilian, Thai, Indian, …). For the general evaluation model, it is important to include an influence of macroeconomics and organizational characteristics. For this paper, this group of characteristics is named “organizational characteristics”. This group of characteristics influencing the readiness for Industry 4.0 implementation includes:

- A sector – a sector is a key aspect to be able to assess an importance of particular readiness evaluation measures for a concrete company. For example, an importance of existing technological maturity of an automotive enterprise is higher than in a hairdressing saloon. This importance will be expressed by a coefficient for each sector multiplying the evaluation areas.
- A company size – a company size measured by number of employees has a significant impact on the readiness for Industry 4.0 implementation. The bigger a company is, the more difficult the implementation is. A negative influence is seen also in a decentralization of its organization.
- Financial indicators – Industry 4.0 brings technologies with high costs. Therefore, a financial state of a company is another important indicator of its readiness for Industry 4.0 implementation. Besides the basic indicators of the finance analysis like profitability indicators, performance indicators, a turnover, a profit etc., it is recommended to focus on amount of finance assigned to company development.
- An external economic and political environment – the economic and political environment where a company operates can have a big impact of its readiness. There is a better readiness in prosperous national economies with national policy supporting (e. g. by subsidies) technology development in companies. These influences can be quantified by macroeconomics indicators and an amount of related subsidy programmes.

The second part of the evaluation is an operational readiness. The operational characteristics demonstrating Industry 4.0 implementation readiness are:

- Technological maturity level – a default state of company technologies is an important aspect. A level of utility of organizational software, digitalization, automation etc. directly influences next steps of Industry 4.0 implementation.
- IT security – An often-neglected area of the readiness to digitalization is IT security. Encryption methods, work with data, a software and hardware maturity are elements which need to be take in account during the readiness evaluation.
- Lean Manufacturing implementation – most of the authors agreed that Lean Manufacturing (or similar process-driven approach) implementation level is a key for a high level of the Industry 4.0 implementation readiness. An evaluation model should contain an assessment of a process management use across management, manufacturing, quality, HR, logistics, supply management and customer management areas.
- Agile customer approach – Industry 4.0 stands on mass personification and customization of production. To achieve that, it is necessary to set an agile approach up which reflects customer requirements, measures and evaluates them.
- Level of enterprise communication – each change (implementation of new approaches) is based on its proper communication. Therefore, a right functioning of company communication is another important factor conditioning a successful implementation.
- Enterprise strategy – an implementation of Industry 4.0 needs to be driven on a strategic level and enters the strategic company planning.
- Human resources – the implementation of Industry 4.0 is related to a creation of specific work positions. Therefore, the readiness for the implementation is influenced by an existence of qualified personnel.

The complete evaluation of the readiness for Industry 4.0 implementation will be created by a model integrating the organizational and operational characteristics defined above. Firstly, a survey including all the evaluation areas has been created. It includes 21 questions. The first 5 questions are related to the defined organizational characteristics, concretely it asks for:

- number of employees (a company size characteristic),
- annual turnover in last year (financial indicators characteristic),
- profit/loss in last year (financial indicators characteristic),
- annual budget for development activities (financial indicators characteristic),
- business sector according to CZ-NACE (a sector and an external economic and political environment characteristics).

Remaining 16 questions map the operational characteristics. There are 4 questions focusing on existing technological maturity level, 3 questions evaluating Lean Manufacturing implementation, 3 questions about agile customer approach, 3 questions assessing a level of enterprise communication system and per 1 question for IT security, enterprise strategy and HR characteristics.

As part of further research, the survey will be sent to Czech companies across business sectors, sizes etc. Then, it will be necessary to set up the quantification of particular characteristics effectively and logically to avoid a distortion. For that, coefficients for each operational characteristics' question evaluation will be set up taking in account an influence of organizational characteristics and their relation. Comparative values of the characteristics will be set up and complete evaluation model will be based on scoring model method.

4. CONCLUSION

The paper introduced Industry 4.0 approach and its relation to Lean Manufacturing. The existing literature sources related to an evaluation of readiness for Industry 4.0 implementation were found and described. The sources were ordered chronologically and the main aspects of the models included were presented. It resulted into a complex view of the readiness measurement issue.

The own evaluation model of readiness for Industry 4.0 implementation was proposed. It is based on 4 organizational and 7 operational characteristics. The evaluation survey was presented and a method of its assessment was outlined. As a part of further research, the survey will be sent to Czech companies and the evaluation model will be used in practise.

ACKNOWLEDGEMENT

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DIAGNOSTICS OF THE OSCILLATING MECHANISM

DIAGNOSTIKA OSCILAČNÍHO MECHANIZMU

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Abstract

As part of the modernization of the continuous casting machine (ZPO1), the electromechanical swing mechanism was recently replaced by a modern hydraulic swing mechanism. Current analog accelerometers have been replaced by modern digital accelerometers. New digital accelerometers have helped more accurately diagnose the oscillating mechanism. The goal of this upgrade is to use a three-axis chip instead of the existing two two-axis chips, which introduce noise and possible measurement errors.

Key words:

Oscillating mechanism, continuous casting, mold.

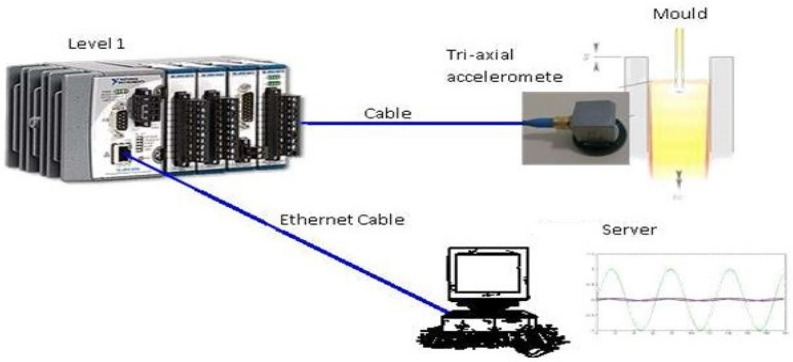
1. INTRODUCTION

In recent years, emphasis has been placed on predictive maintenance in order to optimize production efficiency and reduce production downtime. Accurate and prudent information on the possible occurrence of a fault condition can prevent economic losses and non-compliance with the production plan. In the past, a frequent phenomenon of production losses in the operation of continuous casting of steel number 1 (ZPO1) was a breakthrough in the casting stream caused by poor seating of the oscillating table. This phenomenon due to the rupture of the casting crust causes the given casting stream to stop during the replenishment of the currently casting sequence and possible production downtime for work related to removing steel spatter in the casting arc and replacing the damaged casting unit.

The old oscillating mechanism diagnostics system was based on an analog accelerometer mounted in the corner of the oscillating mechanism. The principle of accelerometer functionality was based on two biaxial chips encapsulated in a metal cooled box. The accelerometer evaluated the acceleration in three axes and, using an analog card, converted the acceleration to a deviation in millimeters, which is caused by a poorly seated casting unit. The functionality of the DGS system is absolutely crucial. This system evaluates and displays data of all 3 axes continuously during the casting process. The operator has an overview of the events associated with the oscillating mechanism.

This is a product for analysis of mold oscillator performances, and their effect on steel quality. There is a strict correlation between good performances of mold oscillator and steel quality, for this reason the oscillator system must be checked from time to time by test unit tool. The proposed test unit allows off-line testing of the Oscillating Bench during maintenance operations. The test data is collected from accelerometers attached to the Oscillating Bench.

This challenge of replacing digital accelerometers has thus provided the potential of the current practice of continuous casting process control to move further towards a concept compatible with the requirements of Industry 4.0. The Simatic PLC is connected to the PC server via an Ethernet



network cable (remote connection) and the PLC unit is connected to the triaxial accelerometers on site using a green box. Using this tool, it is possible to evaluate data coming from collection units and store this data green box. Using this tool, it is possible to evaluate data coming from collection units and store this data in data files for online and offline viewing. Figure 1 shows a block diagram of the new system.

Figure 1 Oscillating mechanism diagnostic system. Source: [own]

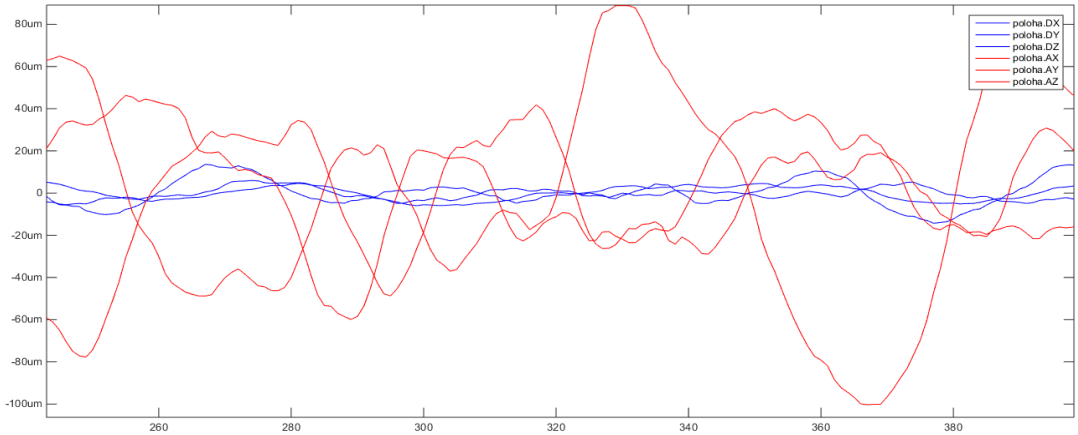
2. DIGITAL ACCELEROMETERS FOR MORE ACCURATE DIAGNOSTICS OF THE OSCILLATING MECHANISM

The digital triaxial accelerometer was tested as an extension of the developed ABS anti-breakout system to evaluate the state of the oscillating mechanism. Currently, analog accelerometers are used on ZPO1. During the test on one casting stream, it was confirmed that the digital accelerometer is more accurate, and this signal can be used as an additional input to the friction hazard evaluation algorithm.

The former DGS system used two biaxial analog accelerometers housed in a cooled housing. The signals of the individual accelerometers were connected to an analog DGS electronics card, which uses a NUCLEO microcomputer card to filter out and evaluate the signal and then store it in data files on the server using the DGS application.

The new system developed is based on one three-axis digital accelerometer. The accelerometer itself in the housing was stored in place of the existing accelerometer during the tests. During the testing of the possibility of connecting the crystallizer motion diagnostics to the TŽ information system, the parameters of the existing analog solution as well as the digital replacement were measured. The noise of the acceleration sensor can be converted from mV, resp. LSB to mm. This means what deflection the accelerometer would display if it were not subjected to dynamic acceleration (if there was no movement of the oscillating table). A high-quality 24-bit B&K analyzer was used as an A / D converter for the test, it was measured in laboratory conditions. In addition, in an industrial environment full of interfering signals, the analog version will add noise induced to the cable and this noise will increase with the length of the cable. It follows that the signal of an analog accelerometer will show even worse parameters in an industrial environment than those found in comparative tests.

Since the digital variant showed significantly better noise parameters, as can be seen in Figure 2, the connection of the analog accelerometer was not continued. With the designed digital accelerometer, a maximum error in the order of 10–20 μm can be assumed. For analog up to 100



μm.

Figure 2 Analog (red) vs. noise comparison digital (blue). Source: (own)

A device collecting data from the accelerometer, which performed filtration, was designed for the accelerometer. Data from an accelerometer with a sampling frequency of 1 kSps were decimated, filtered and integrated into an output signal of 40 Sps. Figure 3 and Figure 4 show the test result of a digital accelerometer in three axes. These curves will be plotted in the In Touch visualization on the device operator's cab.

The operator performs an oscillation mechanism test after each conversion of the casting unit to a different casting format. The test itself consists in switching on the oscillating mechanism in a defined time interval. During the test, the accelerometers evaluate the individual axes and display them in the information system. If the resulting graph shows an X, Y or Z axis deviation greater than 0.5 mm, this anomaly is considered a fault condition.

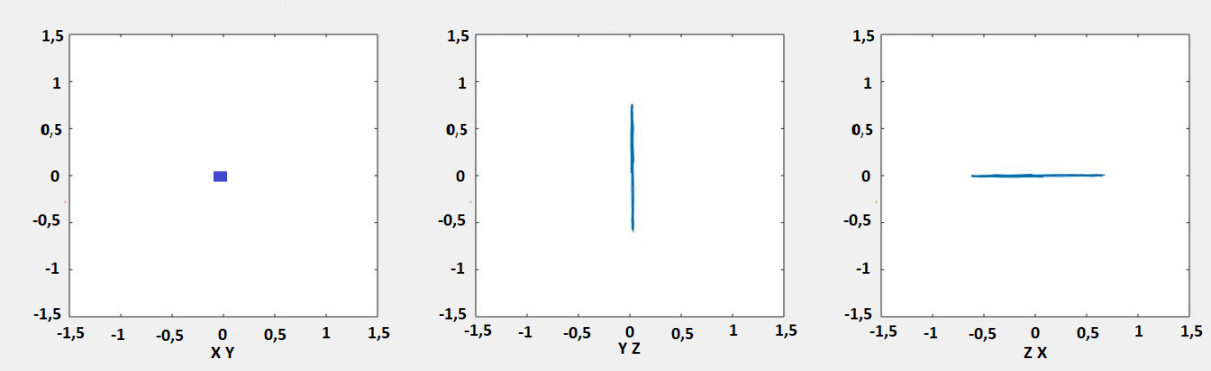


Figure 3 Calculated X, Y, Z, position, oscillating motion of the mold. Source: (own)

From the measured data it can be concluded that after completing the visualization and static processing in the superior system, it will be possible to fully replace the existing analog system. Subsequently, it will be possible to connect this system with the anti-breakout system and achieve a more accurate and forwarder prediction of risk situations.

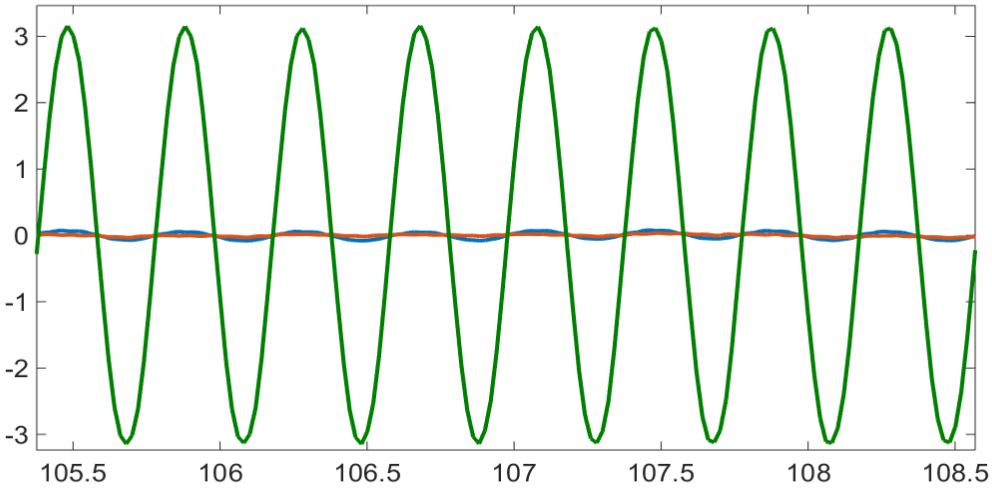


Figure. 4 Calculated position, fs = 40 Hz, oscillating motion of the mold. Source: [own]

3. CONCLUSION

In the conditions of continuous casting No. 1, a new system of diagnostics of the oscillating mechanism was developed, based on a new digital accelerometer. A triaxial accelerometer was used as a suitable chip to evaluate the acceleration. It has also been shown that the data from the new system is more accurate and not subject to analog current loop interference. In addition, the developed oscillation mechanism diagnostics system makes it possible to predict mechanical deviations in the swing table mounting during the oscillation mechanism test and to prevent possible

fractures caused by rupture of the face crust during steel casting on ZPO1, which is in line with modern Industry 4.0 requirements. The new system also replaced an outdated system that was no longer supported by the supplier. The old system appeared as a "black box", fault maintenance was not able to make any adjustments, each fault had to be consulted with the supplier, which was costly. The new system is based on a user-accessible programmable computer. The Anti Break-out system has been expanded with a new three-axis digital accelerometer, the implementation of which will make it possible to further refine the detection of risky conditions and perform diagnostics of the entire oscillating mechanism.

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AGILE ELEMENTS OF PROJECT PORTFOLIO MANAGEMENT

AGILNÍ PRVKY ŘÍZENÍ PORTFOLIA PROJEKTŮ

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Abstract

The goal of this paper is to present the current state of knowledge in the researched area of agile principles in project portfolio management as an important theoretical part of the dissertation thesis. This paper presents outputs of research within agile project portfolio management and existing process models that will be an important for practical part of dissertation thesis. The final part of this paper describes a research gap based on the critical evaluation of the available literature results.

Key words:

Agile, Portfolio, Project.

1. INTRODUCTION

Agile methodologies and principles have their roots in software development projects. However, their gradual implementation to other areas within last couple of years shows their contribution. The basis of agile methodologies is focused on customer satisfaction and its involvement in the process, a constant focus on changes during the solution, selection of the right teams and teamwork, transparency of individual elements, processes and strategies.

2. THE METHODOLOGY OF THE PAPER AND DATA COLLECTION

The main sources of the paper inputs focusing on agile project portfolio management are from the current research outputs and publications especially from foreign researches. Databases used for the literature recherche are followed:

- **WEB OF SCIENCE,**
- **SCOPUS**
- **ELSEVIER SCIENCEDIRECT,**
- **EMERALD,**
- **RESEARCHGATE,**
- **SPRINGERLINK,**
- **GOOGLE SCHOLAR.**

3. THE CURRENT STATE OF KNOWLEDGE

Currently there are not many available resources that focus on project portfolio management using agile principles or methods.

Kaufmann et al. [1] describe in their research that agile principles are becoming increasingly popular in project, program and portfolio management as they allow more flexibility to adapt to a dynamic environment than traditional methods. Based on a study published in 2020, where the consequences of agile practices in project portfolio management processes were tested, it was found that the application of agile elements generally has a positive effect on portfolio management from developing its strategy to successfully meeting the goals. Furthermore, opportunities for agile approaches to change the uncertainties that appear in the portfolio were identified. Agile principles help to increase the complexity of the portfolio, especially in the exchange of information and resources within individual portfolio projects. According to the authors, an important element is the

general expansion of agile thinking into corporate culture. Only thanks to this can progress be achieved in project portfolio management [1].

Stettina and Hörz [2] tried to understand the application of agile methods in project management and portfolios, especially in the field of information technology. Their research, published in 2015, emphasizes an important element of top management sponsorship for introducing agile elements into portfolio management. They also defined three aspects that are generally key to portfolio management - routines, structures, values. Agile management needs to include transparency of resources and tasks, close cooperation in the team and with customers, with elements of feedback and a commitment to a strategically managed portfolio. As part of this research many questions have been identified for future research. The most important are:

- What is the best management of an agile organization in relation to a portfolio?
- What strategy to choose for implementing agile elements in existing organizations?

Hoffmann et al. [3] focus on portfolio management of information technology projects that require strategic alignment, efficiency and agility. Currently, problems as inconsistencies are identified within the project portfolio management between elements at the level of portfolio management, where formal rules are often circumvented, resulting in resource overload, malfunctioning projects, inability to respond to changing strategies. Given these findings, agility clearly has a positive impact on portfolio management, as clear transparency complies with all rules, thus increasing the efficiency of portfolio management. On the other hand, the research identified concerns, and that is the implementation of agile elements in the organization so that everyone understands their benefits and that the impact on portfolio management is positive. The time failure was caused mainly by lack of human resources to cover all important tasks. This issue very often caused by lot of collateral projects in the process and shared resources.

Rautiainen et al. [4] presented a case study on agile project portfolio management in a software company environment. Within the presented outputs, the contribution of agile elements (back log, extreme programming, etc.) is observed, thanks to which problems with:

- setting and changing priorities,
- visibility of projects,
- project structure.

After the introduction of agile elements, a clear plan for change management and prioritization is set, projects are transparent, including the structure of projects, which was helped by the involvement of top management [4].

Hörlach et al. [5] describe that organizations face a growing number of possible approaches for agile portfolio management and management but emphasize that resources on best practices for the selection of a suitable methodology for the implementation of agile elements are rare. The focus of their research is again focused on the portfolio in the field of information technology, which is an area where the portfolio differs diametrically from manufacturing industries.

It is worth mentioning the research from Petrinska-Labudovikj [6] which deals with theory and project portfolio management practices. Points to the importance of using software support for effective portfolio management and at the same time describes the great diversity in the approach to the implementation of project portfolio management, which varies across organizations. It states that there are few resources and knowledge available on implementation on a global scale.

A comprehensive search for project portfolio management was carried out by Fotr [7]. As part of his research, he describes the basic components of portfolio creation - determining the overall evaluation of projects, selecting projects for the portfolio, optimizing the portfolio and evaluating performance and periodic portfolio reviews [7].

4. PROCESS MODELS

Within the methodology of implementing project portfolio management, it is possible to reflect on several process models that can help in the creation of the methodology. Process models of creation and project portfolio management are listed in Table 1.

Table 1 Process models of creation and management of project portfolio

Process model	Process model phases				
	1	2	3	4	5
Bible & Bivins [8].	Creation (revision) of strategy and setting of strategic goals	Two-stage preparation and evaluation of projects (prescreening a screening)	Portfolio creation, its analysis and evaluation	Measurement and evaluation of project performance, implementation of corrective actions	Measurement and evaluation of portfolio performance, determination and implementation of its changes
Knutson [9].	Strategy creation and strategic planning	Identifying opportunities and generating ideas for projects	Prioritization of projects	Selection of projects for the portfolio	Portfolio monitoring and correction
Morris & Pinto [10].	Preliminary examination of proposed projects	More detailed processing and analysis of proposed projects	Screening and decommissioning of non-compliant projects	Project portfolio optimization	Adjustments to the optimal portfolio
Bayney & Chakravarti [11].	Categorization of projects	Project risk analysis	Project portfolio evaluation	Project portfolio optimization	Project prioritization and portfolio management
Portfolio Management for Transforma-tion [12].	Strategy analysis, confirmation of strategic goals and creation of ideas for projects	Transformation of ideas into projects	Project prioritization and portfolio creation	Portfolio approval	Risk identification and preparation of risk reduction measures
Ramsay [13].	Formulation of strategy and strategic goals	Generating project proposals in relation to strategy	Project screening and prioritization	Portfolio optimization	Portfolio realization

All process models shown in Table 1 have five steps and generally describe the framework of project portfolio management based on standard methods with different approaches but none of them include agile methods or principles and how to implement them.

5. CONCLUSION

The critical evaluation of the available professional literature results in a research gap in the implementation of agile principles in project portfolio management. All analyzed studies have one thing in common, they generally describe the benefits of agile elements in project portfolio management, but do not sufficiently address:

• for which types of project portfolios are agile principles suitable for which only partially and for which they are not suitable at all,

• integration of agile principles into project portfolio management as a key approach to project portfolio management,

• methodology for implementing agile principles in project portfolio management in large industrial companies.

Based on the mentioned subject of research, the current state of knowledge and the definition of the research gap, the main goal of the dissertation are outlined.

The main goal of the dissertation is to create a methodology for implementing agile principles in the management of the project portfolio of a large industrial enterprise, which will include specific recommendations, and which will enable systematic work to increase the agility of project portfolio management.

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INTELLIGENT FLOWMETER FOR METALLURGICAL INDUSTRY

SMART SENZOR PRŮTOKU PRO METALURGICKÝ PRŮMYSL

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Abstract

In the global industry, the volume of products produced is currently growing up, and there is also pressure to reduce input costs. One of the ways in which this can be achieved is to focus on the correct measurement of individual process variables already during the technological process. This paper is devoted to the analysis of the current possibilities of measuring the flow of liquid media and development of a new type of sensor, which has these functions and will directly contribute to the gradual reduction of production costs.

Key words:

Flow meter, auto-detection, IoT, smart sensor, heavy industry.

1. INTRODUCTION

With the roll-out of Industry 4.0 and the associated cost reductions in the near future, manufacturing companies will start to install measuring devices that are more accurate, less disruptive, and offer more functions than traditional and dedicated solutions. Flow sensors are one of the most widely used measuring devices in the metallurgical industry. The main problem today is that metallurgical production often takes place in specific, sometimes even extreme conditions, and therefore when servicing the measuring equipment, it is necessary to manually remove the equipment from the circuit, install a by-pass, take the equipment away, perform service operations and then reassemble.

All this takes a lot of time and employs several people, while some, especially software service operations can be performed with remote access to the equipment and in this operation, it is not necessary to shut down a specific technological circuit, but this can be done from the command room, which is a huge advantage for night shifts when there are not so many maintenance technicians present in the company. It also has the opposite advantage in that the service can be performed by a technician directly on the built-in industry display and sees in real time how the device behaves and whether the service operation was performed correctly. There are a large number of principles that are used to measure the flow of media and therefore there are several basic types of flow meters. However, the difference between mass and volume flow measuring must be explained.

2. REVIEW OF CURRENT PROBLEM

In the metallurgical industry, to measure the flow of cooling water are often used rotary flow sensors. Input medium - water - it can often be contaminated due to loose corrosion particles, which cover the inner wall of the adjoining pipe and subsequently reduce the accuracy of the measurement, which can lead to the failure of the whole measuring device. For this reason, an intelligent sensor has been developed which works software-based and uses a fuzzy model for accurate flow estimation feedwater and for monitoring the operation of hardware components.

The fuzzy model works in combination with a genetic algorithm-based method of least squares. The operation of the sensor is verified using real data that occur at a particular pipeline node of the cooperating company. The aim of developing an intelligent flow sensor is not only to measure the flow of a specific medium, but a versatile tool that allows monitoring of multiple variables at once, in one place, at one time, and then, using advanced mathematical models to evaluate the process flow on a specific pipeline circuit. Existing research in the field of flow measurement has focused only on the development of new measurement principles, but no relevant research on smart functions that

would integrate this equipment into the Industry 4.0 concept has been carried out. This may be since in heavy industry this concept is quite difficult to apply and there is not much competition to push modern trends in practice. The device whose development is described in this article provides multiple measurements of different physical and chemical properties of the flowing medium, in particular temperature, flow rate, pH, and viscosity.

The operation of the device is continuously monitored using the software under development and in the event of a malfunction, there is the possibility of detecting it before it actually occurs, using a neural network. Individual data, that are measured here are then sent to the cloud and the control system (PLC), which is managed by the operator. The main advantage of this device over other devices in this segment is that it includes a local touch display that allows monitoring and management of the measured values, including on-site software service, whereas other brands do not do this and when servicing, it is always necessary to remove the device and treat the site with a by-pass, which takes a lot of time and ultimately money.

3. DESIGN OF SMART FLOW METER SENSOR

As the new equipment being developed is intended for use in heavy industry, a collaborating company was contacted to determine the diameter of the cooling water pipe, the pipe width, the static pressure, and the approximate flow rates that have been observed in this cooling circuit for a long time. This information is summarized in Table 1 and was used to select the appropriate type of flow meter. Figure 1 shows a comparison of flow sensors based on accuracy and industry use [1].

It shows that orifice and thermal mass sensors generally have the highest accuracy, but these are used to measure gas flow. Therefore, for cooling water measurement, linearity, high repeatability, and accuracy are the most important parameters, which implies that rotary sensors are best suited to this application as they use a helical rotor for low-pressure drop. In this paper, its design will be proposed mechanically, electronically, and software-wise as a prototype (1). The calculations associated with the ideal design under the given conditions can be found below (2, 3).

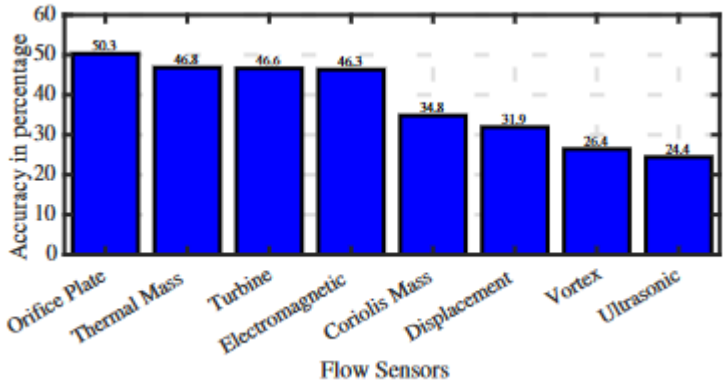

Figure 1 Graph of accuracy of each type of flow meter. Source: [2]

Table 1 Features of flow meter tube. Source: (Own)

Feature	Value
Tube cross-section	22 mm or 3/4"
Tube material	Polyurethane (thermoplastic)
Static pressure of inlet medium	4 - 6 bar
Temperature of the cooling medium	8 - 15 °C
Fixed flow rates in cooling circuits	8.0 - 11.0 l/min

4. METHODOLOGY OF DESIGN

The flow rate can be determined by the interrelationships of various quantities (4). The velocity of the medium in this case depends on the actual pressure in the pipe. The pipe cross-section is already known and remains constant throughout the measurement (5, 6).

The basic calculation for determining the fluid flow rate is:

$$Q = V \times A \tag{1}$$

where:
Q = volume flow (l/min),
V = average flow velocity (mm),
A = cross-section of tube (m/s).

Pulse frequency (Hz):

$$pf = 7.5 \times Q \tag{2}$$

where*:*
pf = frequency of pulses (Hz).

$$volume\ flow\ \left(\frac{litres}{hour}\right) = \frac{pf * 60\ minutes}{7.5 * Q} \tag{3}$$

In other words:

$$Sensor\ rotation\ frequency\ (Hz) = 7.5 * Q\ (\frac{l}{min}) \tag{4}$$

$$litres = \frac{frequency\ (\frac{pulses}{minute})}{7.5} * \frac{time\ (seconds)}{60} \tag{5}$$

$$litres = \frac{pulses}{7.5 * 60} \tag{6}$$

5. MICROCONTROLLER AND SOFTWARE

During the course of the dissertation assignment, the optimal microcontroller best suited for this application was selected. The choice was between the Nvidia Jetson and the Raspberry Pi 4 Model B. Nvidia chip comes out parametrically better, however, it was decided to choose the Raspberry Pi 4, mainly because it has the possibility of connectivity via Wi-Fi and also allows to add a custom display thanks to the integrated DSI display port [Figure 2].

The software for controlling the entire device is programmed in C ++. Official libraries are used for I / O communication, the functions of which are well described in the official documentation, which is part of the appendices. An important part of the entire software is the technical documentation, explaining how the entire device works, both electronically and in terms of software. Smart functions, which consist mainly in the autodetection of possible errors, work based on neural networks and were designed in the MATLAB program [2]. This method is based on statistical generative models of the behavior of the present sensors. The first was to mathematically describe the normal behavior of the sensor. The individual parameters of a certain model are optimized thanks to the help of an online mathematical algorithm in maximum preserved reliability. The individual measured values by the input sensors are then compared with the model, and if the measured value is not the same as the calculated value within the tolerance, then an alarm is triggered. The parameters of the mathematical model are adjusted online over time with the help of deep learning. The system can automatically adapt to conditions that change dynamically.

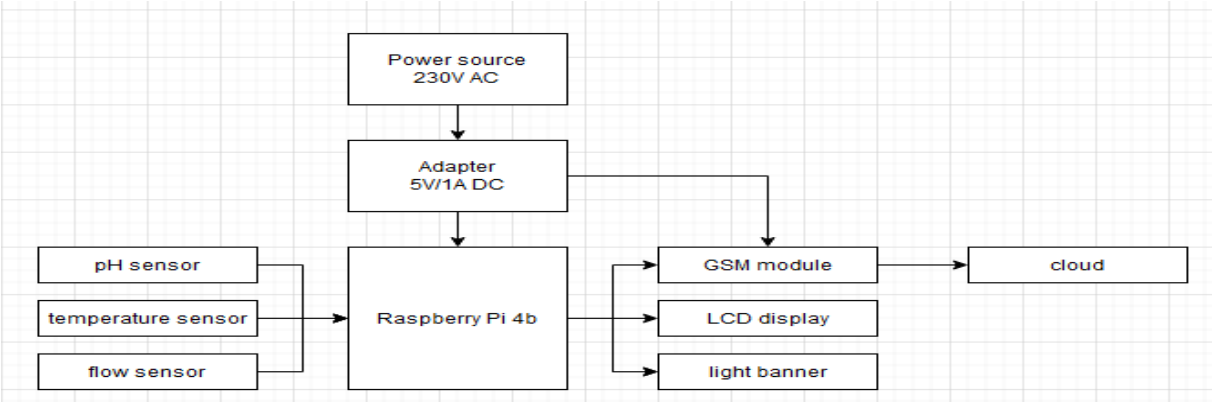

Figure 2 Electronic scheme of smart flow meter. Source: (Own)

5. CONCLUSION

The output of this paper is the design and construction of the sensor from the mechanical and electronic point of view so that it can be used mainly in the metallurgical industry, but ideally it should be used in a wide range of applications to provide greater coverage of demand in the metallurgical market. The second output is the software under development including documentation and visualisation using C++ programming language and neural network. This software is sufficiently robust and intuitive for safe operation without special training [3].

Software of this smart flowmeter is based on fuzzy model, using a substractive clustering method, that was developed to validate actual flowmeter values. Internal software is optimized by genetic algorithm and least-squares algorithm. This device estimates flowrate value using all measured signals. These signals are able to remove fouling degradation of the rotameter. The contribution of the development of this sensor to science is that it was developed using modern methods with mathematical models and software platforms so that it can be classified as Industry 4.0 device and it uses Industry Internet of Things. The developed platform is open source, so it can be used for teaching a students. The software is written in such a way that it can be adaptable for use on other devices, including ready communication with various communication protocols used in industry [2].

This device is also of high practical benefit as it allows companies operating in heavy industry to participate in the Industry 4.0 trend, as heavy industry in general is not yet making much use of this trend. An employee who is responsible for a controlling of a specific production technology where this equipment is implemented, has the unique opportunity to analyse the process on a given pipeline circuit in real time, which in the past he had to do with more single-purpose devices where the result was never as accurate as a one-point, one-device, one-time analysis. Staff, who physically move around the production environment (maintenance staff, or regular rounds) gain a powerful tool, that allows them to use the display to get operational information from previous hours, trend this information, and reconfigure the equipment according to the current needs.

ACKNOWLEDGEMENT

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NEW MODERN APPROACHES TO MANAGING METALLURGICAL PROCESSES

NOVÉ MODERNÍ PŘÍSTUPY ŘÍZENÍ METALURGICKÝCH PROCESŮ

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Abstract

The agglomeration is an integral part of the metallurgical enterprise, its main task is production agglomerate used for the production of pig iron in blast furnaces. The production of the agglomerate consists of in the treatment of fine - grained ore material into a material with the required grain size, chemical composition and mechanical strength. The treatment of the material on the agglomeration is called sintering. In the presence fuels (anthracite coal or coke coal) and reducing agents in the mixture, fine-grained particles. The work defines the required functions of two-dimensional measurement of sintering carts, its assumed benefits and structure.

Key words:

Expert system, sintering plant, agglomeration.

1. INTRODUCTION

During the agglomeration process, chemical and physical parameters such as alkalinity and average must be used values of other components, meet predetermined target values within defined standard deviations in order to meet the quality requirements. The quality of the agglomeration mixture begins with the selection of and by mixing the raw materials in a mixer and dosing device to be integrated into a common control model of the agglomeration process. Chemical properties are homogenized automatically by adapting the mixture to the raw materials. Proposed sintering control system that takes into account the physical and chemical properties of the agglomeration mixture respond to changes caused by fluctuations in the input raw materials, which is achieved by closed-loop control. The sintering process itself is a key transformation process. Undesirable phenomena can occur during this process. One of them is a fall on the sintering carts or clogging of their vents. These side effects worsen the sintering effect, in terms of higher amounts of unbaked material or worsening of sintering. Due to the depression or hole on the sintering belt, the negative pressure acting on the individual chambers deteriorates.

2. METHODOLOGICAL APPROACHES

Optimized agglomeration operation requires accurate dosing of raw materials (see Figure 1). Calculation of exact chemical analysis of product agglomerate for Basicity, SiO_2, MgO, FeTot. Calculation of raw mix composition. Monitoring of the dosing device. Detection and compensation of dosing deviations. Based on the required composition, design the dosage of the agglomeration mixture. Based on the actual chemical analysis, correct the recipe for dosing the agglomeration mixture. Monitoring of materials starting at the dosing station, going through the whole agglomeration process and ending with sampling. This procedure brings:

- Comprehensive monitoring of recipes and data from dosing processes up to laboratory analysis.
- Helps the operator track material changes.
- Allows accurate evaluation of the impact of changes in the recipe and process parameters.

Long-term archiving of recipes, chemical and physical analyzes and process data enables retrospective analysis of the best process conditions for specific raw materials. This should allow:

- Display of the chronological sequence of active recipes.
- Assign product analyzes to related recipes.
- Statistical evaluation of individual operations related to the active recipe [1, 2].

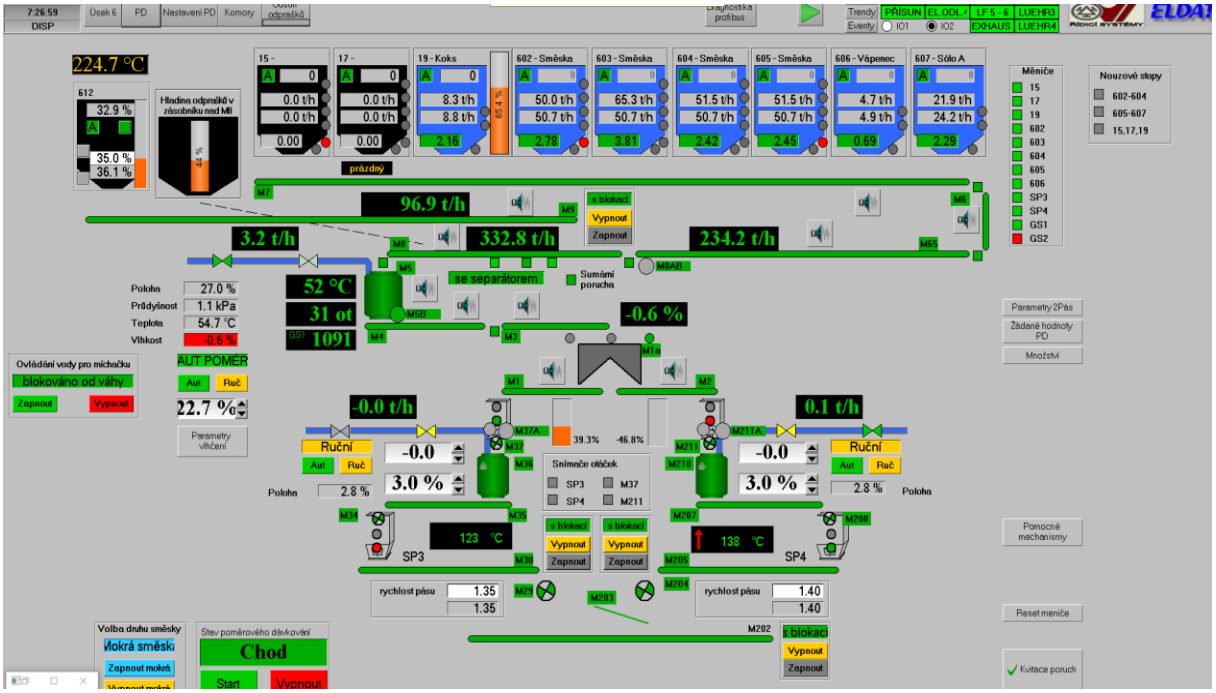

Figure 1 Agglomeration visualization. Source: (own)

The task of the agglomeration manager is to regulate the operation of the sintering process (see Figure 2), so that the best quality of the agglomerate is achieved during maximum production, suitable for blast furnace processing. In order to ensure the maximum production of the agglomerate under the given batch conditions, it is necessary that the maximum temperature of the exhaust gases is maintained in accordance with the valid regulations. According to the sintering conditions, the foreman controls:

- sintering belt speed,
- the amount of water in the batch,
- amount of fuel in the mixture,
- the amount of return material in the mixture.

The course of sintering is also affected by fluctuations in the dosing of solo ores outside the homogenized mixture on belt scales, because then the composition of the batch fluctuates. The speed of the sintering belt depends on the vertical sintering speed, which is given by the breathability of the charge, depending on a number of factors. The speed of the sintering belt is regulated according to the flue gas temperature and the appearance of the agglomerate at the fracture of the sintered layer at the end of the belt. The quarry must show: sintering of the agglomerate up to the grate surface, red heat, cohesiveness of the agglomerate cake. The foreman must adjust the flow of the charge, including the return agglomerate, so that during the sintering process there is no shortage or excess and as a result the sintering belts are stopped or the feed line is stopped frequently, the mixture cools below technologically acceptable temperature and also significant evaporation of moisture, which has a very adverse effect on the sintering technology. Frequent stopping of the feed line also results in excessive dust deposition in the water tanks of the redler transporters, the impossibility of smooth removal of the return agglomerate. By controlling the technological process, the foreman significantly influences the amount of emissions into the air, energy and fuel consumption. A 2D lidar was used to eliminate other side effects. The leader has the ability to occupy all the bars mounted on the sintering cart and thus identify the absence of the bar. A model of individual rods was created for testing the lidar. In the case of a missing rod (see Figure 2), the lidar sends a signal to the PLC digital input

system. The signal is further displayed on the visualization of the engineer. He has the option of either automatically blocking the sintering belt or just being informed [3, 4].

Figure 2 Model of individual rods and sintering carts. Source: (own)

The lidar used for this application was set to the lowest scanning frequency of 25 Hz, as the sintering speed is very slow, so this frequency is sufficient. The scan point density was set with respect to the frequency option of 0.1667 °. Due to the model, an evaluation field and conditions were created for the resulting state of the digital output of the device, which signals the undesirable state of the truck defect. If this zone is violated, the output will be activated. The zone turns yellow when activated, this condition signals a permeable sintering wagon (see Figure 3). The example shows the field how it responds to the state of illumination by the lidar.

Figure 2 Conditions signals. Source: (own)

3. CONCLUSION

The expected benefit should be due to a reduction in the proportion of back agglomerate, an increase in agglomeration productivity and a stabilization of material quality. In terms of operation, this is a large financial return. Simplified diagnostics of the sintering belt problem for the operator. The temporary disadvantage of the application is still in the high radiant heat at the application site.

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MARKETING PROCESSES FOR THE COMMERCIALIZATION OF INNOVATIVE TECHNOLOGIES IN THE CHEMICAL INDUSTRY

MARKETINGOVÉ PŘÍSTUPY PROCESU KOMERCIALIZACE INOVATIVNÍCH TECHNOLOGIÍ V CHEMICKÉM PRŮMYSLU

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Abstract

The article presents the main reasons for the search for new approaches to the process of commercialization of innovative technologies. The purpose of the article is to identify modern marketing approaches in the commercialization of innovative projects in the chemical industry with subsequent study to form answers and solutions to the current challenges of the industry.

Key words:

Commercialization of innovations, marketing of innovations, technology commercialization.

1. INTRODUCTION

In the modern world, innovative projects and developments have become the most important part for competing in the market and shaping the economic growth of any sector of the economy, including the country's economy. Enterprises in the innovation sphere are a priority area for economic growth, realizing the importance of innovation, the governments of countries use various methods to stimulate and support this activity. Enterprises that are trying to actively use innovation have an advantage in the market. They pay special attention to innovations during the period of overcoming crisis situations arising in the economy.

Effective commercialization of innovations is the most important factor in scientific and technological progress and the creation of high-tech production, which forms the preconditions for stabilizing the country's economy and in the future leads to an increase in its efficiency. That is why the commercialization of innovative projects is such an important factor in progress, and theoretical approaches, which are subsequently applied in practice on actual projects, are very relevant and significant research for the practical tasks of commercialization.

The relevance of the topic is determined by the urgent need to develop the theory of marketing innovation, caused by the desire of innovators to master new markets for products. At the present stage of economic development, the issues of not only creating, but also bringing an innovative product to the consumer are becoming topical.

2. MAIN PART

Commercialization is the extraction of benefits in the process of transforming an innovative idea into a final product, which can be knowledge, technology and be sold both in the form of formalized intellectual property (pre-market stage of the innovation process), and in the classic version of a completed market product. Intellectual capital is becoming the main product of the modern economy. To achieve a sustainable positive result, it is necessary to obtain economic benefits from the introduction of the results of intellectual activity into production. In other words, the result of intellectual activity must be commercialized. The tools for promoting the result are shown in Figure 1.

Figure 1 Promotion tools. Source: (own).

where:
Public Relations (PR) – communicative function of forming the image of a specific object in society,
Advertising – any one-sided paid form of non-personal presentation and promotion of ideas, goods or services,
Personal sale – type of promotion, which is based on direct interaction and communication between the seller and the buyer, the result of which is the presentation of the characteristics of the product and a decision is made on the transaction,
Direct marketing – the use of any means of communication between the seller-buyer to influence actual or potential customers,
Sales promotion – various short-term incentives aimed at stimulating the purchase of goods, services, property.

The six most common investment models highlighted:
- business angels,
- venture investments,
- strategic investors (partners),
- lending (including indirect financing - factoring, forfeiting, leasing),
- other investments (friends, family, crowdinvesting, personal savings),
- sale of shares on the stock exchange (public funding).

The commercialization process is inherently associated with many risks, primarily due to the individuality of each individual innovative project. Studying the works on this topic over the past 20 years, it can be noted how various authors point out the errors and shortcomings of methods, classical approaches, proposing the modernization of processes and arguing that it is his work that is the very magic pill that can solve the equation with such volatile variables [1].

It is worth noting that in the modern world, resources are at the head of any activity and at the very beginning of work it makes sense to turn to energy and resource conservation and give yourself an answer to the question, are you ready to risk wasting your own resources? Further, starting to study the object, the first step is to form your own idea of the scale of the object and external factors that can be influenced. Of course, in the future it is necessary to study all levels of the environment (-micro-, -macro-factors, internal or external), but the result of studying these factors directly depends on the competence of the person studying this issue. There are many different models that can help in reducing risks when implementing the management of an innovative product or project, but it is worth noting that they require stringent conditions that in practice are usually not feasible in advance. [2].

Bringing innovations to market that are not needed later is a devastating blow to the viability of an enterprise. In this regard, the task of ensuring all conditions for the successful completion of this process is of particular importance for enterprises. It is rare for one person to combine those competencies that can lead him to the successful implementation of an innovative idea, project or product alone. Therefore, the best way of successful commercialization is to create a team of different personalities with different characteristics and knowledge that can jointly lead to success. [3].

The key to the success of commercialization is the timely selection of the most promising innovations from the entire volume of potential projects (the first stage of commercialization as a process), which allows enterprises to rationally allocate available resources and make forecasts of possible changes and difficulties in the potential market . Such a selection is based on various methods and techniques for assessing the potential of innovation as an object of commercialization, called a technology audit.

It should be noted that in the modern market, the assessment of the commercial potential of innovations is presented as an independent sphere of economic relations along with the development of innovations and their commercialization, financial and other similar services. Audit (appraisal) companies develop their own unique methods and techniques for assessing the potential of innovation that compensate for the shortcomings of many publicly available methods. Similar services are also

provided by some financial institutions that conduct innovation assessments in order to decide whether to grant loans to enterprises.

A typical assessment structure (technology audit) can be represented as follows: information gathering - analysis - synthesis (development of recommendations) - reporting. All the necessary information investigated in the framework of the audit is based on a group of questions, the list of which includes several sections: advantages for consumers, characteristics of a possible market, main competitors, provision of resources, feasibility and security of the idea (see Table 1).

Table 1 The main sections for assessing the prospects of innovative products. Source: (own).

Section name	Section Contents
1.Study of technology	The production technology, its profitability, and the study of the manufactured products are evaluated.
2.Benefits for consumers	A search for similar products is carried out, the advantages of the evaluated product in comparison with analogues are considered, potential methods of motivating and increasing consumer interest in the proposed innovation are selected.
3.Characteristics of a Potential Market	The dynamics of development and growth of the market, its size and segmentation are studied, whether there are barriers to entry.
4.Main competitors	The main competitors, their partner organizations (suppliers, funds, etc.) are determined, in which market segments they promote their developments, whether they show interest in relation to a specific segment in which the evaluated innovation will be positioned.
5.Feasibility of the idea	The complexity of creating a working prototype is manifested, the ability to develop innovations without additional costs (other innovations or own materials / raw materials / components), as well as compliance with accepted environmental standards, laws and regulations.
6.Security of the idea	The article considers the ease of obtaining a patent right for the developed innovation, its reliability in the case of presentation of adjacent technology by competitors, and the protection of innovation from copying even at the stage of its development.
7.Provision of resources	The possibility of commercializing innovation using the existing equipment, the availability of the necessary resources (labor, financial, information, etc.), their reserve for unforeseen situations is assessed.

Considering commercialization as a process of bringing innovative products to the market (from a new idea to its implementation), we note that the study of the state of the market in the framework of a technology audit is of paramount importance. At the same time, a favorable completion of the commercialization process for an enterprise is possible if:

- there is an unsatisfied demand on the market for any product, service,
- there is a high dynamics of market growth,
- some competing enterprises occupy a rather weak position in the market, which allows them to be crowded out later.

When assessing the benefits of an innovative product, special attention is paid to motivating potential consumers to abandon the use of common products and services in favor of this innovation, to purchase products of a previously unknown manufacturer (if the company is just entering the market) or equipment for its own development [4].

As the main information regarding competitors (if the information is not a trade secret), which it is desirable to have in the commercial implementation of innovations, there are:

- full list of types of products,
- full list of all R&D carried out and started at the time of the assessment,
- full list of prices for their products, services, including the cost of their production or provision,
- full list of partners and main consumers of products and services,
- potential expansion plans.

In fact, if the innovation is successful, most competitors (both existing and new) often attempt to obtain instant benefits by taking advantage of the innovative product or technology for their own

purposes. Therefore, ensuring maximum protection of intellectual rights is another of the conditions for successful commercialization.

The technology audit is based on a qualitative comprehensive analysis of innovation, in this regard, all methods and techniques of assessment used in the audit process, depending on the uniqueness of the innovation, are based on several dozen classical methods.

4. CONCLUSION

Methods for analyzing and studying innovative projects have general and universal approaches that are fully applicable to projects in the chemical industry; no separate theoretical features have been identified. Features of projects in the chemical industry introduce additional criteria for studying the factors influencing the commercialization of innovation. Effective commercialization and optimization of methods for the implementation and analysis of this process can significantly affect the possibility of implementing modern innovative projects, without which, the commercialization process could be afraid to carry out, as a result of the analysis, this factor disappears. On the example of the economies of leading countries, one can observe how the growth and interest in investment potential affects the possibility of commercializing projects, including the chemical industry.

Since the chemical industry basically has a serious state influence and the need for significant resources for the implementation of innovative projects, modern approaches and methods of commercializing innovative projects can have an extremely positive effect on the development of the sector and partially move away from the influence of many external factors. The topic is extremely complex and requires more detailed analysis in the future. As soon as large enterprises of the chemical industry can partially get rid of external influences, then perhaps we will be able to observe how the formation of the root system (small and medium-sized enterprises) will generate interest in the chemical industry and its innovations.

This topic has a lot of features, each of which requires separate attention and analysis, but it can be argued that on the example of the IT, we can expect a bright future and a similar boom in the chemical industry.

ACKNOWLEDGEMENT

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TRENDS IN EMPLOYEE EDUCATION

TRENDY VE VZDĚLÁVÁNÍ ZAMĚSTNANCŮ

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Abstract

Organizations face constant changes in the external and, consequently, internal environment in order to achieve competitive advantage. Employee training and development is thus an increasingly important and burning topic. The article contains an overview of modern tools and techniques that are currently often used in companies for employee development. The aim of this article is to present modern trends in the field of employee training and to identify those that companies should focus on in the coming years.

Key words:

Digital educational techniques; training; trends; human resource.

1. INTRODUCTION

Employee training and development is one of the building blocks of long-term prosperity and competitiveness of organizations and companies. Companies that support the development and training of their employees not only achieve better economic results, but also increase their value and image in a highly competitive market. There are several reasons to invest in development and education. It is necessary to realize that employee training is an investment in the future of them and the company.

In recent years, knowledge has come to the fore, suggesting that sociological and psychological factors also have a significant impact on the business process. Knowledge and skills are closely linked to people. A qualified workforce has the necessary supply of knowledge, skills, abilities, talent and creativity. The company's employees thus become a source of economic benefit.

The importance and level of human capital can be increased both through formal education and through training and further training. From the point of view of organizations and companies, education and training are among the most important investments in human capital.

2. MODERN TRENDS IN EMPLOYEE EDUCATION

Modern education today can generally be divided into offline and online methods according to how they take place. Education is also divided into internal and external education, depending on where it takes place and who leads the course. The type of educational activities depends on the needs of individual companies [1].

Modern trends in education are focused on the development of professional knowledge and skills, but not only for business purposes. There is an increasing emphasis on employee well-being, a proactive, personalized approach. When employees get the opportunity to be educated, they are simply happier and feel that they are moving somewhere, that the company cares about them. The feeling that they can be promoted thanks to the completed courses or that they would find it easier to find a job elsewhere if they had to leave the company, also plays a role [2].

For decades, selected educational institutions in European countries have been cooperating with companies in the field of education and training of their employees. This practice is rarely applied and still has great potential today. This type of cooperation brings together the requirements of practice with the school curriculum and influences the profile of the graduate so that it is as useful as possible in practice. Thanks to this, schools and companies perceive this form of cooperation as very beneficial not only for the interested parties but also for the whole region. In practice, it is not only about building knowledge, skills of qualified graduates, but also their attitudes to work, loyalty, teamwork, responsibility.

There are several examples of such cooperation in the Czech Republic. These include Škoda Auto and their educational institutions - the Secondary Vocational School of Engineering in Mladá Boleslav, which was established for comprehensive education of pupils and adult employees for positions in the company [3]. Another example of successful cooperation of this type is the Secondary Vocational School in Otrokovice, which has been cooperating with the company Barum Continental, s. r. o. to provide retraining and training of its employees [4].

In recent years, educational activities have been greatly developed with the help of digital devices, which are becoming more important every year and are being used more often. However, the main "stimulating" impetus for the development and implementation of educational activities using modern technologies and especially the Internet was the coronavirus crisis, beginning in 2019. As a result, online methods are currently being used more actively, offering greater flexibility for employees, financial savings and control over the training for employers.

Below there are examples of modern online external and internal methods of employee training, which have become common practices in Czech companies in recent years:

- Webinars:

They represent a form of seminars via the Internet. They can replace a lesson when the lecturer is not personally present or the course needs more people from different parts of the country or the world and it would be difficult to train them all. Webinars "break down" the walls of classrooms, on the other hand, they can be challenging in terms of maintaining attention and getting feedback [5].

- E-learning:

It is an electronic online education system designed for the distribution of study materials. A typical example is online safety training and interactive online courses [1]. Employees prefer to study at their own pace according to their time possibilities. The advantage of digital training tools is the wide coverage of the needs of employees in various industries and the precise focus on their type of work [6].

- Video Lessons:

They usually consist of short, consecutive lessons, where one can take either the entire course or only selected lessons, and in addition, one can return to the individual parts at any time according to one's needs [6].

In 2021, experts from various countries also focused on the development of little-known modern online methods and their prospects in the following years. They discussed approaches and technologies that will influence the form of education and the way in which they will shape it. Frequently discussed methods today include the following:

- Personalization:

Addressing individual needs is what used to be a bottleneck in education. Some educational institutions are conducting surveys of individual activities in order to subsequently use this data to adapt the content to the needs of their users. In this way, specific learning practices and pathways that follow the temperament, strengths and weaknesses of individuals and their needs are followed [7].

- Remote and Real-time Collaboration:

Technologies are beginning to focus on greater flexibility and asynchronous (remote) learning. Modern tools today allow people to collaborate in real time, turning materials into interactive whiteboards, where everyone has the opportunity to share an opinion, draw and write directly to files. It is also possible to divide your own tasks into group projects and work at your own pace [7].

- Nano Education:

An approach where individuals are provided with less information in a shorter period of time. Learning in smaller doses has been shown to increase the ability to understand and store information and to increase productivity, attention and learning. In addition to identifying the needs of individuals, setting educational goals and selecting content, nanoscience is about making this content concise, ideally within 2-5 minutes [8].

- Interactivity:

The interactive environment allows you to learn faster and remember more information that users learned during the lesson. There are plenty of options to choose from - real-time quizzes, questionnaires, surveys or interactive tutorials. An example of this method is the Kahoot game-based learning platform, which allows you to incorporate quizzes into the learning process [9].

- Digital Work Environment:

Digital whiteboards have many benefits when it comes to online education. First, they can be used synchronously or asynchronously. Second, managers can provide quick feedback on employee work, allowing them to improve their access. In addition, these tools also include timers that monitor individuals' performance at a specific time [7].

- Learning Analytics:

Learning Analytics allows teachers to measure and evaluate individuals' learning only through the web. This allows them to better understand and optimize learning. When teachers read knowledge from individuals' learning processes, they can correspondingly improve the acquisition of their knowledge and skills. For example, trainees can see what type of information (text, images or videos) individuals like best and can use it more in the following study materials. Teachers may also notice what knowledge has not been effectively passed on and improve it next time [10].

- Gamification:

Adding game interactions in non-game settings is a great way to increase user engagement. Some platforms include unlockable content and animations; others opt for achievement badges and daily goals. The great thing about gamification techniques is that they are diverse and help trigger different emotions. Badges support friendly competition between users [11]. An example of gamification is the geolocation game Foursquare, which allows users to share their activities and visited places with other users [12].

- Rich Media and AR:

Breathtaking experiences are becoming very popular in modern education. Rich media and AR (Augmented Reality) are great ways to improve learning because the human brain is firmly set to process visual information much faster. Another important aspect of the immersive experience is media diversity. Lessons that combine video, audio, text and AR provide faster and better learning through lower cognitive load [13]. An example of virtual reality today are modern glasses for virtual reality, they can be included in both the educational process and gaming activities. Škoda Auto, together with the Brainz Immersive creative studio, has developed an augmented reality project for the predictive maintenance of various production facilities in order to streamline the work process and speed up the training of new employees [14].

3. CONCLUSION

The decision of which company education should be offered to employees depends on the current needs of the company, specific job positions or also the need to adapt to changes in technologies or work processes.

Today we have a large selection of methods and techniques for training and developing employees, their knowledge and skills. Modern technologies contribute to the simplification and clarity of the needs of individuals, facilitate communication, help them understand their way of thinking and lay out the most appropriate training technique to achieve a high level of qualification, personal and business development.

Smaller companies could actively focus on developing employees' communication and personal skills using modern digital techniques that would contribute to the development of the individual and increase their motivation and confidence. They would also contribute to improving market position, attractiveness, thus attracting a large number of qualified candidates with new ideas and thoughts. In today's struggle for position and existence in the market in general, they would certainly have a more secure future.

Larger companies should also not forget the development of their employees. By actively participating in the events of the organization, they can contribute to the development of a sense of importance of each individual for the company, the desire to try new things, better communication between departments. Due to their strong market position, they often have more resources for employee development, which is a great advantage for an organization to keep up with modern techniques and technologies.

Modern techniques are beneficial for all organizations that want to operate in the market long and successfully. New trends bring opportunities that facilitate internal communication between employees, increase their value and affect the future of companies.

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PROTECTION FROM CYBER ATTACKS

OCHRANA PŘED KYBERNETICKÝMI ÚTOKY

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Abstract

The article describes the issue of cyber threats. It describes what cyber security is, then the threats of cyber attack and last but not least, it gives tips on how to protect yourself against cyber attacks. The aim of this article is to learn about cyber threats and how to protect against these attacks.

Key words:

Cyber attack, cyber security.

1. INTRODUCTION

In today's world, cyber attacks are a major threat, with critical sectors such as transport, energy, healthcare, finance and industry increasingly dependent on digital technologies for their core business. It is very important to know how to defend against these attacks, because if an attack is successful, it can, for example, leak sensitive data or even bring down an entire system. This is why the term cyber security, or protection against cyber attacks, is increasingly common. Thanks to modernisation, which is largely represented by computer technology replacing the human element, businesses, organisations and other institutes are exposed to cyber attacks. This logical step has led to the creation of certain security advice and tips on how to defend against attacks, and new institutes and authorities have been created to ensure cyber security, including the protection of classified information in the field of information and communication systems and cryptographic protection.

This article is primarily aimed at providing an introduction to cyber security and basic hints and tips on how to protect yourself from cyber attacks. This advice can be very useful and will often protect data from potential attacks.

2. HOW TO PROTECT YOURSELF FROM CYBER ATTACKS

What is cybersecurity? It is a branch of IT known as information security, and it is applied to both individual computers and networks. Cybersecurity, must ensure that information and assets are protected from theft, thus preventing attackers from gaining important data which could then give rise to corruption extortion etc. [1].

Cybersecurity has certain standards. These standards are digital security techniques developed to prevent or mitigate cyber attacks. Many businesses have chosen to adopt a general framework of industry cybersecurity standards, such as the ISO/IEC 27001 series of standards. While this is an excellent first step, it may not adequately address all of a business's legal, regulatory and business obligations. This is because generic standards do not take into account industry or regional requirements. For example, a financial institution limiting its framework to ISO/IEC 27001 standards exposes itself to risk and potential liability by not considering standards required by relevant financial regulators (e.g., the Office of the Superintendent of Financial Institutions/OSFI in Canada) or other mandatory industry or regional requirements, such as those set by the Payment Card Industry (PCI) Security Standards Board, society for Worldwide Interbank Financial Transactions, Telecommunications (SWIFT) or the European Union (EU) General Data Protection Regulation (GDPR). Instead, a business should identify all mandatory cybersecurity requirements and controls that it must meet and combine them with core industry standards in a single integrated framework. The rationale for including these standards or controls should be reflected, at least at a high level, in the overarching cybersecurity strategy of the business [2].

Cybersecurity in Industry 4.0. Many experts highlight the main future risks with the lack of corporate cybersecurity. Due to the increasing digitalization of production and technological processes in Industry 4.0, these threats may become more and more numerous. For these reasons, companies transitioning to Industry 4.0 should not take this issue lightly and should also invest in the cyber security of their software in addition to upgrading. Why are these threats increasing with the introduction of Industry 4.0? It's simple, the machines used in manufacturing are connected directly to the IT infrastructure, or directly to the internet.

Manufacturing is the second most contested industry, yet the sector lags behind in terms of security. Smart factories can be exposed to the same vulnerability exploitation, malware, denial of service (DoS), device hacking and other common attack methods that other networks face. And the extended attack surface of a smart factory makes it extremely difficult for manufacturers to detect and defend against cyberattacks. These threats are now operating at a whole new level with the dawn of IoT and can result in serious physical consequences, especially in the IoT space [3].

Here are a few of the new security challenges that organizations face in the age of Industry 4.0.

- Every connected device poses a potential risk.
- Manufacturing systems such as industrial control systems (ICS) have unique vulnerabilities that make them particularly susceptible to cyberattacks.
- Industry 4.0 connects previously isolated systems, increasing the attack surface.
- Upgrades are often installed piecemeal because the systems are so complex.
- Manufacturing has far fewer regulated compliance standards than other industries.
- Visibility is poor across separate systems and isolated environments.

It can be noticed that the battle is definitely unbalanced. While organizations must protect a wide range of technologies over a very large attack surface, attackers need only identify the weakest link.

The scale of the risks requires a safe, vigilant and resilient approach to understanding and addressing these threats:

- Be safe. Take a measured and risk-based approach to what is secured and how to secure it. Is your intellectual property safe? Is your supply chain or ICS environment vulnerable?
- Be vigilant. Constantly monitor systems, networks, devices, personnel and environments for potential threats. Real-time threat intelligence and artificial intelligence are often necessary to understand malicious actions and quickly identify threats across the range of new connected devices that are introduced.
- Be resilient. Incidents can happen. How would your organization respond? How long would it take to recover? How quickly could you remediate the effects of an incident?

High-profile security breaches. One of the first attacks took place in 2009, when malware manipulated the speed of centrifuges at a nuclear enrichment facility, causing them to spin out of control. This malware, now known as Stuxnet, was introduced into separate networks via flash drives and spread independently across production networks. The sophistication of Stuxnet served as a powerful first example of the potential for cyberattacks in a world of connected factories. Recently, a new type of malware called Trident has been discovered that undermines Security Instrumented Systems (SIS) and allows attackers to destroy or damage any processes that protect these systems by providing false data.

Type of how to prevent cyber attacks. While resources are not currently available to test computer systems and make security recommendations by an outside expert, simple and cost-effective steps can be taken to reduce the risk of becoming a victim of a costly cyber attack: [4]

1. Identify the weakest, most vulnerable points. This is the most valuable data available to the Institute. The place where this data is stored must be protected as much as possible, it is necessary to think how this data can be stolen. Also, the risk and subsequent consequences if this data is stolen need to be considered.
2. Protection of equipment and computers. Anti-virus and anti-spyware software needs to be updated, as hackers look for vulnerabilities in software, these vulnerabilities are fixed in new software updates. Staff need to be trained not to open, for example, emails that have been blocked by anti-virus software, this will lead to unwanted virus intrusion into the network. Another recommendation is to have a firewall installed, the function of the firewall is that it separates the different parts of the network and only those who are allowed to browse the network are allowed to do so. The firewall will

prevent hackers from targeting an individual PC by obscuring the identity of that PCLaptops, tablets and phones can be particularly vulnerable to attacks as they are portable and not always connected to a secure network, which hackers exploit. One of the most effective ways to protect portable devices is to install a VPN that encrypts the data passing through.

3. Important data must be backed up. Data can be irretrievably lost not only in a natural disaster, but also through hacker attacks. It is advisable to occasionally test whether the backup works, this can be either on a physical device e.g. a second hard drive, or to cloud storage.

4. Strong enough passwords are also an essential part, it is advisable to train employees how strong the password should be. Easy to remember passwords are not suitable as they are easily and in a short time hacked. A contributing factor to good security with passwords is that they will be changed regularly. Sufficient password strength can be verified with online tools that will show how strong the password is. If the password still does not appear to be strong enough a random password generator can be used.

5. Grant of authorisation. Most institutions have a problem with the number of people who have access to sensitive data. There is a need to restrict access to certain sections to employees who are not authorized to install software by establishing administrator accounts.

6. Wireless network security (Wi-Fi). These networks communicate over a radio connection, not a physical cable. This makes it not that hard to penetrate this network, even free software programs that are freely downloadable are enough to do so. However, most routers and other Wi-Fi devices are equipped with a feature that prevents a hacker from getting into the network, unfortunately these features are disabled at the factory for easier setup. When using a Wi-Fi network, it is therefore advisable to make sure that these protection features are turned on or the other protection options, restricting access only during working hours and restricting access only to work devices through access points.

7. On the internet only safely. When working on the Internet, activity is monitored and can be exploited by third parties without anyone knowing. Beware of dangerous sites that can steal data.

8. Employee education on cyber protection. If all the measures described in the previous points are in place and staff are not sufficiently trained, all it takes is for one employee to unknowingly download, for example, malware and the measures are useless. Therefore, this point is the most important of all. If a cyber culture is brought into the workplace, i.e. training employees on cyber threats and how to defend against them, these employees are the most effective protection against cyber attacks. You need to make sure that each employee has a strong enough password and has understood the cyber protection training. However, hacker attacks are changing and improving, so it is important to repeat this training at intervals so that your employees always learn about new developments in a timely manner.

3. CONCLUSION

Modernisation in the form of IT brings not only advantages, but also certain pitfalls in the form of cyber threats. These threats can have fatal consequences. Hackers are ready to attack to gain sensitive data or to bring down the overall system. However, if certain security steps are followed and employees communicate securely over the network, these attacks can be prevented.

The article describes what cybersecurity is, the importance of security in Industry 4.0, a real-life example of an attack on a nuclear power plant, and advice on how to improve cybersecurity. In the future, as we move to Industry 4.0, this problem will become even more acute as components that were previously controlled by humans will be connected to the network and every connected device poses a risk. The importance of cybersecurity is well known thanks to examples from the past. The attack on a nuclear power plant where malware manipulated the speed of the centrifuges at the enrichment plant, causing them to spin out of control, is warning enough for humanity to prevent these attacks before the attackers cause damage.

Tips on how to protect yourself from attacks, a strong password that will be changed at certain intervals. Training employees not to take the threat lightly and to be able to safely navigate the network. Checking for software updates if none are installed. Securing the wireless network. Grant powers only to the limited group that desperately needs them. Identify soft targets and focus on protecting them, backing up their sensitive data.

Today, there is still not as much emphasis on cyber security as there should be. Institutions do not adequately protect their data, they do not train their employees, and they then allow access to third parties who misuse their data for their own enrichment. If institutions had at least implemented these

tips to improve cybersecurity, much of the attack might not have happened at all. Going forward, institutions should reflect on this issue and not take it lightly.

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BUSINESS MODELS FOR ADDITIVE TECHNOLOGIES

OBCHODNÍ MODEL PRO ADITIVNÍ TECHNOLOGII

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Abstract

The paper presents business models for additive technology. It identifies already established business models for additive technology. The aim of the paper is to compare the established business models and design a new business model for additive technology.

Key words:

Additive manufacturing, business models, metal.

1. INTRODUCTION

Additive manufacturing (AM) involves a family of different technologies that create components by adding materials layer by layer on a digital 3D solid model. It allows the optimization of the design and produces custom parts with almost similar material properties as conventional manufactured parts. It does not require the use of coolants, jigs, cutting tools and other aids. This method allows the development of geometrically complex objects that cannot be produced by conventional methods and the ability to make rapid prototypes.

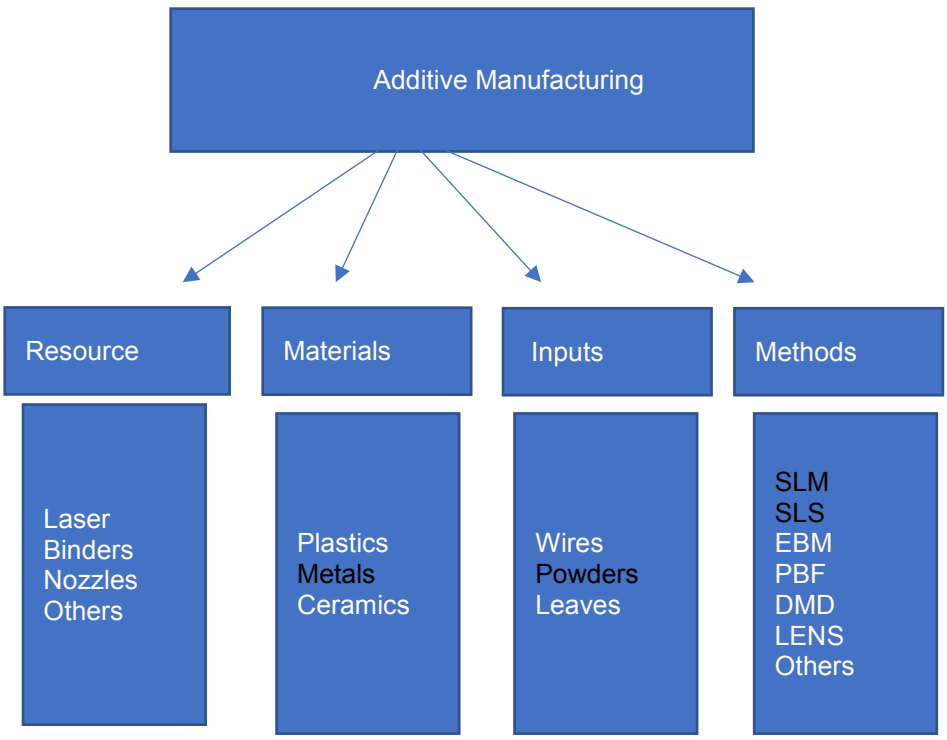

Figure 1 Distribution of additive production

Additive technology has the potential to be used in 18 separate fields that support the development of industries focused on high value added per 1 kg / production, such as: electrical

engineering, energy, production of aircraft parts and components, automotive industry and healthcare. The application of metals and their ability to combine with non-metallic materials in the field of powder metallurgy creates the preconditions for expanding the future competitiveness of industrial companies in the Czech Republic and the European Union.

Additive technology provides unrivaled freedom in component design and manufacturing. In the aerospace industry, 3D printing technology has the potential to produce lightweight components, improved and complex geometries that can reduce energy consumption and resources [1].

Additive technology in the automotive industry has opened up huge opportunities for the production of new designs, lighter, safer and more economical products with reduced material waste, costs and delivery times that are not achievable with conventional production techniques [2].

Additive technology is used mainly for the production of prostheses, dental implants, orthopedic aids, etc. With the help of technology, it is possible to produce various complex shapes and especially tailored to the patients.

One of the main reasons for the development of additive technology in individual fields is the rapid change in the market environment, due to the globalization of the market. Additive technology has an extremely high added value. The aim of the article is to find out if there is a business model for additive technologies or to make a new business model.

2. BUSSINESS MODELS

Business models for additive manufacturing are an evolving field of research where tangible evidence based on specific cases is still scarce. Additive production has and will have effects on the production of business models (BM) and business value chains. Additive technology is likely to change the current way of producing business value. Additive technologies will change the business either gradually, when companies increase their profits in individual branches or strengthen their market position, or additive technologies will have a radical effect on economic values in production.

Model by Hopkins and Dickens

Hopkins and Dickens developed their model with the intention of comparing additive manufacturing processes (especially stereolithography (SLA), melt deposition modeling (FDM) and selective laser melting (SLS)) with the classical manufacturing process, injection molding. This model can be used for different components and batch sizes to identify specific unit costs in order to accurately identify balancing points. The authors' approach provides a breakdown of costs into three elements. Machine costs, personnel costs and material costs [3].

Model Ruffo, Tuck and Hague

Ruffo, Tuck and The Hague have established another cost model to estimate the cost of small to medium batch sizes in the SLS manufacturing process. As an extension of the Hopkins and Dickens model, the authors understand their model as a full-cost model and observe more impacts than previously recognized costs for materials, personnel and machinery [3].

Model by Gibson, Rosen and Stucker

Additive production costs are divided into four main categories by Gibson, Rosen and Stucker. They relate to machine costs, production costs, material costs and labor costs. The sum of these cost categories represents the total cost [3].

Model Ingole et al.

The cost model of Ingole et al. was developed in a study that seeks to improve fast tools - the FDM process makes it faster and cheaper. The cost model was used to evaluate the rate of process change or investment [3]. The costs in this model consist of machine costs, materials, labor costs, and pre- and post-processing costs. However, there is a fundamental difference in the calculations compared to other models.

Model Lindemann et al.

Lindemann et al. choose a time-controlled approach to activity-based costing for cost model design. To identify cost-relevant processes, initially all activities are divided into four main process steps [4, 5]. These main process steps are the preparatory activities, the printing process, the post-processing and treatment of the material in order to improve the properties of the material.

An analysis of the business model was performed, where it was found that there are business models for additive technology, but only models that address costs. The analysis also shows that no business model was found that would address the input factors from material identification, material properties, design processing using a CAD system, selection of a suitable method to outputs and test system.Therefore, at the end of the work, a new business model was proposed, which would address from the identification of the material to the output of the finished product.

3. CONCLUSION

During the research, cooperation was established with the company Dental Sinteo s.r.o., which is based in Brno. The company is engaged in the production of dental crowns using the SLM method, the material used is based on CoCr. A new business model was designed, which is shown in Figure 2.

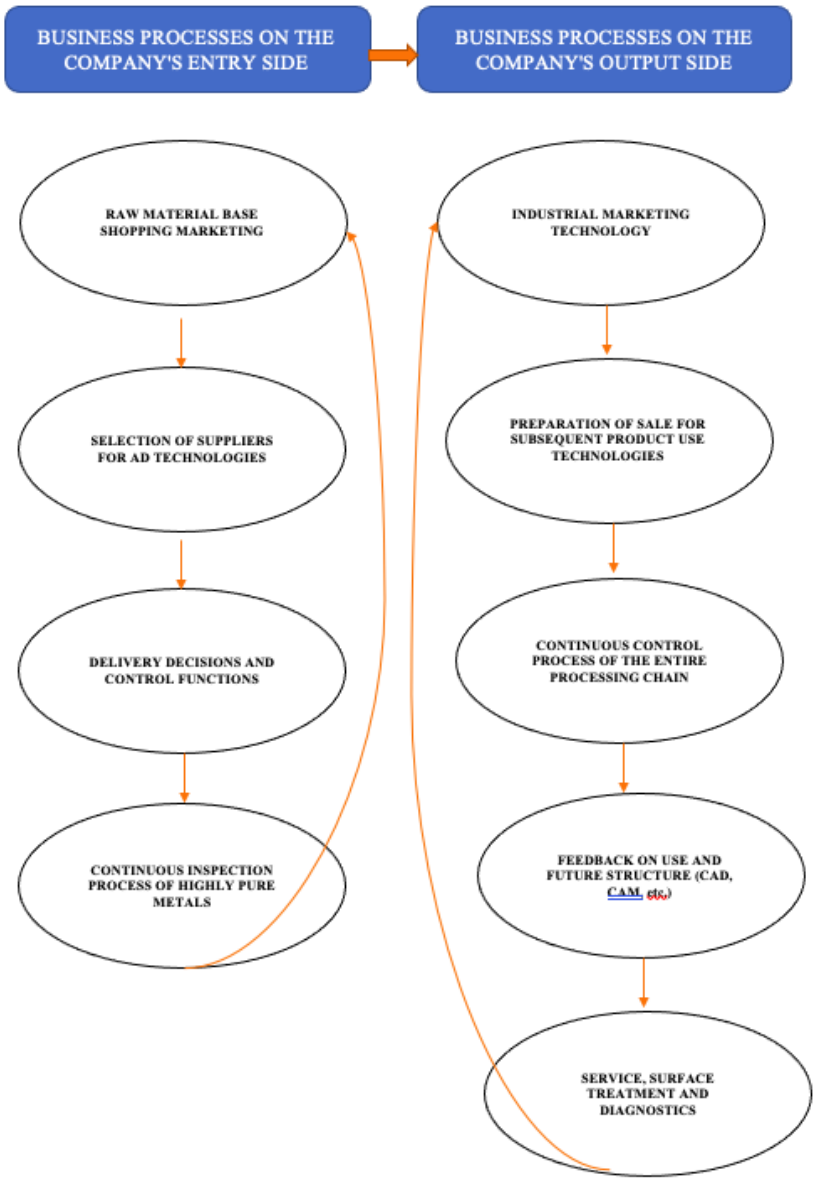

Figure 2 New business model AT

The business model is divided into two sides, with the input business processes on the left and the output business processes on the right. The individual steps on the input side follow each other. It starts with the marketing purchase of input material, when it is necessary to find out the material structure and properties. This is followed by the selection of the supplier of the technology with which the given product will be produced (SLM, SLS, EBM, PBF, etc.). This process is constantly repeated. Once everything is in order, we move to the right.

On the output side, we deal with industrial marketing technology, sales preparation for subsequent product use technologies, followed by a process of continuous control of the entire processing chain, we receive feedback on use and design, and the last step is service and diagnostics. The sales representative must fully understand not only what he is selling, but the entire technology within the supply chain of the final product.

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MARKETING ANALYSIS OF AN AIRCRAFT MANUFACTURER IN THE CZECH REPUBLIC

MARKETINGOVA ANALÝZA VÝROBCŮ LETECKÉ TECHNIKY V ČESKÉ REPUBLICE

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Abstract

The paper presents a marketing analysis of manufacturers of parts and components of aircraft in the Czech Republic. A marketing analysis and marketing research of selected aircraft companies in the Czech Republic were performed, which could establish possible cooperation with research centers.

Key words:

Marketing analysis, aircraft companies, research centers.

1. INTRODUCTION

Thesis is a marketing analysis that could help reveal new opportunities for external cooperation with manufacturers of components for aircraft with a research center. In today's world, there is a need to constantly learn and look for new ways to enter the market and how to build a strong position against the competition.

The aim of the work was to prepare the conditions for the cooperation of materials engineering research in relation to industrial companies, while mastering the application of theoretical tools of marketing research and marketing analysis. The tools of marketing analysis and marketing research were used, secondary marketing research or marketing "research from the table" was used. [1] This research was supplemented by primary marketing research or "field research".

To determine the number of aircraft manufacturers who are located in the Czech Republic and who could cooperate with the research center, it was necessary to use marketing analysis. Subsequently, the searched companies were offered services and cooperation with a research center.

2. MARKETING ANALYSIS OF AIRCRAFT MANUFACTURERS

The process to achieve this goal was clear: the use of secondary marketing research or marketing "table research". [2] Information that is incomplete or outdated will be supplemented by primary marketing research or "field research".[3, 4]. In order to achieve the set goal, information must be collected first and finally the results obtained must be evaluated. The collection of information, from which a marketing analysis was subsequently carried out, was carried out partly on the Internet. [5] The official websites of the companies and also the websites of the Association of Aircraft Manufacturers of the Czech Republic were used. The largest number of aircraft manufacturers were found using the Internet. It was found that only 35 companies belong to the Association of Aircraft Manufacturers of the Czech Republic.

It was necessary to conduct primary marketing research, when the author personally participated in the International Engineering Fair, which took place in Brno. This fair is the most important industrial fair in Central Europe, which is attended by more than 1,500 exhibitors every year. Over 35% of exhibitors from more than 30 countries come from abroad. The majority of companies were from the Czech Republic. According to the author, the largest share of companies from abroad were Chinese companies.

With the help of marketing analysis, companies of aircraft manufacturers of the Czech Republic were sought, the so-called representative sample, which is suitable for cooperation with RMTVC. A representative sample was divided into three parts: parts, subassemblies, final products.

There are a wide range of products found in the aerospace industry. For example, they can be wheels, brakes, propellers, chassis, motors, valves, pumps, motors, generators and many other components. It also includes plastic, metal, ceramic and composite parts. After comparing the manufacturers of aircraft on the Czech market with the foreign market, it can be said that in the Czech market it is mainly manufacturers who specialize in the production of individual parts for aircraft and manufacturers who produce sports and ultralight aircraft. In the foreign market we can also find manufacturers focused on the production of parts, but mainly mainly manufacturers who specialize in the production of aircraft as a whole, such as The Boeing Company, Airbus S.A.S. Significant companies in the Czech Republic are listed in Table 1.

Table 1 Basic characteristics of Czech producers

THT Ostrava CZ, a.s. (Mošnov)	teflonové tlakové hadice
STROJCAR, s.r.o. (Opava)	letecké díly
MGL s.r.o. (Bělotín)	plastové díly
SOEX, spol. s.r.o. (Třinec)	kovové díly
AEV, spol. s.r.o. (Kroměříž)	Elektronika
ZLIN AIRCRAFT, a.s. (Otrokovice)	kola a brzdy
MESIT holding, a.s. (Uherské Hradiště)	díly pro letouny
Aircraft Industries, a.s. (Kunovice)	letouny L410
Alucast, s.r.o. (Tupesy)	přesné hliníkové odlitky
Česká zbrojovka a.s. CZ-AUTO (Uherský Brod)	převodovky do leteckých motorů
EPUZ, spol. s r.o. (Otrokovice)	skelné lamináty
KRILL. B. P., spol. s r.o. (Kunovice)	Elektromotory
Evektor, spol. s r.o. (Kunovice)	sportovní letadla
Czech Sport Aircraft a.s. (Kunovice)	ultralehké letadla
Verner Motor (Šumperk)	Motory
RayService, a.s. (Staré Město)	elektronické součástky a kabelové svazky
STARTECH, spol. s r.o. (Říčany u Brna)	Servomotory
Elektromotory EM Brno s.r.o. (Brno)	Elektromotory
MejzlikModellbau (Brno)	uhlíkové vrtule
Unis, a.s. (Brno)	řídící jednotka turbínového motoru
WollnerPropeller (Miroslav)	výroba vrtulí
Brück AM, spol. s r.o. (Zámrsk)	výkovky včetně válcovaných kroužků
JIHLAVANairplanes, s.r.o. (Jihlava)	hydraulické přístroje
Jihostroj, a. s. (Velešín)	součástky leteckých motorů
Explat, spol. s r.o. (Blešno)	díly do leteckých pístových motorů,
LA composite, s.r.o. (Praha 9 - Letňany)	sendvičové a lepené konstrukce
SPEEL PRAHA s.r.o. (Praha 9)	palubní záznamový systém
NordGlass Distribuce, s.r.o. (České Budějovice)	Skla
CHARVÁT AXL, a.s. (Semily)	hydraulické válce
AERO Vodochody AEROSPACE a.s. (Odolena Voda)	výroba civilních letounů
AVIA PROPELLER, s.r.o. (Praha)	vrtule, kotouče
GE Aviation Czech, s r.o. (Praha 9 – Letňany)	turbovrtulové motory GE
LATECOERE Czech Republic s.r.o. (Praha 9 – Letňany)	kompozitní díly

3. CONCLUSION

The data obtained by the research were subsequently evaluated. The first evaluation was focused on all aircraft manufacturers located in the Czech Republic. A total of 96 companies registered in the Czech Republic were found. From these data, it was concluded that aircraft manufacturers are located throughout the Czech Republic.

The region with the highest frequency of frequencies was clearly the Zlín Region, where 14 companies are located. The second region with the largest number of companies was Prague, where 13 companies were found. Eleven companies are located in the South Moravian Region and the Central Bohemian Region, where 10 companies were found. There are 6 regions in the range of 5 to 10%: Královéhradecký, Jihočeský, Vysočina, Olomoucký, Liberecký, Moravskoslezský. Figure 1 shows the Czech Republic with a specific number of companies engaged in the production of components for aircraft technology.

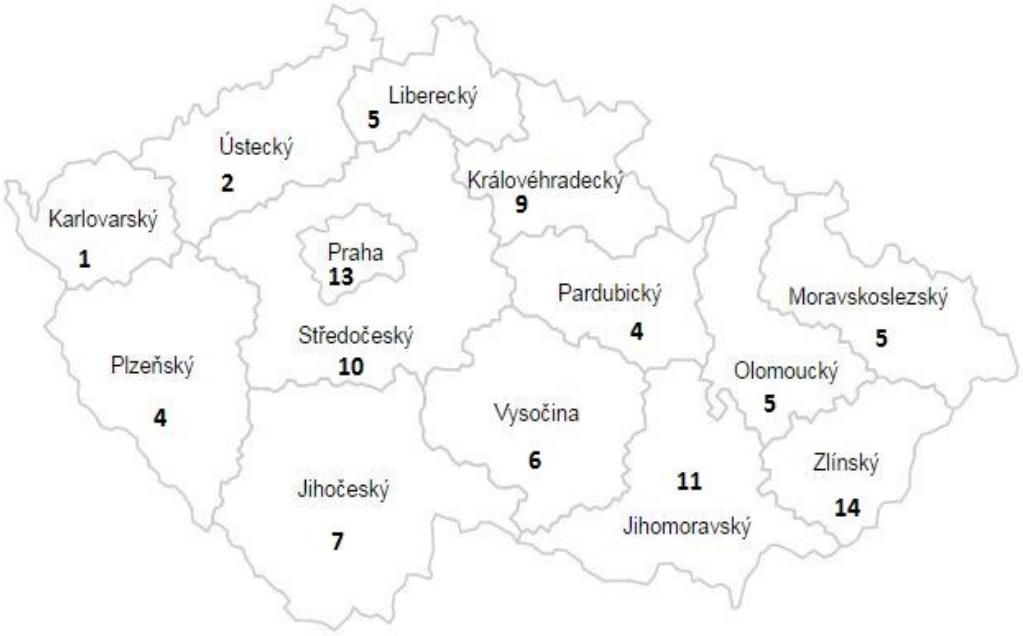

Figure 1 Segmentation of producer distribution in the Czech Republic

As mentioned above, the companies of aircraft manufacturers were divided into three categories in this work: parts, subassemblies, final products. There are fifty companies in the Czech Republic that focus on the production of parts, which accounts for 52.1 % of the total number of aircraft manufacturers. Companies engaged in the production of aircraft subassemblies account for 27.1 % of the total number of aircraft manufacturers in the Czech Republic. The category of final products consists of 20.8 % of the total number of companies found.

A total of 17 companies were contacted. These were companies located in the Zlín Region, the Moravian-Silesian Region, and the South Moravian Region. A letter was sent to the companies about possible cooperation. Companies that did not provide feedback on possible cooperation were assigned to the NO category. Companies that showed interest were included in the YES category. Some companies sent an invitation to the International Engineering Fair, where possible cooperation was personally discussed.

After applying the data, it was found that most companies will find a research center in the Zlín Region for possible cooperation, a total of four companies. There are a total of 3 companies in the South Moravian Region and only one in the Moravian-Silesian Region. From the research, a swot analysis was performed, which is shown in Table 2.

Table 2 SWOT analysis

Strengths	**Weaknesses**
The aviation market is in every region	Most companies have a foreign owner
Opportunities	**Threats**
New products of industry 4.0	Purchase of other Czech companies or shares abroad.

I propose to focus on the development of pure metals and special alloys of low specific gravity, which would mean focusing on individual parts in the field of aviation and aeronautics. In the Czech Republic, these could be hydraulic cylinders and smaller components for aircraft engines. Furthermore, they could be products that could be manufactured using 4.0 technology, such as hinges, holders, grilles, etc. In the Czech Republic, there are companies that already produce components for the automotive industry.

ACKNOWLEDGEMENT

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GLUCOSE SENSOR BASED ON GRAPHENE FUNCTIONALIZED WITH ENZYMES

GLUKÓZOVÝ SENZOR NA BÁZI GRAFENU FUNKCIONALIZOVANÉHO ENZYMY

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Abstract

A graphene field-effect transistor enzymatic biosensor was developed for selective glucose detection. The sensor is based on graphene utilized as the sensing platform and functionalized with enzyme glucose oxidase. The sensor detected glucose levels by measuring the resistance of the graphene channel in two different setups. Through the measurement of the Dirac point shift in dependency of resistance on continual change of gate voltage, and through the device resistance response in real time at constant gate voltage. This paper indicates that graphene holds great promise for the implementation in glucose monitoring devices.

Key words:

Glucose sensor, Graphene, Glucose oxidase, Functionalized graphene, Field-effect transistor.

1. INTRODUCTION

Over the last decades, chronic diseases are becoming more prevalent, and the most advanced example is diabetes. Diabetes mellitus is caused by a disorder of glucose metabolism, about 9 % of the world's population (age 20 – 79 years) suffers from diabetes [1]. Monitoring of glucose level in blood is crucial in the treatment, therefore, the development of glucose sensors is of considerable interest to biotechnological and pharmaceutical industries.

A biosensor (Fig. 1) is a device which transforms changes in an **analyte** substance into a measurable signal. Such changes are caused by biological or chemical reactions between detected molecules in **analyte,** and a **biological recognition element** (**bio-receptor**). **Transducer** is an element which transforms such bio-recognition event into a measurable signal. The signal is further processed by an **electrical converter** and digitally interpreted on the display [2], [3]. The most common glucose sensors work on the principle of a selective reaction of glucose with an enzyme glucose oxidase (GOx). The reaction produces hydrogen peroxide, which is further decomposed into ions and accompanied by charge is transfer [4], [5].

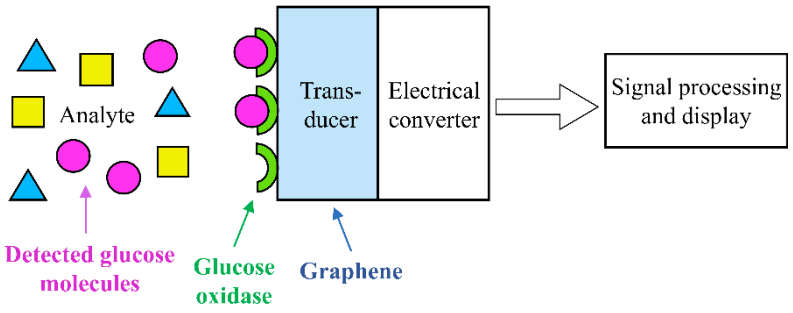

Figure 1 Schematic of a typical biosensor. Source: (own)

Graphene is a two-dimensional carbon crystal with exceptional electrical properties, graphene lattice is shown in Fig. 2b. This biocompatible revolutionary material responds to events taking place in

its environment by changes in its electronic characteristics. All the atoms on graphene are directly exposed to the analyte which provides a highly sensitive platform [6], [7]. However, such sensing platform would lack selectivity to detect only a certain molecules. The functionalization of graphene with relevant bio-receptor element provides a highly selective response on corresponding biochemical substance. In combination with remarkable electrical conductivity of graphene, such system meets the requirements for application in an ideal glucose biosensor.

2. METHODS

The key to develope a highly selective glucose sensor based on functionalized graphene is to immobilize the enzyme glucose oxidase on graphene. In 2003, Besteman *et al.* [8] introduced the immobilization of GOx on the surface of carbon nanotubes (graphene rolled into a cylinder) *via* an intermediate linker 1-pyrenebutanoic acid succinimidyl ester (PSE). The linker PSE binds to carbon lattice through π-π coupling which preserves the electronic properties of graphene-based material [8]. A schematic of the immobilization on graphene is shown in Fig. 2b.

The sensor consists of a solution-gated field-effect transistor (FET), where graphene is used as a conductive channel. The density of charge carriers in the graphene channel (and hence the conductivity/resistance of the channel) is modulated by a local electrostatic field. Mechanisms that alter the electrostatic field include the applied top-gate voltage, or changes in the environment of the sensor, e.g. due to the presence of detected molecules [9].

2.1. Experimental setup

The experimental apparatus of the graphene FET sensor is shown in Fig. 2a, and the device is designed for the detection in two different setups.

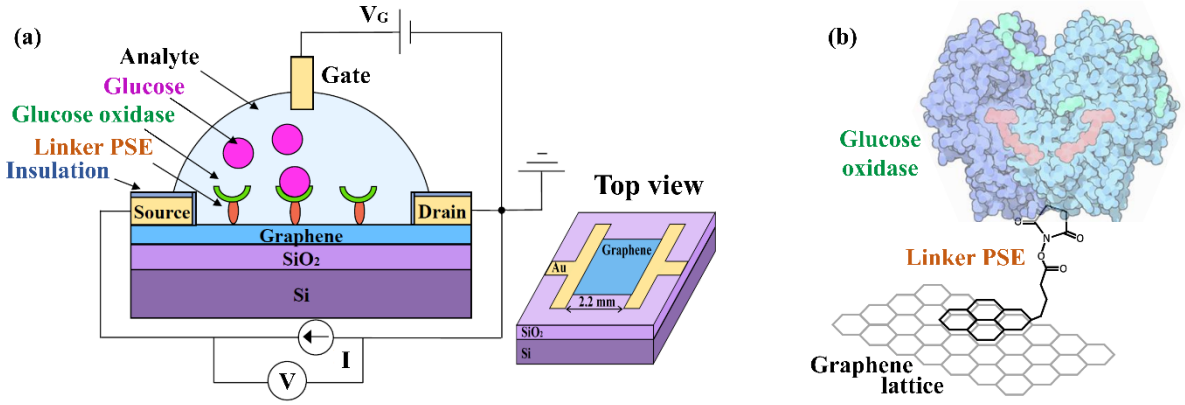

Figure 2 (a) A schematic representation of the designed graphene glucose sensor based on field-effect transistor. The graphene channel is functionalized with PSE linker molecules and enzyme GOx which reacts with glucose molecules in the analyte. **(b) A diagram of the graphene functionalization.** Source: (own)

First setup is characterized by the transfer curve, *i.e.* the channel resistance R as a function of the applied gate voltage V_G. Transfer curves in FETs are obtained by sweeping the gate voltage V_G while maintaining a fixed voltage U between source and drain electrodes. The measurement is performed at a fixed point in time and provides an informative picture of the before-after state. For graphene FET, the transfer curve typically results in a V-shape curve, where one branch corresponds to the hole conductivity, where majority of charge carriers are holes (p-doped), and the other branch corresponds to the electron conductivity, where majority of charge carriers are electrons (n-doped). The maximum resistance is indicated by the Dirac point V_{DP}, where the type of charge carriers (holes or electrons) is changed. The shift of the V_{DP} indicates what doping effect is induced to graphene by the environment. When the V_{DP} shifts to more positive values, electrons are taken from graphene (p-doping occurs), when V_{DP} shifts to more negative values, electrons are transferred to graphene [9].

Second setup is based on the direct dependence of the channel resistance R on different glucose concentrations in real-time. In such real-time measurement, the gate voltage is constant, and the evolution of the resistance is collected as a function of time. Nevertheless, before this measurement, it is necessary to determine the position of the V_{DP} by measuring the transfer curve. As a result, it is determined in which branch is the selected fixed V_G located, and whether the charge

carriers are holes (p-region) or electrons (n-region). Thereafter, from the behavior of the channel resistance it is derived whether electrons are delivered or withdrawn from graphene.

2.2. Fabrication and functionalization

The device consisted of a fundamental sample based on a silicon substrate, graphene grown by chemical vapour deposition (CVD), and a system of gold electrodes (top view in Fig. 2a). Glucose solution was prepared using phosphate buffered saline (PBS) solution and D-(+) glucose.

The graphene sample was incubated with a 5 mM solution of PSE in dimethylformamide for 3 hours at room temperature to attach PSE molecules to graphene. Then, the sample was rinsed several times with isopropyl alcohol and deionized water to wash off excess unbound PSE, and was connected into an electrical circuit. After that, 10 mg/mL GOx solution in 1xPBS of pH 7.4 was introduced to the device overnight in the refrigerator to immobilize GOx onto graphene. The GOx functionalized graphene device was washed with PBS and deionized water a few times. Finally, a silicone reservoir was placed on the graphene channel to maintain the same detection area.

3. RESULTS AND DISCUSSION

Transfer curves, Fig. 3. Initially, a pristine buffer PBS (0 mM glucose concentration) was present in the sensor. After stabilization, the Dirac point was located around -0.3 V, which means that the graphene channel was initially n-doped, and majority of charge carriers are electrons.

Glucose was then added to the buffer to obtain the concentration of 5 mM. The Dirac point shifted to positive values and after another 4 mins stabilized at -0.25 V. The presence of glucose molecules caused p-doping of the graphene channel, therefore, electrons were taken from graphene. As the concentration of glucose was increased to 8 mM, the Dirac point moved further to more positive values and reached -0.24 V. The analyte was then diluted to almost zero glucose concentration and the Dirac point gradually stabilized at the value corresponding to the pristine buffer. The concentration was increased to 21 mM, and the Dirac point shifted up to -0.23 V, confirming the p-doping effect caused by glucose molecules. Finally, the analyte was diluted to 15 mM glucose, and the corresponding transfer curve (Fig. 3b) served as a basis for further measurements.

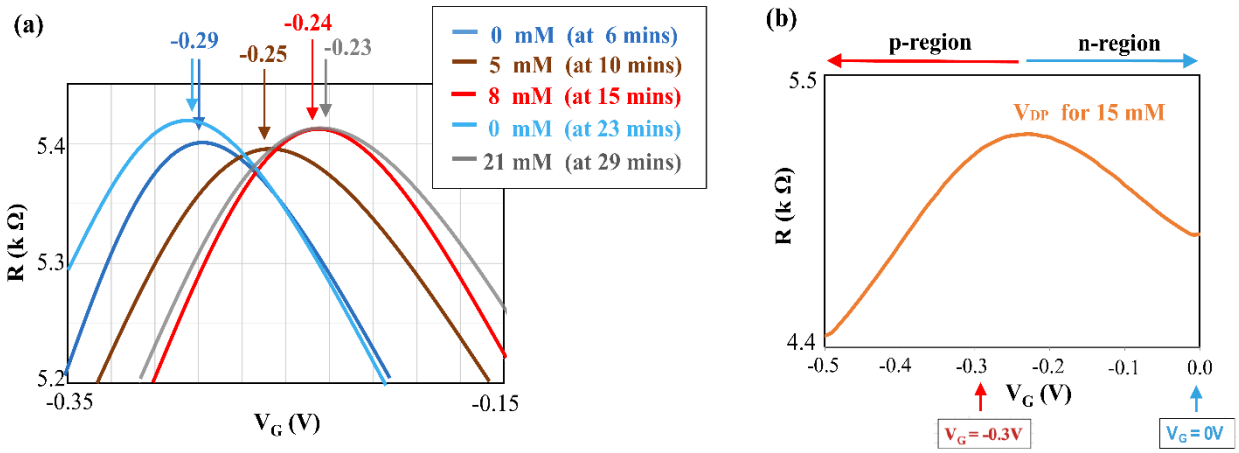

Figure 3 (a) Transfer curve of the sensor in response to the addition of various glucose concentrations in the range of 0 – 21 mM. The circles represent the Dirac point VDP. **(b) Transfer curve for the concentration of 15 mM.** Source: (own)

Real-time series, Fig. 4. At first, the concentration was kept on 15 mM at 0 s, and the device resistance response in real-time was studied for various glucose concentrations. The blue curve in Fig. 4 represents the sensor response at 0 V gate voltage which corresponds to the n-region. A gradual addition of glucose to the analyte caused an increase in the channel resistance. As the glucose concentration decreased, the channel resistance decreased, confirming that the sensor response is reversible. At 800 s, the gate voltage was switched to -0.3 V, and the response of the sensor was studied in the p-region, represented by the red curve in Fig. 4. The resistance response had the opposite tendency than for the n-region. As the glucose concentration was increasing, a gradual decrease of resistance was evident. On the contrary, the resistance was increasing during the addition of glucose.

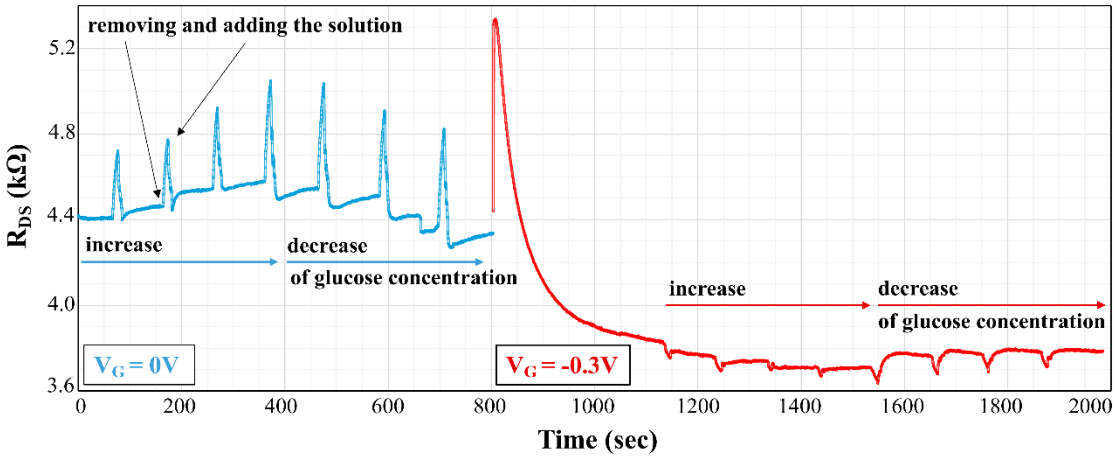

Figure 4 The sensor response in real-time. Source: (own)

4. CONCLUSION

It has been successfully demonstrated that the proposed glucose sensor based on graphene field-effect transistor can detect glucose in two different setups. The sensor responded to a glucose concentration from up to 40 mM. Both types of measurements showed that in the presence of glucose p-doping of the graphene channel occurs, hence, electrons are withdrawn from graphene channel. The sensor response was confirmed to be reversible for both setups.

The initial functionalization with PSE linker was confirmed to be suitable for CVD graphene, and enables to immobilize several different bio-receptors used for the detection of biological substances. These include bio-receptors for the detection of DNA [10], bacteria or viruses, including newly emerging SAR-CoV-2 [11]. Moreover, thanks to excellent electrical and mechanical properties, graphene allows miniaturization of electronic devices, such as biosensors or monitors. As a results, it is not only healthcare that is fascinated by the development of graphene sensors, but there is both strong interest and investments from the industry as well.

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ALTERNATIVE METHODS OF IRON PRODUCE

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Abstract

This age focused to ecology and even requires iron as material for daily using. Due to producers of iron are looking for other more ecological alternatives of iron produce, but still majority of iron is producing by blast furnaces, approximately 80 %. There are lot of reason why this way of producing is used. Mostly higher amount of iron, which cannot be made by alternative methods. But still these methods are getting more advanced because pressure of society are on the ecology and these methods present more ecological way of iron produce and even cheaper possibility, because material, which is used is cheaper. Other reason why it is more ecological it is because it is possible produce without coke and agglomerate. Especially preparing of that also pollute environmental like blast furnace and the iron produce.

In this article will be presented alternative methods as DR and SR. DR method is specific by iron sponge and solid final product and SR is feature of using less expensive material like low-grade fine ores, iron-bearing plant wastes and also coke is not required primary, effort it eliminate it completely. Instead of that is used coal or oxygen or electricity. Firstly, it will be explained, how simple methods work and then they will be compare with blast furnaces and shown advantages and disadvantages of them. It is even important to inform more about these methods, especially in European countries, where these methods are not used as much as in countries outside European Union.

Key words:

Iron ore, SRI and DRI methods, coke, ecology.

1. INTRODUCTION

The iron is material which was utilized in past and even in these days. Still it is important metal for our life, it might be said that we live at iron age. Of course, there are a lot of possibilities instead of iron, but any of them cannot be a perfect substitute. Importance of iron is obvious thanks higher price of that. Now price of iron has increased by 150 %. Reasons are shortage of iron and expensive essential material – iron ore. So, there are no way to stop the producing of iron. Unfortunately, the producing of iron are not ecological at all. Not only itself production but even previous operations of that as agglomeration or coke production.

Now almost 80 % of iron is produced by blast furnace. This method is one of the least ecological, it is involved by 7 – 16 % at the total pollution by CO_2 emission, it depends in which country. That's why European Union set of strict rules related with iron production. Due to producers in EU must have high price according to other producers from third countries, which do not have to follow same environmental requirements. Fortunately, EU has determined protection quotas against transport of steel from third countries. So, ecology and expensive production leads to looking for another ways of iron produce, which will be more eco-friendly and cheaper.

In this article there will be introduced alternative methods of blast furnace processing and summary evaluation all of them like advantages and disadvantages. Some of alternative methods are already using but not too much, because it is not typical, and lot of producers do not have any experiences with that and change the form of iron produce means other investment. How it was written at the beginning of introduction, majority of iron is produced in blast furnace, and it will take time when alternative methods supersede blast furnaces mostly. So, it is useful show these alternative methods more and even make them more advanced.

2. SR AND DR METHODS

In these days is big pressure at ecology and ecological producing. That's why there are alternative methods of blast furnace (BF). Even shortage of high-grade coal and more expensive producing lead to finding other possibilities for iron produce. The percentage of utilization these methods is still low, because they are not perfect and, in some parts, they are still under development. It will take a time when these methods will be common in world, mostly in European Union.

2.1. DR method

About DR (direct reduction) method might be said it is kind of way how was iron produced in past. It means that final product from DR is solid iron sponge, which was produced in small furnace utilized by our ancestors. Of course, there are some differences, mainly in using technologies and processing.

Main sign of this method is iron sponge, which is show in Figure 1. This term was using until 1980 when direct reduction iron was made as common [1]. Materials use for producing are pellets, fines and lump. Reason why this product was called as iron sponge is that it reminds sea sponge.

Figure 1 Iron sponge. Source: [2]

Other product of this method is BRI (hot briquetted iron). All of these products are used in electric arc furnaces, as a substitute for scrap, induction furnaces, as a feedstock or open heart furnaces as a charge for melting and etc [1]. Next sign, which make this method more ecological, is producing temperature – 700 – 1 000 °C. Due to iron ore is reduced to the solid-state either by solid or by gaseous reducing agents, because temperature is lower than temperature of melting [3]. For this method is usually using nature gas, therefore this method is more typical in county with large amount cheap nature gas like USA. The reductants are hydrogen and carbon monoxide made from reforming nature gas or brown coal. Reforming of nature gas is made by vapour and oxygen [4]. Hydrogen does not make for pollution, that's why it is eco-friendly.

The most common technology is MIDREX (Midland Ross Experimental), which is shown in Figure 2. Pellets or lump ore are reduced in the shaft furnaces by natural gas. For reforming of natural gas is used nickel catalyst. Instead of reformer/heater combination is utilized a single reformer and reforming nature gas does not need to be cooled before it is used in the process. When the gas leaves shaft furnace, its temperature is about 400 – 450 °C. It is cleaning and cooling in a gas scrubber. Around 60 % this gas is getting back to the produce like a fuel and gas which is heated at 900 °C and is mixed with natural gas. In finish phase its temperature is 850 °C and hydrogen and carbon monoxide are occurred largely.

By MIDREX process was produced 67.7 million tons in 2019. It is 5.1 % more then in 2018. MIDREX plants are located in Iran and it its neighbourhood or India mostly. Even despite of COVID – 19 pandemic DR production reaches 104.4 million tons [5].

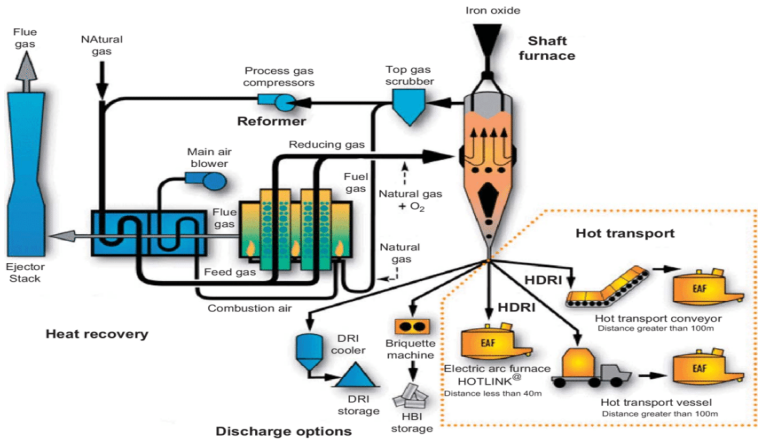

Figure 2Schematicdiagram of the MIDREX process. Source: [6]

2.2. SR method

SR (smelting reduction) method is similar with produce in BF, because final product is liquid iron, but without utilizing a coke. Thanks to this method is reducing the carbon footprint, utilizing of coal, oxygen and electrical energy. This reduction represents a process in which the melting reactor and the pre-reduction reactor are combined. In the melting reactor, a residual reduction of iron oxides from the liquid phase takes place and a reducing gas is formed. In the pre-reduction reactor, iron oxides are pre-reduced in countercurrent to form pig iron [4].

In the upper, reducing unit, the lump iron ore raw material is reduced by the gas transported from the lower melting reactor. There is an almost complete reduction (above 98 %). The reduced iron is fed to the smelter reactor. The lower part of the melting reactor serves as the hearth of the blast furnace. Liquid metal (pig iron) and slag collect at the bottom. Above the surface, there are exhaust pipes, through which heated air with the addition of oxygen is blown. In addition to the reduced iron, coal is transported to the upper part of the smelting reactor, the carbonization of which produces coke, which is burned before the exhausts and the gas which, together with the reducing gases from the final reduction, forms a gas which is fed to the reduction unit [3].

The most used is the COREX technology (Coordinated Electronic Countermeasures Exercise). The COREX process is shown in Figure 3. However, coke is replaced by coal in this case, making this alternative more environmentally friendly.

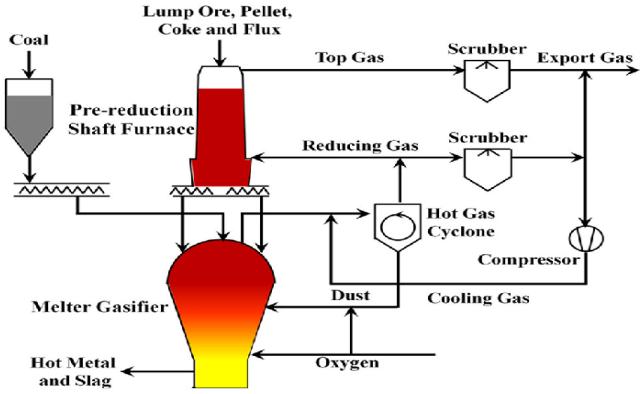

Figure 3 Schematic diagram of the COREX process. Source: [7]

2.3. Comparing blast furnaces and alternative methods

Ecology is the most required aspect in these days, so one of main reason, why these methods are used because are more eco-friendly than in BF. In both alternative examples it does not need a coke. Coke producing is referred to one of the worst air pollutants. Even raw material, which is used is better for environment – there is not use agglomerate, its produce is also one part of environmental

pollution. Generally used raw material in DR and SR method are less expensive, so it leads to reduce the cost of production.

Unfortunately, iron belongs to the most demanded material, so there is big needs of that, which is connected with its big produce and alternative methods cannot produce too much amount of iron like BF. It also means, if there is not any possibilities of high producing, economy of scale is not exploit in that case. When it produces less amount of iron, it can not help with lack of iron like BF. So, there is ecology against economy and demands. But on the other hand, in the case of DR process, smaller module size might be seen as an advantage.

Because DR and SR methods are newer methods of iron produce, technology is more advanced, so process is easier for control and improved process are manoeuvrability in most cases.

Some disadvantages of DR methods comparing with BF are in the final product. Less temperature during process and utilizing of natural gas or other fuel instead of coke is amazing possibility, but thanks less temperature the final product is in solid state and subsequent processing is more difficult, equally low carbon contained – steelmaking is getting harder.

3. CONCLUSION

Producers of iron are looking for other alternatives of producing iron, which is more ecological and more economical. These methods exist but there are some disadvantages make that uninteresting for producers. Especially possible amount of produce iron. It is connecting with no utilizing the economy of scale and any possibilities satisfied a demand of iron. That is a reason, why price of iron is getting higher.

According with ecology, these alternatives are solution, how make producing of iron gentler to environment. Unfortunately, it requires some initial investment, which might be a problem for some plants. Especially in European Union change the producing for these alternatives would be smart step, because of strict environmental rules. One solution for build and utilise these methods might be support of European smelter by grant for innovation in that way.

On the other hand, SR and DR method need to get more advanced. There should be bigger pressure to that and slowly change way of produce iron. Of course, it is impossible stop the produce iron in BF, because of high quantity, but where is not necessary make high amount of iron, these methods, especially SR method might be utilized instead of BF.

One reason why these alternative methods are not used might be even low knowledge about that, so it would be useful to write, show and talk more about alternatives method of iron produce. And in European smelter it might help against future transport of iron from third countries, because they will be able produce iron with lower cost and more ecological.

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TECHNO-ECONOMIC ASPECTS OF THE USE OF LOW-EMISSION ENERGY SOURCES

TECHNICKO-EKONOMICKÉ ASPEKTY VYUŽITÍ NÍZKOEMISNÍCH ENERGETICKÝCH ZDROJŮ

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Abstract

Fossil fuels are a deposit form of dead organic matter in the earth's crust and on its surface. Combustion of fossil fuels produces pollutant emissions that have significant health impacts as well as environmental and, last but not least, economic impacts. Coal as an energy raw material does not have a very long future in Europe. However, it will still not be resolved by what it will replace, especially in regions that are dependent on coal exploitation and mining. The Moravian-Silesian Region is one of these regions in the Czech Republic.

The current development of coal, natural gas, and emission allowance prices does not yet support the economically natural transition from coal to natural gas. It is necessary to analyze in detail the possible variants of replacing coal resources with natural gas resources, including an analysis of their impact on the economy of industrial enterprises and environmental impacts. A key aspect is to ensure a reliable, affordable, and long-term sustainable supply of energy to industrial companies. The aim of this article is to evaluate the current situation in the field of energy resources in Europe and the Czech Republic, and therefore in the Moravian-Silesian region.

Key words:

Energy sources, fossil fuels, CO_2 emissions.

1. INTRODUCTION

Climate change and environmental degradation pose a threat to both Europe and the world. To overcome it, a Green Agreement for Europe [1] was created to transform the EU into a modern, competitive and resource-efficient economy where:

- zero net greenhouse gas emissions will be achieved by 2050,
- economic growth will be decoupled from resource use,
- no individual or region will be left out.

When assessing possible energy sources that could be considered, it is necessary to proceed from the specifics and possibilities of individual regions. Within the Moravian-Silesian Region, whose specificity is coal mining and utilization, it would be possible to focus on the gas that is bound in the coal deposit. Significant gas reserves are located together with coal in the North Moravian region, therefore this raw material belongs to the domestic sources of natural gas in the Czech Republic.

In the context of the EU's ever-tightening requirements to reduce emissions, it is necessary to look for substitutes for coal-based technologies. These technologies should use low-emission energy sources both to obtain heat for the supply of the population and for the supply of heat for technological processes in industry [2]. Figure 1 shows world CO_2 emissions from coal and gas.

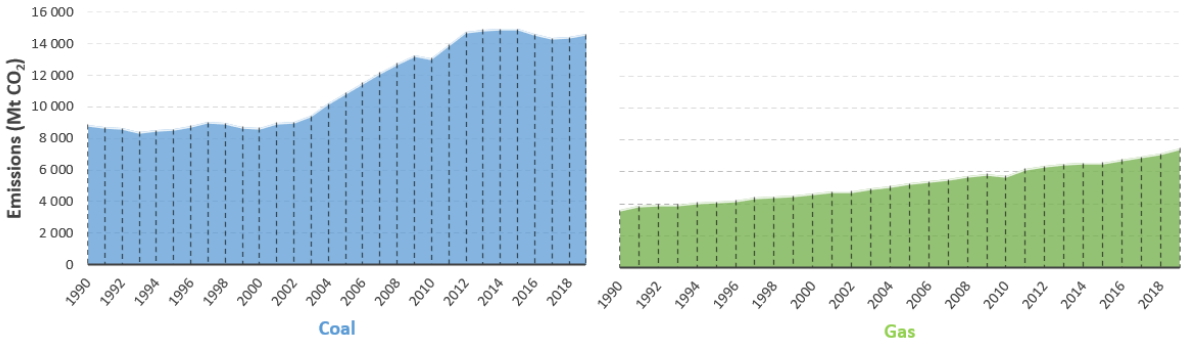

Figure 1 World CO_2 emissions from fossil fuels. Source: [3]

Different fuels emit different amounts of carbon dioxide (CO_2) in relation to the energy they produce when burned. To analyze emissions across fuels, compare the amount of CO_2 emitted per unit of energy output or heat content. [4]
The CO_2 emission factors according to the IPCC methodology are listed in the Table 1.

Table 5 The CO_2 emission factors according to the IPCC methodology. Source: [5]

Type of fuel	The final CO_2 emission factor (kg CO_2 . GJ^{-1} in fuel)
Brown coal (energy)	99.18
Brown coal briquettes	94.15
Black coal (energy)	92.71
Light fuel oil	73.33
Solid biomass	0.0
Natural gas	55.82
Biogas	0.0

Burning both black and brown coal has the worst impact on the planet's climate. At present, the concentration of CO_2 in the atmosphere is about 40 % higher [6] than it was at the beginning of industrialization.

Achieving carbon neutrality, i.e. not producing carbon dioxide emissions or producing only such quantities that can be offset by various compensation projects that ensure the absorption of CO2 is one of the objectives. In line with this goal, energy should thus move away from fossil fuels and focus primarily on renewable resources in the form of the sun, wind or biomass. [2]

Energy Resources of the Moravian-Silesian Region (MSK)

The current industrial production in MSK is mainly focused on heavy industry. MSK is described as a coal region in transition, which is dealing with a high share of coal energy, traditional metallurgical industry and hard coal mining and related mining gas mining. The share of fuels / technologies in electricity generation within the MSK is given in Figure 2. [7, 8]

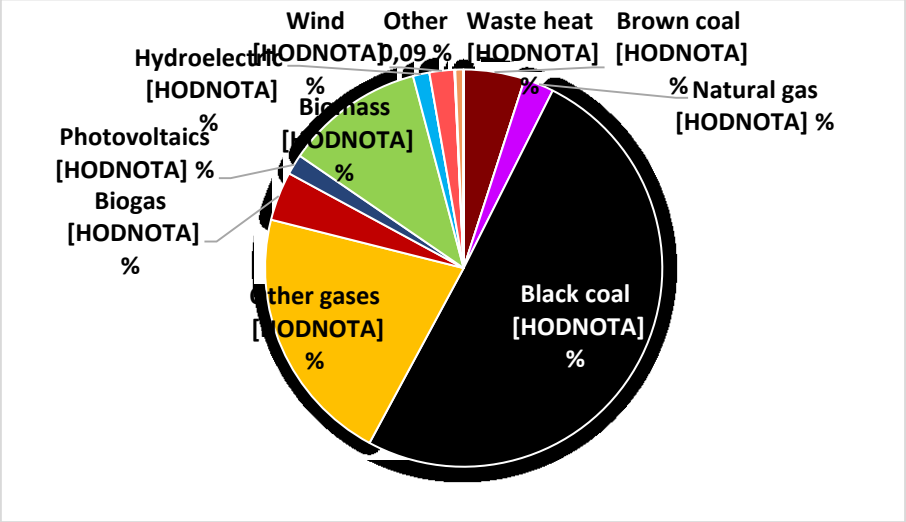

Figure 2 Share of fuels and technologies in gross electricity generation in the Moravian-Silesian Region in GWh. Source: [7, 8]

Consumption of material resources and energy in metallurgical production affects not only the demand of this sector for raw materials and energy, but also indirectly the relationship to the environment. The character of possible measures to reduce the burden on the environment within the MSK is shown in Figure 3. [9]

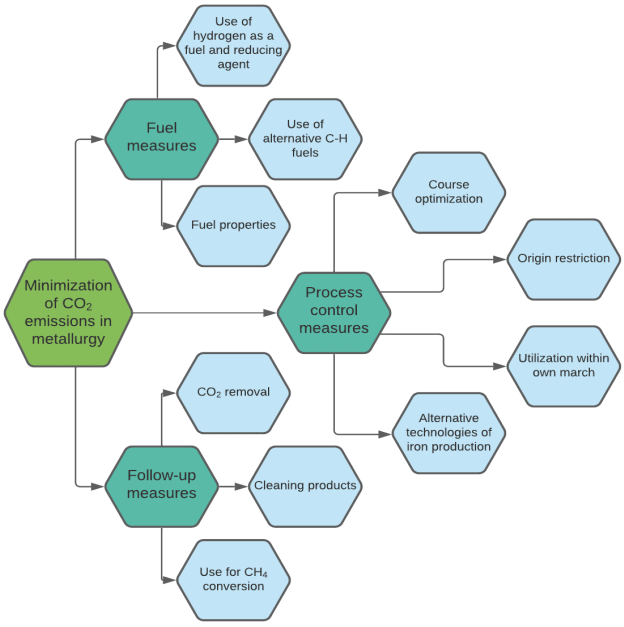

Figure 3 Minimization of CO_2 emissions in terms of the nature of possible measures. Source: [9]

Measures to reduce the burden on the environment are divided into three groups: measures in the field of fuels, measures in the field of influencing processes and follow-up measures.

Possibilities of biomass utilization

In terms of waste management and the environmental impact of fossil fuel use, most countries have begun to implement measures to reduce / mitigate environmental impacts.

Anaerobic digestion of organic waste, subsequently leading to biogas production, provides an opportunity to meet these goals.

The emission factor is zero for both solid biomass and gas. The use of waste biomass to produce biogas creates a carbon-neutral cycle in which carbon emitted by gas combustion is reabsorbed by new crops, the remnants of which can again serve as a substrate, which is associated with the reduction of greenhouse gases. [10]

At least 25% of all bioenergy in the future may come from biogas produced from organic materials. [11]

2. CONCLUSION

Energy diversion from fossil fuels to renewables, or at least low-carbon resources mean a significant change not only for industry. Especially from the point of view of economic aspects. Within MSK, a region with a strong industrial base, it is necessary to look for suitable sources of possible alternative fuels. Suitable sources include non-traditional fuels related to coal mining (and downturn) (carbon dioxide gas, degassing gas), the possibility of using hydrogen (e.g. from coke oven gas), or the use of biomass gas.

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THE ROLE OF HUMAN RESOURCES IN QUALITY MANAGEMENT

ROLE LIDSKÝCH ZDROJŮ V OBLASTI MANAGEMENTU KVALITY

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Abstract

Human resources management, as a part of organization-wide management, is closely linked to the building and further development of modern management systems. The aim of this paper is to define the role of human resources in quality management system and to highlight the evolution of this role over time. Based on the observed trends, also the forecasting of the position of the human factor on the labour market in view of the ongoing fourth industrial revolution.

Key words:

Human resources, Industry 4.0, Quality 4.0.

1. INTRODUCTION

The need to respond more flexibly to changes is reinforced by the pandemic situation of covid-19. Also, the current high rate of growth in demand for products and services, digitalisation, automatisation and the rapid evolution of technology brings with it a number of changes to which organizations and individuals are exposed. The competences and knowledge of people significantly influence this ability. They are an essential factor of the organization's competitiveness and are a precondition for the achievement of goals and the organization's performance growth.

Quality management is an integral part of enterprise-wide management, providing functions such as maximizing stakeholder satisfaction and allegiance, minimizing costs, creating an environment for innovation, improvement and implementing changes, and ultimately creating a base for organizational excellence. [1] For the entire management system to function, it is necessary to provide resources, including human resources. Therefore, this paper deals with the temporal development of human resources in the quality management field, defining the trends associated with them and forecasting the position of the human factor in the labour market.

2. HUMAN RESOURCES IN QUALITY MANAGEMENT

The term „people“ as a human resource is naturally used by the ISO 9000 family of quality standards. The role of human resources can be seen in all seven essential quality management principles on which these standards are based. According to the requirements of ČSN EN ISO 9001:2016, the organization shall provide the persons who ensure the effective implementation, operation and control of all quality management processes. The organization is tasked with creating an environment where people are engaged and where teamwork and learning concept is encouraged. Education and training of all employees plays an important role here, as well as top management which takes responsibility for the effective functioning of the quality management system. The current edition of this criteria standard already deals with the concept of organizational knowledge, which shall be determined, maintained, made available to the extent necessary and continuously expanded, as well as employee competences. [2] This is a significant shift from earlier editions of this standard, not only in the view of the role of the human factor in the organization, but also in the terminology itself, from employee to worker to person or human resource. [1]

The expanded role of the human factor is protected in the ČSN EN ISO 9004:2019 standard, which views human resources as one of the key resources of the organization. This standard provides recommendations on processes for attracting, retaining and managing people at all levels throughout

the organization in a planned, transparent, ethical and socially responsible approach. Separate chapters are dedicated to engagement, empowerment and motivation of people, and knowledge and competence. All this is done to satisfy all stakeholders and achieve sustained success for the organization. [3] The continuous search for better practices, methods and tools in the overall management of companies logically leads to organization excellence. [1]

In the context of the importance of the human factor in corporate management, the engagement of all employees in management at all levels is part of successful organizations. The high level of "personal quality" of each individual is the source of all other qualities, influencing all performance factors of the organization, generating competitiveness, prosperity, reputation and ultimately the culture of the entire organization. [4]

3. TRENDS IN HUMAN RESOURCES MANAGEMENT

From the first comprehensive guidance for the field of quality management system, which are considered to be the already mentioned international standards ISO 9000 series (first published in 1987), [1] there is a current trend towards the integration of management systems. Today's concept of quality management significantly differs from that of the past due to the orientation towards increasingly demanding customers, a significant share of exports and the operation of business activities in a period that is no longer bound by non-market principles. Similarly, greater demands are being placed on the entire quality management system (QMS), not only in connection with the development and improvement of the ISO 9000 series of standards. The new requirements for the management system are mainly focused on the environment and occupational health and safety. The isolated managing of these systems requires the deployment of considerable resources. Therefore, there is an increasing demand for integrated management systems and the gradual creation of an integrated management system (IMS), along with the progressive harmonisation of documentation. [4]

Ensuring a sustainable future for all of-society is also a pressing issue in the context of corporate social responsibility. The traditional economic objectives of the organization are complemented by activities that go beyond the business and add value to both the organization itself and its stakeholders, including society as a whole. The three pillars on which the concept of corporate social responsibility is as follows - economic, social and environmental. [4]

Along with the implementation of innovations in areas such as automatization, robotics, technology, information and communication technology (ICT), new materials, etc. comes the fourth industrial revolution, also known as Industry 4.0. It cannot be seen as a revolution taking place only across industry sectors, as it is also affecting areas of everyday life. The interconnection of the physical world with the virtual world brings new manners of conducting all activities. [5] The implementation process can be divided into four main phases: [6]

- fully digitalised organizations,
- implementation of autonomous machines and devices,
- sophisticated methods for data processing,
- automated managing of production processes and the entire supply chain.

The survey of 253 German companies revealed a number of barriers that organizations may face when implementing the Industry 4.0 concept, including lack of standards, low technology maturity, poor legislative conditions, difficulty in formulating an Industry 4.0 strategy, lack of qualified employees, lack of a funding programmes, etc. [7]

Closely linked to the concept Industry 4.0 is the concept of Quality 4.0, covering all areas of an advanced quality management systems in a digital world that uses advanced technologies to improve the quality of products and services. Innovations in manufacturing process control are used to solve quality problems and enable sophisticated real-time analysis of outputs. The concept of Quality 4.0 is not only applied to internal production processes, but also to the entire supply chain up to sales and after-sales services. [8] To underline the role of quality personnel and their need in the organization, as of 1st of Novermber 2021, 389 quality engineers were in demand via jobs.cz alone, 253 of them with a starting salary of over CZK 45,000. [9]

The aforementioned information and communication technologies affect people lives in both their professional and private lives. In order to benefit from technological innovation, organizations or individuals need to have reliable access to the Internet. Eurostat survey conducted in 2020 shows that approximately 80 % of the adult population uses the Internet on a daily basis. [10] The use of ICT is essential towards keeping organizations competitive, flexible and opening up new business

opportunities. This trend has been reinforced by the Covid-19 pandemic, together with a number of restrictive measures. Organizations have been forced to remove imaginary boundaries to increase the swiftness of decision making, accelerate innovation processes and make use of ICT in ways that no one thought possible until then. [11] The Covid-19 pandemic has accelerated the transformation of the labour market and there has been a significant increase in the number of people working from home. [12] Nevertheless, working from the comfort home brought some negative findings. The social isolation associated with working from home combined with job insecurity has resulted in a crisis affecting the mental health of employees. The challenge for top management and HR leaders is therefore to take steps to actively engage employees, promote social interaction and work-life balance, and provide employee mental health benefits and support. It is obvious that the working from home trend will continue, whether it is fully remote or a hybrid model. [11] In the area of human resource management, organizations should take into account the current state of the population and its structure. Diversity management, age management and the differentiation of generation management approaches, currently dominated by two types, namely generation X and generation Y, are becoming more urgent. [1]

A phenomenon in the field of employee training, which is also supported by the EFQM Excellence Model, is a "learning organization". If the quality management system of the organization is well-established, learning and continuous improvement of the organization's performance is a common part of the company's processes. Adopting the philosophy of the learning organization is the task of the top management that puts this concept into practice, and the process of continuous improvement becomes an essential need for them. [4] Enterprises are currently facing problems related to communication, determination of competences, resource utilisation, lack of employee qualification, etc. The solution lies in educating people and lifelong learning. [13]

4. FORECASTING LABOUR MARKET CHANGES

Since human resources, and primarily managers, maintain the quality management system of the organization, the core areas of human resource management are the attracting of new employees, the retention of current employees and the continuous improvement of their professional skills. The current demand for products and services brings with it new job opportunities. However, due to the very low unemployment – the share of unemployed persons in the Czech Republic in 2021 is only 3,92 % [14] – employers are forced to either increase the automatization of manufacturing processes or recruit employees from abroad. [1]

With Industry 4.0, we can expect significant changes in the labour market, namely an increase in the demand for workers with high level qualifications (IT engineers, data analysts, etc.) and a decline in jobs requiring low or no qualification. Pressure will be exerted on further training of employees and the education system itself towards the creation of new fields of study that would better match the requirements of the new labour market.

Organizations will make the decision whether the selected work task will be performed by a human or by a machine. For a fully automatized environment, there are two scenarios – digital technologies used by humans for decision support and process control purposes using autonomous operating systems or, conversely, decision making and process control by IT systems where humans will be in the position of mere performers of manual work. In any case, humans will play an essential role in the maintenance of machines and equipment, as well as in problem solving within the system. [15] Great potential can be seen in the elimination of monotonous and repetitive work tasks that would no longer need to be performed. [16]

Employees will be pressured to learn a range of new skills and abilities in order to use new technologies and work with large amounts of data and information. In the industrial sector, all current and new employees can be involved in the retraining process and the training itself can be carried out directly by the supplier or manufacturer of the machine, equipment or software. The trained people can then manage the operation of automated machines. Another option is to provide training only to selected employees, who then train other employees. [6]

5. CONCLUSION

The importance of engaging human resources to achieve goals of the organization can be seen as early as the first edition of the ISO 9000 series of quality management system standards. As the role of quality assurance of products and services in a competitive environment grows, so does the importance of the personnel management. The evolution over the time has influenced both the terminology itself and the attribution of the role of human resources in quality management.

Nowadays, the success of an organization is not determined by formal written procedures but by organizational knowledge and employees competencies. An organization is dependent on its employees, or rather on the performance that each individual performs. In this context, it is desirable that the organization takes care of its employees, creates the best possible working conditions and motivates them to improve their performance, and also taking into account modern trends such as diversity management and especially age management. Other trends can be seen in the integration of management systems, more extensive use of ICT and other elements brought by the fourth industrial revolution together with the concept of Quality 4.0. The new digital world that is transforming the way we live and changing the labour market will require highly skilled workers, not only in industry but also in services and, above all, in education. With the concept of Industry 4.0, it will be necessary to adopt a new role of the human factor, even more important than it is today.

In the area of quality management systems, the role of the human factor will be crucial in implementing, maintaining and managing the elements associated with the Quality 4.0 concept, as well as in improvement activities to achieve higher organization performance. Enterprises that want to continue performing well in the challenging times ahead should be flexible, socially responsible and learning organizations with motivated and loyal employees, that respond to a rapidly changing market.

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USING INFORMATION MANAGEMENT TOOLS FOR OPTIMIZATION OF METALLURGICAL CLUSTER MANAGEMENT

POUŽITÍ NÁSTROJŮ INFORMAČNÍHO MANAGEMENTU PRO OPTIMALIZACI ŘÍZENÍ METALURGICKÉHO KLASTRU

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Abstract

The paper presents an example of using information management tools to optimize the management of processes within clusters. It helps to create an efficiently working information structure based on arrays for the exchange of information at the international level between cluster members. As an example, ADONIS and OLAP are considered, which are used in the process of searching for participants in an innovative project within the framework of a metallurgical industrial and scientific cluster.

Key words:

Information management, IT in management, cluster management, business associations.

1. INTRODUCTION

Today, one of the pressing problems in the field of metallurgy is the drop in innovation potential in this area in connection with the COVID-19 pandemic, which was caused both by restrictions in international cooperation and international trade, and the allocation of a large amount of resources for the development of pharmaceutical and medical industries. Many analysts in the current economic situation in the world propose to solve the problems of the crisis and the decline in innovation potential by combining various organizations to achieve synergistic effects and for the exchange and dissemination of knowledge. [1] Clusters are a convenient form of such associations at the international level. A cluster is a group of interconnected companies (suppliers, manufacturers) and related organizations (educational institutions, government bodies, infrastructure companies) operating in a specific area and complementing each other. [2] However, such a system is organizationally and informationally very complex and represents a large node of additional complications in the form of international law, customs, transportation, classified data, etc. The authors of the articles [3] note that it is precisely the poorly developed information structure and poor coordination between a large number of complex processes that are the weak point in most existing clusters.

To simplify the management of such structures, you can use the tools of information management, a science consisting of management - the science of management, and from computer science - the science that studies information technology. The main task of information management is to identify and study the patterns of movement and changes in the composition of information in order to obtain the ability to manage these processes. [4] In the case of a cluster, using an information management tool, it is possible to solve the problem of information gaps by forming a single information and communication space with a unique infrastructure.

2. MAIN PART

In this article, information management is considered as a set of tools, methods, technologies and concepts for managing its information resources and their purposeful use to optimize the functioning of the projected organization. [5] From the standpoint of a systematic approach, information management encompasses the planning, organization and control of information activities and processes, which, in turn, coincides with the tasks of the main organizational link of the projected

association - the Coordination Center. A single information space will allow integrating documentation into an information resource, exchanging it within secure channels and thereby building an operating information infrastructure based on arrays of information, information technologies, communication tools and qualified personnel. This will provide efficient management processes between multiple entities within clusters.

The aforementioned Coordination Center is part of the architecture of a cluster association in the field of metallurgy, designed by the author of this article. [6] The task of the projected cluster is to combine the achievements of scientific, industrial and educational objects, as a result of which all the strengths of the participants are used and the exchange of mutually beneficial proposals. During the patent research carried out within the framework of this article, it was revealed that most of such cluster structures (for example, RuhrValley, RITS, CLUTEX) do not have a clearly defined autonomous coordinating link with a good information and technical base. [7, 8] At the same time, the interests of the students are taken into account unevenly, and the transfer and storage of information is chaotic. This leads the organization to possible threats, such as leaving the cluster of larger participants due to loss of interest, organizational difficulties, information leakage. Coordination Center with a modernized information repository can be used to address these issues.

The business combination being developed is international and closely related to technological innovation. Accordingly, the optimization of processes within such an organization is associated with the achievements of information management in order to ensure the effective functioning of such a complex structure. International success is also often based on firms' technological capabilities and technological knowledge. In such conditions of cooperation as online communities or corporate networks, which the project of creating a cluster is focused on, the so-called digital platforms play a fundamental role, the achievement of informatics, which are actively used for management. Digital platforms are complex information systems that provide interconnection functions between participants, open for use by customers and partners, application developers, service providers and agents. [9] Digital platforms play a large role in organizational strategies, they are created to optimize the management of processes and actions, for example, to support collaboration and information management.

However, despite the logical need to use digital platforms to optimize management processes, the potential of digital platforms has not been fully disclosed. Some companies and business networks, such as the large corporation Parker, do not recognize the adoption of digital platforms at all. The reason for this lies in two interrelated problems: on the one hand, in the internal organizational and managerial complexity in the implementation of inter-organizational structures and behavior based on cooperation, and on the other hand, in the absence of guidance on the design and implementation of digital platforms as socio-technical systems. [10]

Therefore, in order to create an effective and understandable digital platform for the metallurgical international cluster with a coordinating element in the form of a Coordination Center, it is proposed to develop a model for the implementation of digital and IT-technologies. One of the components of computer modeling of a cluster structure is the description of the operation of the head program in the form of classical block diagrams, which reflect the sequence of switching on of logistics operators to automate actions within the synchronized software.

According to the developed concept, the Coordination Center can optimize the management processes of such processes as the development and implementation of new technologies, recruiting and selection of qualified labor force, purchase and sale of resources, coordination of innovative large projects. As an example for considering the possibility of using information management tools, this article takes the process of coordinating participants for the implementation of an innovative project. The digital implementation of the process using IT-technologies is presented in the form of a block diagram in Figure 1.

The block diagram combines ADONIS and OLAP tools. The ADONIS system in this process allows you to get a company model, which includes a comprehensive description of business processes, working environment, infrastructure and workflow, contains tools for analysis, assessment and simulation of processes. At the same time, the data is taken from the OLAP cube storage, which has analytical artificial intelligence that allows analysis on several facets of information, checking more than 2 factors. The information from the internal cells of the OLAP array format is transferred back to

the ADONIS system, which, according to the algorithm, either displays ready-made lists in the form familiar to the user, or the program starts the WHILE loop until a suitable participant is found in the storage.

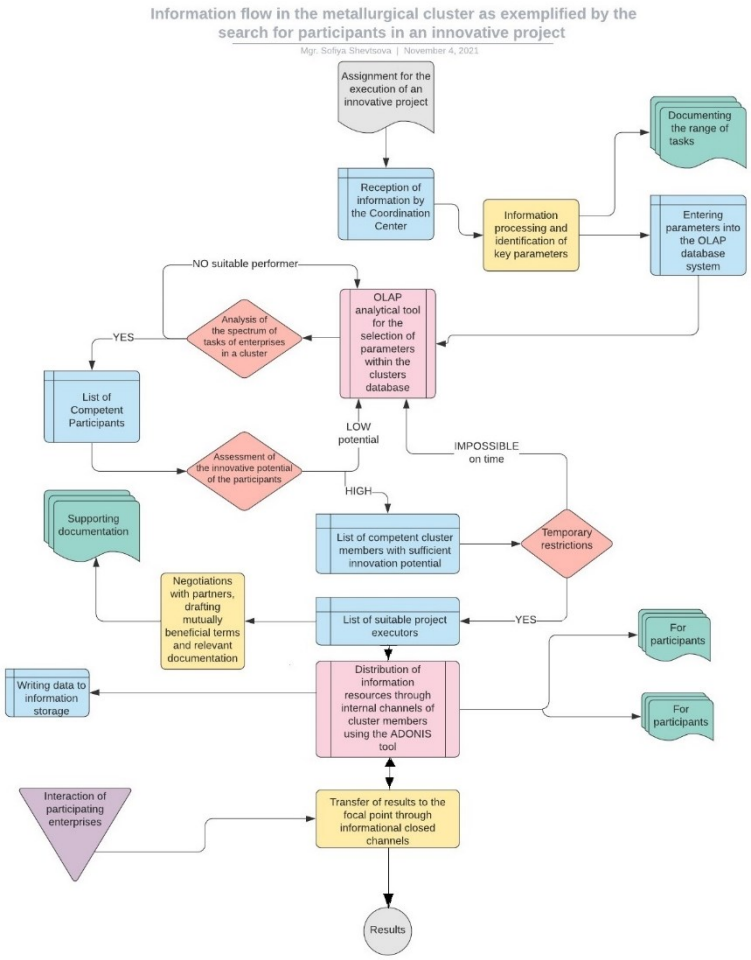

Figure 1 Description of the business process in the ADONIS notation block diagram.
Source: [created by author S. Shevtsova in lucid.applications]

Visually, in P-diagram notation, this process can be written as follows:

WHILE
no (not enterprises tasks spectrum) AND low (innovation potential) AND no (impossible on the time) DO
: search in OLAP again
END WHILE;
IF yes (enterprises tasks spectrum) THEN
: create a list of competent Participants
IF (enterprises tasks spectrum) AND high (innovation potential)
THEN
: create a list of competent cluster members with high innovation potential
IF (enterprises tasks spectrum) AND high (innovation potential) AND yes (possible on the time)
THEN
: create a list of suitable project executors
ELSE
: search in OLAP again
END
ELSE

: search in list of competent Participants again
END
ELSE
: search in OLAP again
END IF.

The flowchart is versatile and can be applied to a variety of processes when making adjustments. A set of similar block diagrams for various processes will serve as a framework for a computer model for the projected metallurgical cluster.

3. CONCLUSION

Using information management and digital technology tools, you can optimize management processes in any complex organization with multi-level business processes. Optimization in the case of using information technology consists in creating an understandable effective coordination infrastructure and creating a single information space protected from espionage and leaks.

A conceptual computer model requires the creation of separate program blocks, but at the stage of model proposal, it can be described in the form of block diagrams and logical operators. This method, firstly, helps managers and investors to clearly see the order of the system, objectives and goals. And, secondly, it is a theoretical basis for writing a program.

The creation of a digital platform for an international cluster with a coordinating link is a new step in the development of innovative clusters and will significantly simplify the interaction between participants and business processes, which will accelerate the development of both individual participants and the industry as a whole.

ACKNOWLEDGEMENT

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POSSIBILITIES OF USING THE VSM 4.0 METHOD TO IMPROVE PRODUCT QUALITY PLANNING

MOŽNOSTI VYUŽITÍ METODY VSM 4.0 KE ZLEPŠENÍ PLÁNOVÁNÍ KVALITY PRODUKTŮ

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Abstract

The article presents the possibilities of using VSM 4.0 method to improve product quality planning (QP). The use of VSM 4.0 method to improve quality planning emphasizes the need to eliminate costs in information logistics and the benefit of quality planning to shorten cycle time. The main aim is to determine the basic features of the theoretical design for pilot design and validation in practice.

Key words:

VSM 4.0, VSM 4.0 method to improve quality planning, cycle time, methods and approaches of quality planning.

1. INTRODUCTION

Eliminating waste is one of the basic approaches of LEAN management to manage a turbulent market environment. Value Stream Mapping is widely used for the purpose of eliminating waste. The concept of Industry 4.0 (I4.0) opened up space for finding further savings in information logistics and the emergence of VSM 4.0. If savings are looked for, it is good to focus on the places that affect the whole product life cycle – i. e. quality planning – and work with it as a narrow spot in the process.

According to available source, the literature does not pay attention to the possibilities of using VSM 4.0 in quality planning process. In order to improve quality planning VSM 4.0 will link the benefits of digitalization resulting from I4.0. where cycle time (CT) is shortened. CT shortening is further supported by life cycle management with a focus on quality planning. The assumption of CT shortening is based on the application of VSM 4.0 based on studies [1] [2], which show direct relationship VSM 4.0 to VSM, and from literature sources [3] [4] [5], which state the time and economic benefits of quality planning.

2. USE OF THE VSM 4.0 METHOD TO IMPROVE PRODUCT QUALITY PLANNING

2.1. Methodological background

The work is based on literary research 1) VSM 4.0, 2) Methods and approaches of quality planning, 3) Concepts of product life cycle with a focus on quality planning. Understanding these 3 basic areas is a necessary basic element for building a new application of VSM 4.0 for quality planning improvement. At this stage, it is a matter of elaborating the theoretical basis of the solution and analyzing the latest knowledge in the given areas. The connection of these 3 areas to the concept design is further supported by primary research in a form of an unstructured interview with experts in companies operating in the engineering and automotive industries. Based on the data obtained so far, it was possible to develop a theoretical proposal for the possibility of using VSM 4.0 to improve quality planning.

Primary research will continue physically in the company in order to obtain data from the field of VSM, information logistics and quality planning. The processing of all the above data, together with unstructured interviews with experts and questionnaire survey will lead to pilot design or the use

VSM 4.0 for quality planning improvement in practice. The aim of this phase will be to compare the theoretical design and the pilot design of the use VSM 4.0 for quality planning improvement in practice. This article is the basic building block for the dissertation, which research into using the VSM 4.0 method to improve quality planning will be continued and validated in practice. Figure 1 shows the methodology of the work.

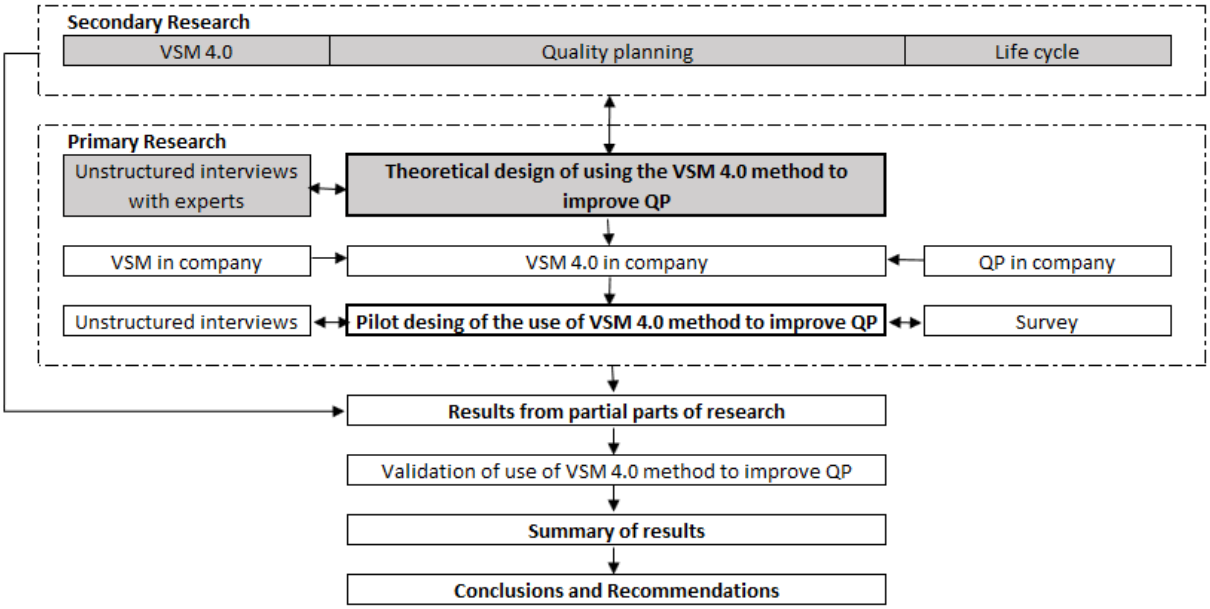

Figure 1 Work methodology. Source: (own)

Figure 1 shows the areas, highlighted in grey, covered in this article; the main goal is to determine the basic features of the theoretical design of the use of VSM 4.0 method to improve quality planning for pilot design and validation in practice.

- **VSM 4.0:** VSM 4.0 is the basic building block of the application of using VSM 4.0 to improve quality planning. VSM 4.0 is based on VSM (Value Stream Mapping), which eliminates waste in the value stream, mainly for material flow, VSM 4.0 enriches VSM with the benefits of digitization and I4.0 and eliminates waste in information flows. Elimination of waste in VSM 4.0 consists of setting up information logistics, which include planning, administration, execution, check and storage of this information, especially important are information flows for decision-making. There are six rules for the implementation of VSM 4.0, waste types, guidelines for the calculation of three KPIs are set, more information is contained in the studies [1] [2]. VSM and VSM 4.0 have a common starting point, which is a defining of added value. Defining of added value is also the right building block for quality planning methods and approaches.

- **Methods and approaches of quality planning:** three basic areas of quality managements methods are often used in the production and development phase in manufacturing corporations: the first area is the most important for this article, it includes methods for product quality planning (QFD, FMEA, FTA, DOE, MSA, capability assessment of processes and machines). The second area includes seven new quality management tools, and the last area is seven basic quality management tools. These methods are mainly used to better meet the product requirements, streamline production activities, facilitate communication, and cost savings throughout the product life cycle. For the design, development, and subsequent production of quality product, it is necessary to properly combine these individual methods and tools of quality planning [6] [7].

- **Concepts of product life cycle with focus on quality planning:** There are a number of product lifecycle approaches in the literature, the most well-known being: PLM (Product Lifecycle Management); marketing approach; LCA – Life Cycle Assessment and based on normative approaches (ČSN EN 60300-3-3 ED.2 (010690), ISO 9004). Today's modern approaches already work with the fact that the final product quality is affected by all phases of the product life cycle, especially by quality planning. The most famous approaches to quality planning with a direct relationship to the product life cycle are: Juran's quality spiral [8], RGA a APQP [9]. For the needs

of the work, product life cycle management is seen as a process based on normative approaches and the APQP method.

2.2. Experimental part

The fundamental of this article is to ensure problem-free product life cycle, which can be achieved with an increased emphasis on product quality planning process, the efficiency of which can be significantly increased by optimizing information flows, which VSM 4.0 method ensures.

The theoretical design of the use of the VSM 4.0 method to improve quality planning, which is shown in Figure 2, is based on linking the product life cycle with quality planning methods approaches in the I4.0 concept given in Article [1] [2]. For the use VSM 4.0 for quality planning improvement it is necessary to determine the processes, activities, direction of information flow (i. e. inputs and outputs), storages, users and quality planning methods. These individual parts were created on the basis of: 1) linking the life cycle with quality planning methods and quality planning approaches to determine the form and content of: processes, activities, direction of activities and quality planning methods; 2) The incorporation of the VSM 4.0 concept created the visual appearance of the map and determined the storages and users.

- **Linking the product life cycle with quality planning methods and approaches:** the processes and activities are based on the APQP methodology, they are: Program planning and definition; product design and development, process design and development, product and process validation and feedback evaluation and corrective actions. These basic processes are enriched by production process; operation and maintenance and termination of product operation, which is based on the normative approach of the life cycle ČSN EN 60300-3-3 ED.2 (010690). Individual processes have their own inputs and outputs, which show take the form of activities in VSM 4.0. Inputs and outputs show the direction of information flow. Process outputs are inputs for the next process. Each quality planning process has its own methods and approaches, which are included in the design of using VSM 4.0 to improve quality planning; quality planning methods include QFD, FMEA, fault tree analysis, DOE, MSA, capability assessment of processes and machines among other QP methods then the methods that are used within the researched company, e.g.: DFA/M, Feasibility Study, etc.

  By appropriate placement of methods in the map a matrix diagram is created between individual activities, users and quality planning methods. After validating VSM 4.0 in practice and obtaining data on these relationships, new area could emerge for further research.

- **Linking the previous point with VSM 4.0:** the determination of storage designs is based on the use of the VSM 4.0 method. Storages can be divided into desirable, those that are digital and undesirable, in printed form or as know-how employee. One of the basic concepts of I4.0 is digitization, without which the basic vision of I4.0 would not be achieved. In the years 2019-2021, the author conducted research presenting “Monitoring the current state of companies with regard to P4.0 and identifying the potential for their improvement” in ten companies operating in the engineering and automotive industries. The research shows the current and planned level of the I4.0 concept in ten areas. In the examined years, the improving situation in the Czech Republic can be seen in I4.0, especially in the points concerning digitization. Based on this data, it can be assumed that companies are ready for I4.0, their plants are digitized and ready for implement of the use of VSM 4.0 to improve quality planning. Based on a comparison of unstructured interviews with experts and the published VSM 4.0, the following storages for data collection were determined: paper, employee, e-mail and electronic form (outside the company’s information system (IS)), IS (information and knowledge management), MIS (managerial IS, using data to improve decision-making), quality planning software outside the IS, PDM (product data management, drawing generator). Users of these repositories are operational and strategic management and customer.

  As with the previous point, it is assumed that after validation of the possibility of using VSM 4.0 to improve quality planning in practice, a new area for research will appear. The follow-up dissertation works on the assumption that to the basic three KPIs, which are listed in [1] [2] (Data availability, Data usage and Digitalization Rate) it is necessary to add a fourth indicator concerning the added value of data collection for the customer – data usage- customer.

3. RESULTS

Based on the knowledge from the theoretical basis and the experimental part of the article, it is possible to propose a Theoretical design for the possibility of using VSM 4.0 to improve quality planning, which is shown in the Figure 2.

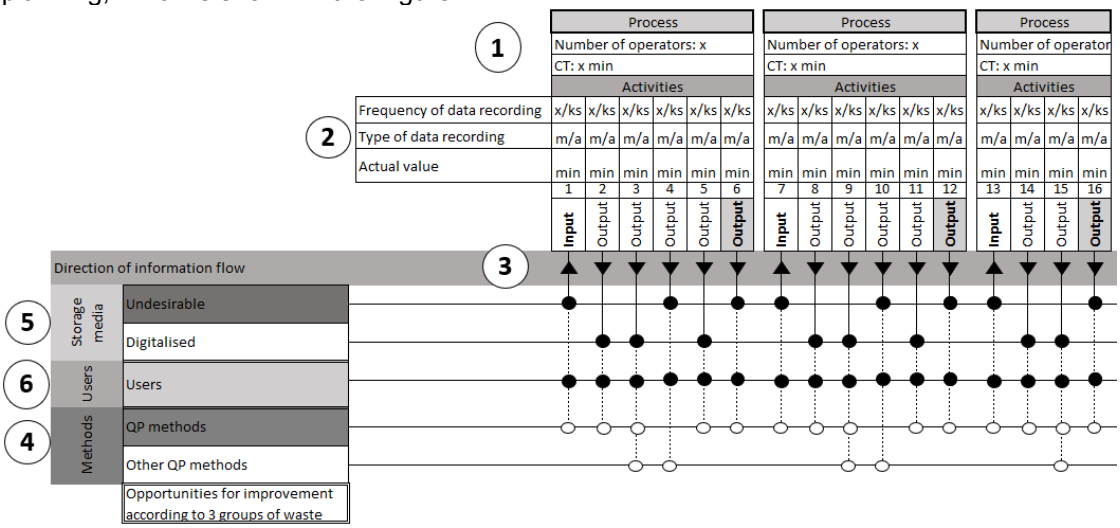

Figure 2 Theoretical design of using the VSM 4.0 method to improve QP. Source: (own)

In article 2.2 Experimental part it is stated that individual areas of the use VSM 4.0 for quality planning improvement have been determined, these areas are shown in the figure under individual numbers 1-6: Processes (1), activities (2), direction of information flow (3), quality planning methods (4), storage media (5), users (6). This proposal will be further used for a pilot design based on data from the researched company.

4. CONCLUSION

Theoretical design of the possibility of using VSM 4.0 to improve quality planning should, thanks to the optimization of information flows, bring streamlining the process of process quality planning. This will further reduce the time of bringing the product to the market and contribute to the smooth running of the entire product life cycle. This article has the character of an introductory study, which will be further elaborated in the dissertation, where it will be validated in practice.

ACKNOWLEDGEMENT

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CONCEPTUAL DESCRIPTION OF THE INNOVATIVE DATABASE OF INTERACTIONS OF METALLURGICAL INDUSTRY OBJECTS

KONCEPČNÍ POPIS INOVATIVNÍ DATABÁZE INTERAKCÍ OBJEKTŮ HUTNÍHO PRŮMYSLU

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Abstract

The article presents the concept of collecting and analyzing data on various parameters of additive manufacturing and powder metallurgy, and using IT-management tools to optimize proces by creating a database based on arrays. The notation IDEF0 and block diagrams are considered as an example. An example of a process is the process of justifying the creation of a database and a block diagram of the first stage of an innovative project in the field of powder metallurgy and additive technologies.

Key words:

Additive manufacturing, powder metallurgy, IT in management, business associations.

1. INTRODUCTION

The modern world is actively using additive technology in the metallurgical industry. This makes it possible to obtain not only lightweight products, but also products of complex configuration. The demand for additive manufacturing, and, consequently, for materials obtained in the process of powder metallurgy, is growing every year. According to data for 2019, the demand in Europe for equipment used in these technologies increased by 36 % [1, 3]. But this production has its pros and cons. There is an opinion that additive technologies are waste-free production. And on the one hand, this is a fair statement. But if we consider the concept of cyclic production at all stages, there are certain wastes that, with a competent approach, can be disposed of with benefit for the enterprise [2]. Also, despite the huge demand, there is still no unified system for coordinating equipment manufacturers, suppliers of consumables and raw materials, personnel training services and organization of environmental protection measures during the operation of equipment.

To simplify the management of the organization and logistics between the structures of the metallurgical direction, it is possible to use the tools of information management - management science, and computer science - science studying information technology. The main task of information management is to identify and study the patterns of movement and changes in the composition of information in order to be able to manage these processes [4]. In the case of systematization of interaction, using an information management tool, it is possible to solve the problem of information gaps by creating a single information and communication space with a unique infrastructure.

In this paper, it is proposed to consider both a closed system and individual stages of obtaining a product by additive manufacturing, clarify the main problems of this chain and create a concept of interaction between objects of the metallurgical industry.

2. MAIN PART

For the process of simplification of work and systematization, it is necessary to consider the basic concept of obtaining products of complex configuration using powder metallurgy products. This algorithm can be considered in Figure 1.

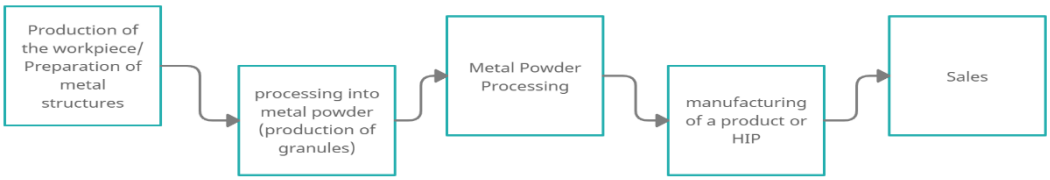

Figure 1 Description of the main algorithm of technology in the direction of powder metallurgy and additive technology.
Source: (*created by author D. Strapolova in programm app.creately*)

This is a multi-step algorithm. This chain can be implemented as separate productions, or as a single network. But in either of these two options there are certain questions. The first question is the disposal of waste or intermediate results of processes. The second issue is the equipment that is used in production processes. Let's imagine an algorithm for the production of metal powder in the form of an IDEF0 diagram (see Figure 2).

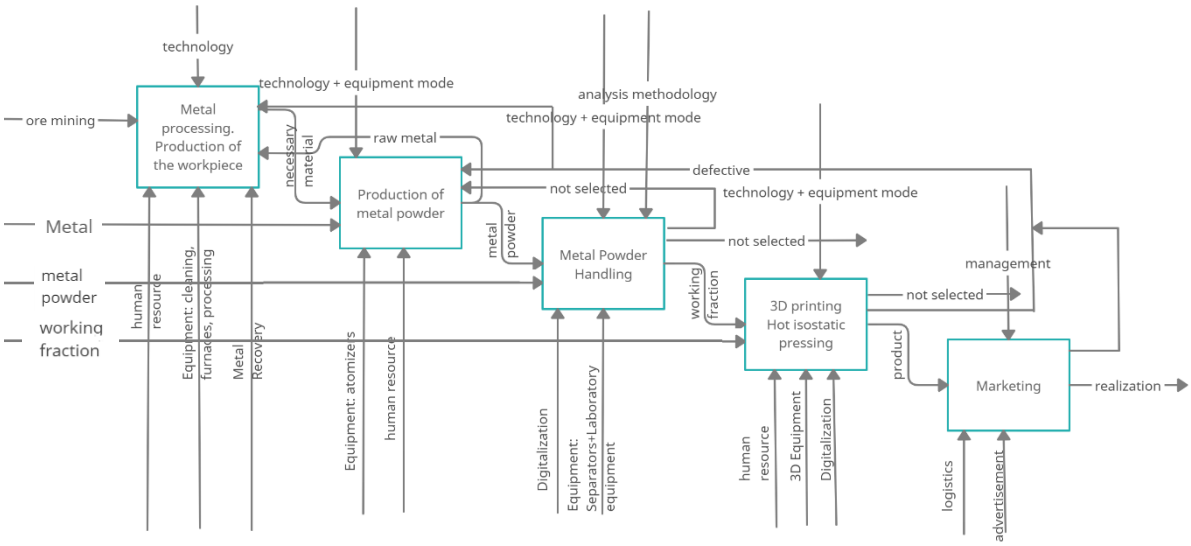

Figure 2 Diagram of powder metallurgy and additive technology processes.
Source: (*created by author D. Strapolova in programm app.creately*)

In this diagram, we see not only the production process, but also the problems that are worth paying attention to. The diagram clearly shows the need for such moments as the disposal or sale of waste, the need to choose and purchase equipment, as well as training people in innovative products. To clarify the issue of recycling, consider the metal powder production unit and its subsequent processing. For example, let's take the production and processing of titanium powder [5].

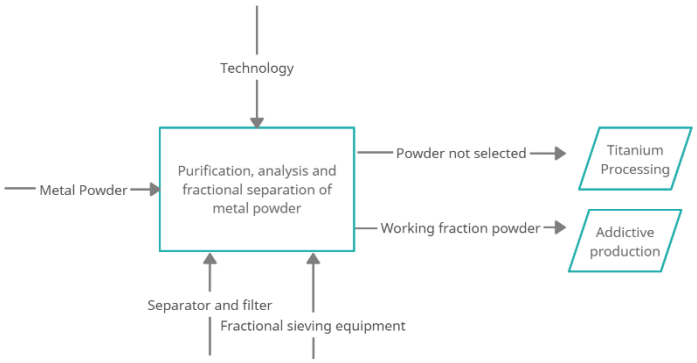

Figure 3 Block diagram of metal powder processing.
Source: (*created by author D. Strapolova in programm app.creately)*

In the process of teaching the powder and in its subsequent processing, it is possible to obtain about 30-40 % [8] the material is not a working fraction. [6]. Non-working particles are oxidized during storage and sent to waste. Based on titanium treatments analysis of the literature [7], the concept of processing waste data related to the purchase of marketable products was formulated. A technique for creating large burning monolithic titanium particles has been developed. Their gorenje in free fall in air is investigated [9]. During such heat treatment, oxidized powder waste is processed in the oxygen stream and as a result, titanium dioxide can be obtained, which can be used as an additive in coating materials and for various other purposes (paper and pigment production, rubber production, plastics processing, etc.). In this case, it is worth considering surpluses and losses not as a disposal problem, but as an economic benefit process.

The second problem is the selection and purchase of equipment. It is necessary to have a competent approach to the choice of equipment, based on the necessary characteristics and principles of qualimetry.

Therefore, there is a need to create a global database in the field of powder metallurgy and additive technologies. This database will provide for requests from all stages of production, starting from the purchase of material for the manufacture of the workpiece and ending with the possibility of selling and selling the finished product. To carry out this work, it is necessary to use management controls. Information management in this article is understood as a set of tools, methods, technologies and concepts for managing your information resources and their effective use to optimize the functioning of the designed algorithm. [10] Information management from the point of view of a systematic approach includes planning, organization and management of information activities and processes, which, in turn, coincides with the tasks of the main organizational article of the projected Association - the coordination center. The unified information space will allow not only to integrate documentation into the source of information, exchange it through secure channels, but also to improve the logistics of processes and, thus, create an operational information infrastructure based on information fields, information technologies, communications and qualified personnel. This is to ensure efficient management processes between several divisions within the metallurgical.

In order to create an effective and understandable digital platform for the direction of powder metallurgy and additive technology, it is proposed to develop a model for the introduction of digital and IT technologies. One of the components of computer modeling is a description of the main activity of the program in the form of classical flowcharts that reflect the sequence of inclusion of logistics operators to automate actions within the synchronized software. The digital implementation of the selection process using IT technologies is presented by the example of the selection of suppliers of material for powder production in the form of a flowchart in Figure 4. Visually, the concept of interaction is presented in Figure 5.

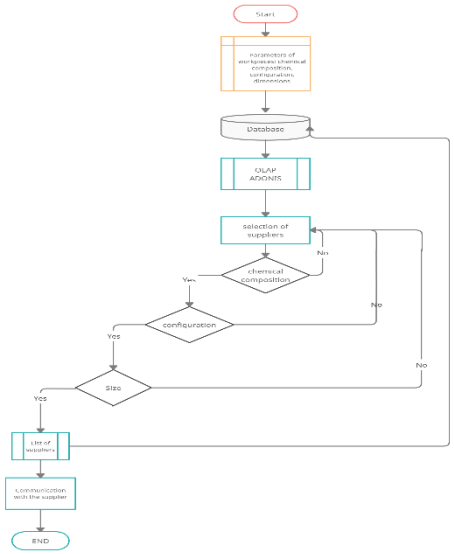

Figure 4 Description of trading processes in the notational block diagram. The first stage.
Source: (*created by author D. Strapolova in programm app.creately)*

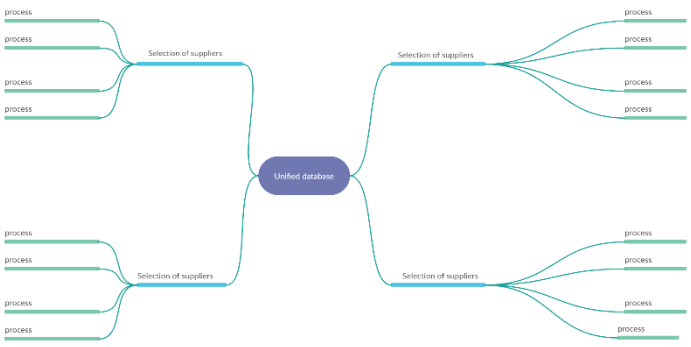

Figure 5 The concept of creating a common system of interaction of processes.
Source: (*created by author D. Strapolova in programm app.creately)*

3. CONCLUSION

The proposed scheme is a kind of concept project that allows, within the framework of a software package and filled databases, to organize a full-fledged launch and maintenance of additive manufacturing, starting from the stage of equipment selection based on a qualimetric assessment (methodology for making decisions on equipment selection) and ending with the organization of the process of waste management in order to achieve maximum economic benefits for the consumer. The proposed scheme, in addition, includes optimization of logistics flows of raw materials, consumables and waste, processes for improving quality and reducing the cost of manufactured products

ACKNOWLEDGEMENT

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USE OF A MIND MAP TO CREATE A MODEL OF THE INTERNAL LOGISTICS PROCESS

VYUŽITÍ MYŠLENKOVÉ MAPY PRO VYTVOŘENÍ MODELU INTERNÍHO PROCESU LOGISTIKY

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Abstract:

With a larger project, there are always more aspects, sub-objectives and tasks. All contexts and ties must be affected. Consequently, they are cleaner and more conscious. However, in the phase of drafting a project and modeling it to its final form, something is often forgotten or some aspect of underestimation is encountered. Usually the smallest, which, however, causes the most damage. Murphy's Laws are relentless. Thanks to mind maps, we can clearly record all the necessary information and aspects and keep them in mind at any time. An example could be the current "Grant" projects and their relatively complex and demanding administration. A quality, well-thought-out project will run out or at least lose points on unnecessary inattention and omissions. The aim is to describe the application of the mind map.

Key words:

Mind map, creativity, goal, thought.

1. INTRODUCTION

„The brain is waking and with it the mind is returning. It is as if the Milky Way entered upon some cosmic dance. Swiftly the head mass becomes an enchanted loom where millions of flashing shuttles weave a dissolving pattern, always a meaningful pattern though never an abiding one; a shifting harmony of subpatterns."

Sir Charles Sherrington [1]

The most suitable method for creating a model of internal logistics processes was chosen a mind map. The basis of the mind map is the recording of thoughts and ideas, their interconnection with others, supplementing with partial information and current ideas so that the individual or group has an overview and keeps all the data in their consciousness.

Mind maps are used as an analytical tool - it is not always necessary to use them only in a "creative way", but they can be used to decompose a problem.

2. CREATING MIND MAPS

There are a number of theories as to how mind maps should be formed. Here it will look at a certain ten, which is represented by the just mentioned Tony Buzan, and it will supplement it with some remarks towards their computer creation. Despite all the theoretical knowledge, the imperative of individuality clearly applies - if someone finds a style that suits them and brings results, there is no reason to try to change their habits. This should also be respected - everyone are different and has different mind structures (here mind maps are closely related to the philosophy of mind) that need to be respected.

How to proceed when creating Mind Maps?

- The beginning of the mind map is always in the middle image or inscription, which captures the concept, idea or idea (the essence of the mind map or the main goal we are heading to)

- Subtopics in the form of curved branches will be based on the main topic (they are curved in order to increase the stimulation of the right hemisphere). Other smaller branches emerge from the sub-essence…
- They are followed by branches of the next level, which supplement this basic idea, and they are followed by other branches according to the thought flow
- Write only one word for each branch and twig, thus ensuring a free flow of ideas
- A good choice is to draw the map clockwise
- It is recommended to draw different pictures, symbols, coloring the branches in different colors on the map
- Mind maps should be concise and clear, so whole sentences are not used here, but only keywords, short passwords or short phrases. [2]

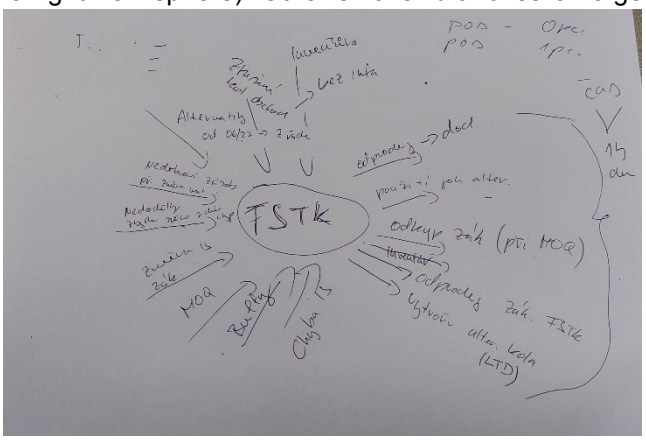

Figure 1 Example of mind map. Source: (own)

Important recommendations for the practical creation of mind maps:

1. Determine the main idea - What is the general intent of the map I am preparing for? It's important to realize why I'm drawing the map. But definitely don't panic when this intention changes during the creation - life is also about changes.
2. Choose the right tool - choosing the right tool is for the basic building block of the future idea.
3. Find a suitable place
4. Use templates
5. Monitor the number of branches - one of the main advantages of mapping is overview, quick orientation and the associated simple association. Therefore, the moment the map is flood with dozens of branches, effectiveness is reduced of thinking through this magnificent tool.
6. Connect and refer - A strong weapon for retrospective analysis and map reading, as well as for solving the current situation, is the connection of two different branches with a broken line with arrows. These connections arise when we have a connection in two different parts of the map
7. Get inspired
8. Come back
9. Divide the points (tasks) that were created on the periphery of the picture into those that you have to prepare yourself and those that you can delegate. Mark them in color and prepare a to-do list from them. [3]

Advantages of mind maps in the process

- They help the thought process
- The mind map helps its user to work from the recorded original idea, thanks to its further development and gradual sorting of ideas, to the specific steps necessary for its implementation.
- They offer a space for a clear arrangement of information
- It provides a hierarchical arrangement of information which indicates to the user the interrelationships between the various topics and thus makes it easier for him to estimate new contexts than in the classical list, where individual ideas are recorded as they came in and there is no indication of interrelationships.
- They facilitate the attachment of new information
- Additional ideas can be freely added to the existing structure by adding a new branch without disrupting the original hierarchy.
- They concretize ideas and concepts
- By graphically displaying his / her ideas and ideas, the user will facilitate their integration into the system, better understand them in the context of other ideas and subsequently be able to handle and manipulate them more easily.

- They help focus on one thing
- Maps can help the user to concentrate on partial ideas and thus better understand the whole.

Creative thinking

The first factor is the ability to create ever new associations, combine different elements, combine existing ideas and re-evaluate or transform old ideas. The connection of ideas into the branches of the mind map is associated with an element called gestalt, which is our natural tendency, which allows us to completely unconsciously and intuitively complement other associations.

The main mission of mind maps is mainly creativity in itself and all the mentioned creative abilities of the mind map include. When the any mind map is created, the creativity is involved to finding new ideas through word associations or drawings. There are not bound by any prejudices or rules, it just give free flow to our thought flows. From common experience, that the creation of mind maps helps to purify the mind and helps to create new concepts, and also helps to better understand any subject matter, because it gives us a certain insight into the issue. [4]

3. CONSTRUCTION OF OWN MIND MAP

In the tree, concept map it will clearly draw the structure and division of the process. For example, the division of the process into key sub-processes, the interconnectedness of the department, the system division. This is probably the most commonly used method for understanding the problem area.

Why?

The minutes of the meeting and its content are drawn in the mind map. It is de facto similar to notes, but with a few differences. On the one hand, this notation is shorter, faster and smaller. It focuses only on the essential and the main, but at the same time you can see what is the main goal and what is expanding. What must always be known and what is extra. What is it related to, what is it based on, etc. The advantage is also that we read the entry in this mind map - we will recall the problem - in the order of tens of seconds. In text form according to the length of the entry much longer.

The mind mapping method can not be overestimated or false excessive expectations to be created. There is also one "but". In order for this form of registration to be really useful and effective, the user must actively participate in the creation of the map. It has been call the element of activity. As soon as it is just a passive recipient of a foreign map - it just describes it, draws it, the added value that I mention disappears or is very small. The benefits really only come when everyone creates their own map. Then he not only remembers more, but also for a longer period of time.

Figure 2 Example of brainstorming.
Source: (own)

Brainstorming and discussion of the problem

Here, the mind map acts as a capture of ideas, opinions or solutions that are offered. By writing them down, sorting them and further processing them, a new solution may appear or we will see the optimal solution, for example with the least number of snags or complications.

Step by step

1) First, make your own raw map. Or rather more. Attention! The topic should correspond to the purpose of the meeting. Ideally, you need to plan a smaller process project. Here you will experience the complexity and complexity of creating maps. The reality is often different from expectations.
2) Before you start creating a map, briefly explain to the other participants what you will do and what it is good for. In short, this explains the system of division - that the

individual branches of the map are divided according to some feature or criterion. You will determine a certain form of analytical thinking and procedure.

3) After completing the map, allow time to think and finally create a summary of what you agreed on. It is also a good idea to allow time for further comments.
4) In the next step, recall everyone, go through the mind map, points from the first meeting and agree on the next parts. This means setting up a project team to prepare the project structure.

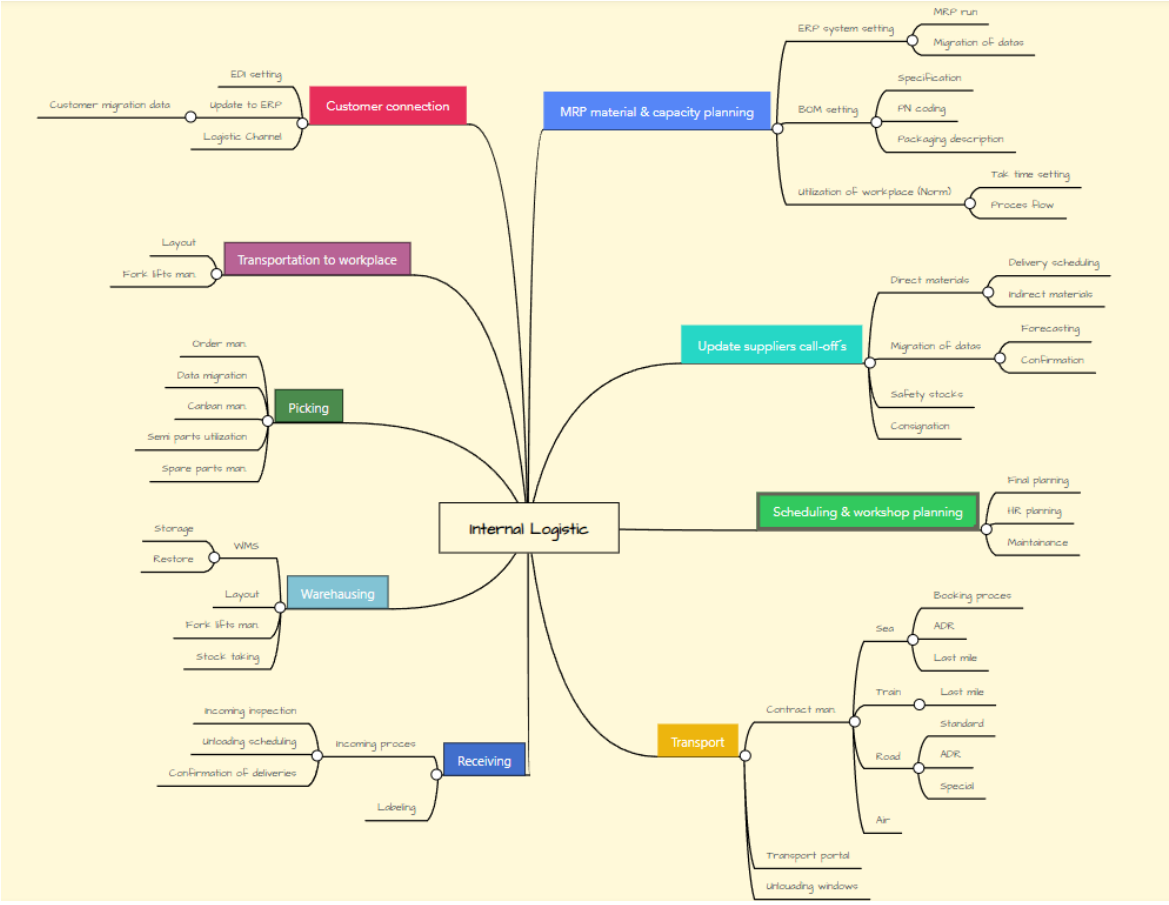

Figure 3 Mind map of internal logistic basic. Source: (own)

4. CONCLUSION

The biggest benefit of mind maps is mainly in their comprehensive display of information arranged in a hierarchy, which allows the user to focus on a particular object (individual idea, idea) and the structure as a whole (a set of all ideas), thus making it easier for him to classify ideas and their mutual relations and thus pave the way for drawing often unexpected conclusions.

In addition to the already mentioned structured note-taking (e.g. in brainstorming), mental maps are often used as a tool in analysis and problem solving or an aid in study, effective planning or solving personal issues.

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MEASUREMENT OF EFFECTIVITY IN DPO, A.S.

MĚŘENÍ EFEKTIVITY V DPO, A.S.

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Abstract

Since the beginning of civilization, large numbers of people have moved and migrated for a variety of reasons. Most often due to climate, natural resources, trade. Mankind's need to travel distances and move objects has led to important inventions. The biggest milestones in transport can be considered the adoption of horseback riding or the invention of bicycles. The greatest expansion of transport occurs after the development of the steam locomotive, which later uses coal as a fuel instead of wood and becomes the largest consumer of this natural mineral. This is followed by the discovery of an internal combustion engine that uses gasoline as fuel. The internal combustion engine was smaller, lighter, more environmentally friendly, and, above all, more efficient. The ever-growing world population is increasingly challenging in terms of transport. Despite the constant development of new technologies in vehicle propulsion, the world's oil, natural gas, and coal reserves are declining rapidly. These resources are non-renewable and threaten to be depleted shortly. For most vehicle propulsion vehicles, their use leads to significant environmental pollution. Due to the serious impact on the environment and the constant growth of the world's population, the current state of transport appears unsustainable and must be transformed soon. An important role is played by efficient and ecological transport with maximum use of natural resources so that the essence of sustainable development is fulfilled. This article aims to establish metrics for measuring efficiency in DPO, a.s., to maximize the use of traffic at given inputs.

Key words:

Effectivity, measurement, public transport, sustainable.

1. INTRODUCTION

The gradual development of world economies has been affected by high levels of productivity due to production methods based on intensive consumption of natural resources and energy. However, due to their significant environmental impact, non-compliance with the beneficial effects of these resources, rapid world population growth, and climate change, industrialized countries have begun to pay attention to environmental issues and the sustainability of their business [1]. Current global development trends in society and changes in the business environment, where the topic of sustainable development is a phenomenon in all directions of human housing, suggests that the next generation of business orientation will be creating sustainable business value and meeting the requirements of sustainable development.

The efficiency of a company or also performance can be viewed from many angles. It can be about the financial efficiency of the company as a whole, individual centers, divisions, departments, etc. There can also be the talk of sustainable efficiency, which is characterized by socially responsible companies. The efficiency of the company varies according to the ideas of individual interest groups. The main measure of efficiency from the beginning is the company's ability to be profitable. The view of efficiency gradually happens over time, as well as approaches and tools to evaluate the financial efficiency of companies for certain developments. From classical approaches based on profit maximization to return on invested capital. Recently, however, more and more emphasis has been placed on modern concepts based on value creation for owners and value management of efficiency.

The classic tools for evaluating the company's financial efficiency in the form of indicators of profit, profitability, cash flow and economic value added are still insufficient and the development trend towards sustainability needs new indicators of an environmental nature. There are many indicators of business sustainability that deal with methods of assessing the sustainability of business efficiency. However, it is problematic to recommend which aspects of sustainability the company should focus on. It is up to the business to choose the appropriate approach and metrics to monitor. Which indicators

will be the most suitable and relevant for a given company will mainly depend on the subject of economic activity, size, place of operation, and the system of management of business activities, etc.

2. MEASUREMENT OF EFFECTIVITY IN PUBLIC TRANSPORT

Public transport or public transport (MHD) is an activity carried out by transport companies in the territory of cities and in its adjacent parts, where the population is moved using appropriate means of transport and technology. The adjective collective expresses the fact that passengers are transported together in one means of transport (in the case of public transport it is not possible to achieve that each passenger is transported from source to destination by one means of transport), without transfer - unlike individual car transport [2].

From the point of view of sustainable development, public transport is a big topic. It appears in the context of the economy, land use, quality of life, environmental pollution, safety, etc. Sustainable public transport must ensure a full-fledged transport system that is in line with society's economic, social and environmental needs and at the same time without adverse effects on the economy, society and the environment.

The impact of transport on the lives of the population is not negligible. The biggest problems are especially in large cities and agglomerations, where the demand for transport increases with the growing population. Transport in the Czech Republic, as in other developed countries, adversely affects the quality of the environment during its development. It is not only about air pollution, which transport causes damage to human health, soil, buildings and materials, but we can also take into account the impact of noise. Traffic noise carries a number of other adverse effects from sleep disorders to cardiovascular disease [3].

The current world development of transport is permanently unsustainable and all major cities have to solve this problem. Transport companies operating their business, the main object of which is passenger transport, thus find themselves in a difficult situation where they are committed to creating sustainable value and saving the environment on the one hand and at the same time must be sufficiently economically efficient on the other. Overall, however, the mobility of the city's citizens must not be restricted.

As key data for measurement have been chosen cost of 1 roadkm, number of transported people per year, number of traveled kilometers per year in the city Ostrava and surrounding areas.

Vehicles of DPO, a.s. are powered by electricity in the case of trams and trolleybuses. For buses with CNG (Compressed natural gas). Cost per 1 km (CZK) according to the individual tractions available to the transport company, see in Table 1. This cost consists mainly of direct costs (fuel, driver's salary, vehicle depreciation, etc.).

Table 1 Cost of 1 roadkm (CZK) according to the type of traction in 2019. Source: [4]

Type of traction	Tram	Trolleybus	Bus
Cost of 1 roadkm (Kč)	73	74	43

Number of transported persons according to the type of traction realized by DPO, a.s. in 2019 see in Table 2.

Table 2 Transported persons (in thousands) according to the type of traction in 2019. Source: [4]

Type of traction	Tram	Trolleybus	Bus
Number of people (2019y.)	47 994	6 881	41 254

Traveled km according to the type of traction realized by DPO, a.s. see in Table 3. The statistics in Table 3 is total number of traveled km by all vehicles owned DPO, a.s. in 2019.

Table 3 Traveled km (in thousands) according to the type of traction in 2019. Source: [4]

Type of traction	Tram	Trolleybus	Bus
Traveled km (2019y.)	12 103	2 885	16 826

For calculate effectivity of vehicle operation is necessary to recalculate the data using by cost coefficient. The author used for calculation cost of 1 roadkm. As base of the coefficient is price for 1 roadkm of bus, which is 43 CZK. This value has been chosen because is lowest price for 1 roadkm. The calculation of coefficient for individual tractions see in Table 4.

Table 4 Coefficient calculation. Source: (own)

Type of traction	Coefficient calculation	Coefficient
Bus	43	1.00
Trolleybus	74/43	1.72
Tram	73/43	1.69

The coefficient itself does not express the effectivity of the operation individual tractions but only their costs per 1 kilometer between individual tractions. In order to be able to express an advantage in relation to the total number of kilometer traveled by a given traction per year and its costs, it is necessary to use a cost factor. And compare the traveled kilometers with the starting base, which in the case of selected bus traction afterwards and total traveled kilometers per year.

Traction effectivity:

$$TE = \frac{Traveled\ km\ by\ Bus}{Coeff \times Traveled\ km} \quad (1)$$

where:
TE – Effectivity according to the type of traction
$Coeff$ – Coefficient of costs
$Traveled\ km$ – number of traction kilometers
$Traveled\ km$ – number of kilometers by buses

The results of the cost calculation see in Table 5. Cost per 1 km in relation to the total number of kilometers traveled according to the type of traction per year. The cost of trolleybuses is only 28.64 % compared to buses. And the cost of tram vehicles is 121.56 % compared to buses.

Table 5 Traction effectivity. Source: (own)

Type of traction	TE (%)
Bus	100.00
Trolleybus	29.49
Tram	121.56

After the calculation, we can express the vehicle utilization effectivity according to the type of traction as the equation called Vehicle utilization efficiency (VUE):

$$VUE = \frac{Transported\ persons}{Traveled\ kilometers} \quad (2)$$

where:
$Transported\ persons$ – number of transported persons
$Traveled\ kilometers$ – number of traveled km

The results of effectivity used according to individual types of traction see in Table 6. The best-rated vehicle in terms of transported persons per 1 km is a tram, which carries almost 4 persons for each kilometer traveled. The result of the bus and trolleybus is similar, where these vehicles transport almost 2.5 people for each of their kilometers traveled.

Table 6 Vehicle utilization effectivity. Source: (own)

Type of Traction	VUE
Bus	2.45
Trolleybus	2.38
Tram	3.96

3. CONCLUSION

In this work, the author suggested how to measure effectivity. To measure effectivity, the price per 1 km, traveled kilometer, transported persons according to individual lines were chosen as key variables. The main tractions include buses, trolleybuses, and trams. The buses are only CNG-powered (compress natural gas), which dominate in the DPO, a.s. The transport company also owns several small electric buses, but these are not taken into account in this work. Trolleybuses and trams tractions are electric only.

Traction effectivity (TE) measures cost by line based on the price per 1 km and the number of traveled kilometers. According to the price data for 1 roadkm provided by DPO, a.s. was the costing factor. The default basic was bus traction and its price is CZK 43 for 1 road km and the number of kilometers traveled per year. It was found that the cost of trolleybuses is only 29.49 % compared to the bus, which is 70.51 % less than bus. On the other hand, tram costs are 21.56 % higher than for buses.

Vehicle utilization effectivity (VUE) measures the usability of the traveled kilometers according to traction in relation to the number of transported persons. Tram traction performed best with a total of 4 people transported per kilometer. Buses and trolleybuses fared worse, with 2.38 and 2.45 people for each kilometer of trolleybus and bus.

In terms of driving effectivity (TE), the tram is the least economical, but in comparison with the vehicle utilization effectivity (VUE), where the tram transports 4 people for every kilometer traveled, it is the best. Trolleybus has the lowest cost and also the lowest number of people transported per kilometer driven. The bus has been chosen as a basis for the calculation.

All data are used from official statistics of DPO, a.s. Data has been selected for 2019 with greater relevance. Data from 2020 has been also available but not very relevant due to the Covid-19 pandemic, when people did not travel so much to school, work, etc., and used a personal cars for their transport rather than public transport.

ACKNOWLEDGEMENT

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DATA MINING TOOLS IN MANAGERIAL DECISION MAKING OF A METALLURGICAL ENTERPRISE

NÁSTROJE DOLOVÁNÍ DAT V MANAŽERSKÉM ROZHODOVÁNÍ HUTNÍHO PODNIKU

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Abstract

The paper presents fundamental reasons for searching for new tools for decission making. It focuses on data mining techniques and tools for cloud computing and various tools for data mining, especially open source tools, widely used in the academic sphere. The paper aims to compare these tools, determine the basic commonalities and differences, and specify them into the area of agile and resilient capabilities.

Key words:

Data mining, cloud computing, artificial intelligence.

1. INTRODUCTION

The knowledge of the technical data from all nodes of the entire chain, despite its considerable volume, enables creating an optimised system to control the entire production. In addition, if we would like to include the environmental parameters in the description of the behaviour, then the control could make optimising interventions in the control system of individual technologies based on the knowledge of data obtained both from the history of the currently processed semi-finished product and from historical data taken from previous technologies, but of course also from downstream and current technologies.

To process such a large data set efficiently, it seems appropriate to use the means of data mining from databases at the process control level. These often include various data analysis techniques using elements of artificial intelligence. Data mining, or analysing the data in a broader context, allows us to look for dependencies that are hidden at first sight; these can then be used for more effective management.

2. MANAGERIAL DECISION-MAKING

Decision making by members of management in any business can be considered one of their most important activities. The importance of decision-making lies primarily in the fact that these actions' quality and outcome usually significantly affects the company's functioning and possible future prosperity. Hence, poor quality or incompetent decision making can be one of the causes of subsequent business failure [1].

The knowledge, experience and judgment of the arbitrator can be considered necessary for:

- efficient collection of information,
- determining the appropriate scope of information,
- the correct interpretation of the information obtained.

At the same time, it is necessary to consider the possible barriers that prevent the right decision or generally prevent the desired quality of the solution to the decision problems. Barriers can be broken down, for example, as follows:

- Subjective:

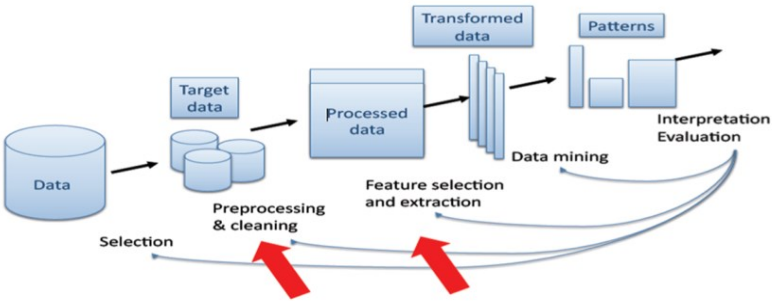
- limited ability to process information,
- the limited scope of knowledge,
- limited ability to formulate and solve complex decision-making problems,
- limited ability to internalise the value system (identification with the value system),
- repeating ineffective solutions (repeated attempts to save a loss-making company, etc.).

- Objective:
  - Insufficient quality of the information base (especially for top management and decision-making),
  - the flexibility of the organisational structure (difficulty in creating temporary teams),
  - a large number of steps in the management hierarchy,
  - imprecision and lack of clarity in the definition of decision-making powers.

For the above reasons, it is therefore very appropriate and desirable to make use of the available options, or methods, in decision-making processes, which include, for example, operational research tools that are available at the current state of knowledge, i.e. available artificial intelligence (AI as artificial intelligence) tools such as fuzzy sets, artificial neural networks, genetic algorithms or data mining [2]. Then, the issue of data mining is elaborated, as it is currently emerging as a key, and yet underappreciated, the tool at the interface between soft and complex methods.

3. DATA MINING

Data mining, or data mining, is a field that uses many techniques used in a wide range of fields, both technical, economic and financial. Thus, it is evident today that after its initial implementation in banking, it has evolved across many industries, from the financial sector to the tertiary sphere to pure manufacturing industries [3].



At the same time, it is always necessary to take into account the area for which the analysis is needed: it is, therefore, necessary to select those data that are related to the expected outcome and are therefore relevant to the desired model [4].

Figure 1 Data mining process. Source: [4]

The data mining process is usually composed of the following stages:

1. Defining **the problem**: This phase also involves the design and development of a plan for solving the problem.
2. Understanding **the data** is essential for further process development.
3. Data **acquisition and preparation**: this is where multiple data sources are integrated, cleaned and modified into the form required by the analytical tools and methods that will later be applied to the data.. The following steps are then necessary in the data acquisition process:
   - **Classification**, or sorting, of **data** is necessary for further processing; typically, data are classified into qualitative and/or quantitative [1].
   - **Sampling** is performed in case of a large amount of data (usually every xth value is used according to a clear specification).
   - **Cleaning** is basically checking the acquired data and removing any errors, including eliminating missing and/or outliers.
   - **Summarisation** is usually necessary in the case of large volumes of data; mathematical operations are usually used to partially eliminate such large volumes of data.
   - **Reduction** means limiting (narrowing) the number of data; segmentation means dividing the data into smaller parts, and transformation means modifying the data (usually by filtering irrelevant data). In general, input data is obtained either by collection and/or purchase. And both options, of course, have their advantages and disadvantages.

4. The next step of working with the obtained and already properly prepared data is the **creation of the model**. Here, depending on the type of data, fuzzy logic, artificial neural networks, genetic algorithms, etc. are used. One of the most important stages of the whole process is the subsequent **verification of the model**. The **implementation** (or the creation of the implementation proposal) is the last implemented step in the whole process. However, it should be noted that the process does not end, but begins to repeat itself cyclically.

If a company decides to implement the results of data mining into its processes, then subsequent and longer-term **maintenance of the model is necessary**.

4. DATA MINING TOOLS

In the following section, four selected data mining tools are introduced and briefly described for comparison.

Rapidminer

According to its own website [5], this software is a simple very powerful interface to support analytical processes. It allows you to use hundreds of methods for data uploading, data transformations, data and results visualisation, access to different sources and also supports machine learning algorithms for data mining. Figure 2 shows the desktop environment. Cloud computing capabilities are also advantageously applied here.

WEKA

The original version of WEKA was primarily developed for the analysis of agricultural data. The Java-based version is considered to be a very sophisticated tool that can be used in many different applications, including visualisations and algorithms for data analysis and predictive modeling. Also, this tool can be used on all major OSes and is freely available. An example of the WEKA environment is shown in Figure 3.

WEKA would be even more effective if it were supplemented with a modelling component not currently included in the programme.

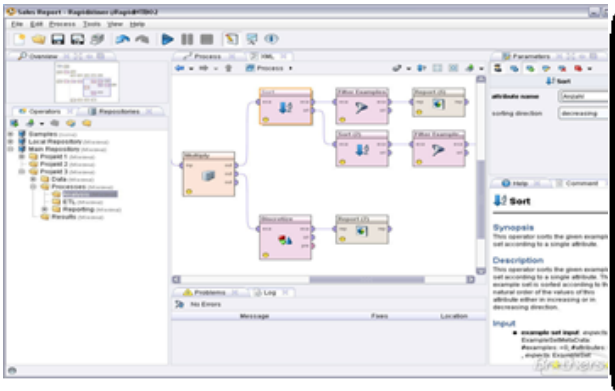


Figure 2 Sample of RapidMiner environment. Source: [5]

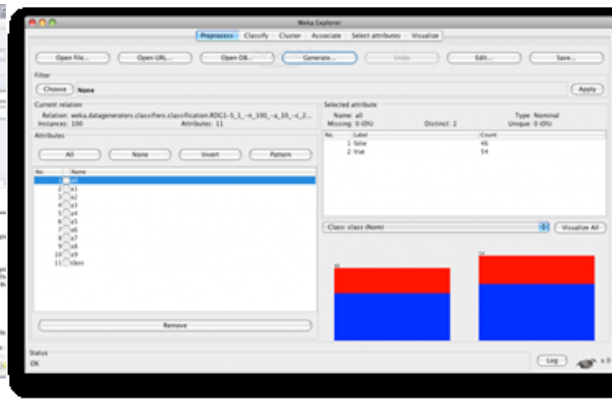


Figure 3 Sample of the WEKA environment. Source: [6]

Orange

The Orange program is freely available and is a suitable tool for beginners and experts alike. Data mining is enabled using visual programming and/or custom scripts. It is a Python tool and also includes machine learning components. Add-ons for bioinformatics and text mining can be installed. As can be seen in Figure 4, it is also equipped with features for data analysis. It is an open-source program that, thanks to its "memory", suggests to the user the most frequently used combinations and the most unused inputs and outputs of processes when connecting data flows between processes.

KNIME

It is a user-friendly graphical environment for supporting analytical processes. Data preparation has three main components: discovery (extraction), transformation and loading. KNIME provides all three. This program is also implemented in Java. It can be easily extended and supplemented with additional features as the work itself progresses. Moreover, many data integration modules are already included in the basic version [7]. This is also illustrated in Figure 5.

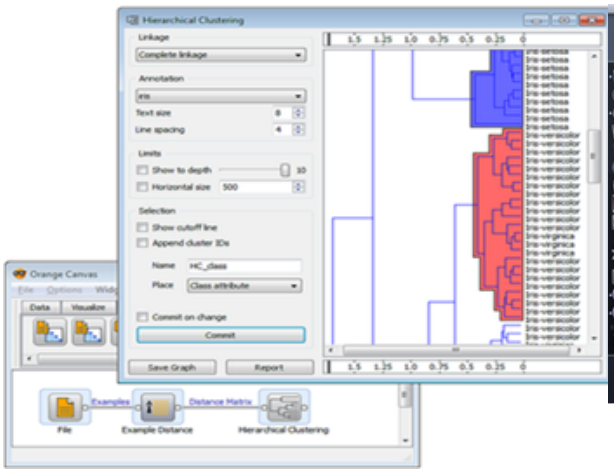


Figure 4 Sample of the Orange environment. Source: [6]

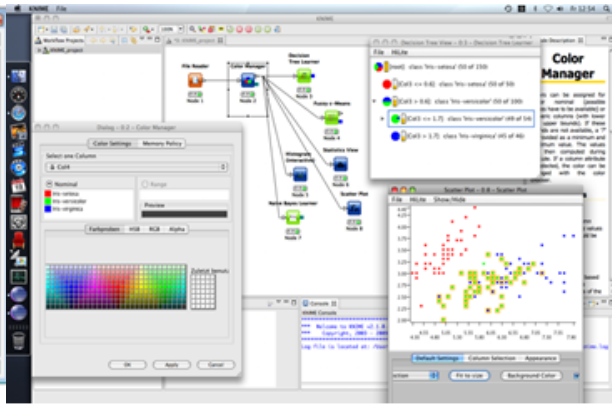


Figure 5 Example of the KNIME environment. Source: [7]

5. CONCLUSION

These programs are essential for data mining, but it must be remembered that the tool itself cannot serve its purpose without appropriate methods. Without a thorough analysis of the structure of the data, its verification or validation of its meaningfulness, then the further progress of the work fails. It turns out that an understanding of the technological process of data processing is necessary both in the analysis phase and in the subsequent phases.

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COMPARISON OF ORGANIZATIONAL STRUCTURES AUTOMOTIVE AND NON-AUTOMOTIVE PRODUCERS

SROVNÁNÍ ORGANIZAČNÍCH STRUKTUR AUTOMOBILOVÝCH A NEAUTOMOBILOVÝCH VÝROBCŮ

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Abstract

The paper presents the organizational structures of three automotive with two non-automotive producers. Automotive producers are the most important automotive manufacturers in the Czech Republic. Non-automotive producers are food producer and producer from the engineering industry. All producers belong to large multinational groups operating around the world. The aim of the paper is a comparison of organizational structures those producers in various levels of organizational structures.

Key words:

Organizational structure, automotive producer.

1. INTRODUCTION

Theoretical basis

The connection between organizational structure and productivity and innovation is described by Drucker [1]. The organizational structure is greatly influenced by the culture, historical consequences and company strategy Fazli, Alishahi [2]. Chen and Huang [3] deal with the role of organizational structure in the knowledge management process. Nonaka and Takeuchi have also considered a suitable structure that facilitates the creation, sharing and use of knowledge [4]. A comparison of organizational structure in a relatively very different environment was made by Hao, Kasper, Muehlbacher [5], who examined the influence of organizational structure on performance through learning and innovation in Austria and China. A much-discussed issue abroad and in the Czech Republic is whether or not a change in the organizational structure is more important than innovation in the company [6].

The most important car producers in the Czech Republic are part of multinational companies with great global influence. The automotive industry is an important part of the Czech Republic's economy and accounts for a significant share not only of GDP but also of employment.

The aim of this article is to compare organizational structures in the automotive industry and two companies from sectors that do not belong to the automotive industry.

Automotive manufacturers are Škoda Auto a.s., Hyundai Motor Czech s.r.o., Toyota Motor Manufacturing Czech Republic, s.r.o. (up to 2021 Toyota Peugeot Citroën Automobile - TPCA). All three companies operate in the automotive industry, are part of multinational groups, and their parent companies operate worldwide.

Non-automotive manufacturers are Hamé s.r.o. and Škoda Vagonka, a.s. Hamé is a food company that belongs to a multinational group and Škoda Vagonka is an engineering company that belongs to an international investment group. These companies are also part of multinational companies and operate worldwide.

Three levels of organizational structure have been identified:

- **top level** - includes the organizational structure at the multinational level;
- **middle level** - organizational structure of the company within the national operation, the company in the Czech Republic;
- **low level** - organizational structure at the level of production within the given production program.

Organizational structures will be compared within a given level.

2. ORGANIZATIONAL STRUCTURES

The organizational structures of these companies are complex and organized into several levels. Each of these companies belongs to a multinational group, which forms the highest level of organizational structure.

Organizational structure - top level

ŠKODA AUTO a.s. is a subsidiary of VOLKSWAGEN FINANCE LUXEMBURG S.A., included within the top parent company and the top controlling company in the VOLKSWAGEN AG consolidation group (the "Volkswagen Group") with its registered office in Wolfsburg, Federal Republic of Germany (see Figure 1).

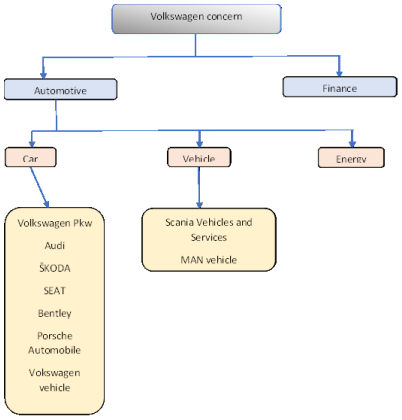

Figure 4 Volkswagen AG – organizational structure. Source: [7]

Hyundai Motor Manufacturing Czech s.r.o. (HMMC) – together with other manufacturing companies, it belongs to the Hyundai Motor Company and is part of the global Hyundai Motor Group (see Figure 2).

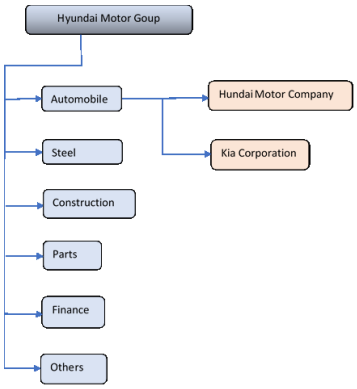

Figure 5 Hyundai Motor Group – organizational structure. Source: [8]

Toyota Motor Manufacturing Czech Republik, s.r.o. – belongs to Toyota Motor Europe NV / SA in the Toyota Group (see Figure 3).

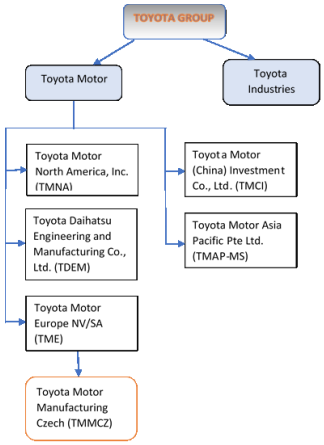

Figure 6 Toyota Group – organizational structure. ***Source: [9]***

The food company Hamé and the engineering company Škoda Vagonka were selected to compare automotive manufacturers with non-automotive companies. These companies also belong to large multinational groups.

Hamé s.r.o. – The owner of this company is the Czech company Orkla Foods Česko a Slovensko (formerly Vitana a.s.), which is owned by the Norwegian holding company Orkla Group (see Figure 4).

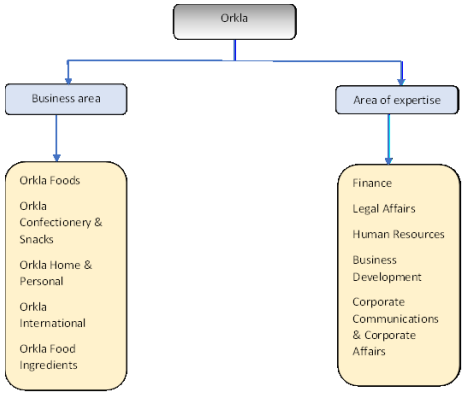

Figure 7 Orkla – organizational structure. ***Source: [10]***

Škoda Vagonka, a.s. – belongs to the Czech company Škoda Transportation a.s., which is part of the international investment group PPF (see Figure 5).

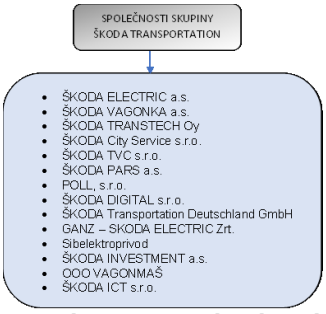

Figure 8 Škoda Transportation – organizational structure. Source: [11]

Comparison of individual levels

Top level

Car manufacturers are grouped into huge multinational companies that are mostly engaged in not only the production of cars but also industries that are not related to the production of cars. The food company Hamé and the engineering company Škoda Vagonka are also part of a multinational unit. Their organizational structures do not differ at this level.

The organizational structure at the top level does not differ between car manufacturers and manufacturers from other industries. Each company has a "head" - a top manager, or a group of managers (board of directors) that makes the highest and strategic decisions within the group. There are also top managers who cover individual areas, important for each company, marketing, finance, legislative background, etc., as well as individual manufacturing companies (companies, divisions) that adhere to the top strategy but operate within their production program.

Middle level

At this level, the organizational structure represents the company within the Czech Republic. The organizational structure of all selected companies is more detailed and captures more information about the production of the company. At this level, companies in the automotive sector and other areas are not fundamentally different.

The middle level of the organizational structure is also very similar to each other. It varies depending on how much autonomy is within the group. Whether the company receives support from its parent company or creates everything itself. The focus of the company (automotive x other focus) does not have much effect here.

Low level

The organizational structure at the production process level has a more detailed division and includes a more detailed view of the individual departments of the company and the links between employees and departments. It is largely determined by the type of production and its needs. Production needs, product characteristics and type of technology, technological specifics, or technological limitations are the main factors that determine the organizational structure at this level.

The automotive industry is industry-specific. There is a lot of competition in this area. Product development and innovation are subject to great secrecy. Related to this is the secrecy of a more detailed division of the organizational structure. The detailed organizational structure shows and reveals the development of the product (car) and its disclosure could help the competition to obtain data and information that could harm the manufacturer of this product.

Stricter secrecy will certainly be in the case of innovative production, in the production of new types of product. In standardized and repetitive production, where product innovations are not so frequent, there is no such risk of disclosure through the organizational structure.

The automotive industry has a specific position within other industries. The trend of developing an organizational structure towards flexible organizational structures that can help a company respond faster and better is right here. However, we can observe the same trends in other sectors of large multinational companies. Unlike the relatively stable business area of the last century, the influences that affect organizations today are more turbulent, to which all companies must respond, regardless of specialization.

3. CONCLUSION

After comparing the organizational structures of automotive producers and non-automotive producers belonging to multinational groups, it was found that they do not differ at the top level. At the middle level, it varies depending on the autonomy within the group. The low level of the organizational structure of automotive producers cannot be compared because it is a kind of production secret.

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PROPOSAL FOR THE USE OF PROFILE MONITORING IN WELD SEAMS QUALITY ASSESSMENT

NÁVRH VYUŽITÍ PROFILE MONITORINGU PŘI POSUZOVÁNÍ KVALITY SVARŮ

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Abstract

The paper presents profile monitoring as a possible alternative to traditional quality assessment methods. The basic concept of profile monitoring and its advantages compared to other methods are briefly described. The aim of the paper is to propose the use of profile monitoring in weld seams quality assessment.

Key words:

Profile monitoring, weld seam, quality assessment.

1. INTRODUCTION

Weld seams quality assessment is an important part of the quality management in manufacturing companies since welded joints often have a critical impact on product quality and properties. The quality of welds can be verified through a number of tests, e.g. evaluation of dimensional measurements, tensile testing or metallographic evaluation. During metallographic evaluation the welding defects like pores or cracks are detected and the measurable weld characteristics like width of weld seam or weld penetration into base material are evaluated. Each of the weld quality characteristics is evaluated separately and the overall weld quality is assessed according to the values of the individual characteristics.

According to the values of weld quality characteristics, corrections of welding parameters are made so that the process is statistically stable and provides the outputs in required quality in the long term. Statistical process control (SPC) methods can be applied to monitor welding process variability. In the traditional concept of statistical process control, the quality characteristic being monitored is treated as a single variable or as a vector in the case of multivariate SPC methods. In case of weld seams quality assessment, it is therefore possible to monitor the trend and changes in the variability of individual quality characteristic – width of weld seam, penetration, or both, provided that there is dependence between the characteristics. However if there are multiple welded joints on a product, each with its own quality characteristics values, SPC methods cannot easily assess the interactions and changes in these characteristics. In this case, the profile monitoring method, which allows also monitoring the dependency between the quality characteristics of individual welds, is a suitable alternative.

2. PROFILE MONITORING

Profile monitoring is an approach based on the fact that in some applications, the quality of the product or process being monitored may be more appropriately expressed by a relationship between two or more variables [1]. In these cases, it is necessary to monitor a group of variables whose values, when plotted on a graph, form a profile.

A profile is a functional relationship between one dependent variable and at least one independent (explanatory) variable. This relationship, called a profile, is monitored over time in profile monitoring. The precondition is to measure n values ($n > 1$) of the dependent variable together with the corresponding values of one or more independent variables. The independent variables often express the position at which the measurement was made on the product.

In contrast to obtaining a single value on each product or unit, the obtained values of quality attributes are recorded as a set of data points, and this set may form a line, a curve, or a surface - generally a profile [2]. Profile monitoring is used to assess and manage the stability of the relationship between the monitored variables across time. Similarly to statistical process control, statistical quality control through profile monitoring takes place in two phases:

- Phase I - the phase of ensuring a statistical stability.
- Phase II - the long-term statistical process control phase.

In the first phase of profile monitoring, the statistical stability of the monitored process is assessed and the parameters of the profile model are estimated in case of statistical stability. To assess the statistical stability of the monitored process, a set of data obtained over a certain period of time is used. Once statistical stability is ensured, the shape of the relevant profile is described by a regression model. The objective of phase I is to determine the parameters of the regression model of the profile that characterises the statistically stable profile. The established model will be further used in Phase II to detect changes in the parameters of the observed profile. For proper parameter determination, a large dataset should be provided in Phase I.

In the second phase of profile monitoring, new values are extracted from the monitored process and the profile that these values create is described by a regression model. The parameters of this model are compared with the parameters of the model for the statistically stable process established in phase I. The aim of phase II is to quickly detect changes in the parameters of the monitored profile compared to the values of the statistically stable process.

To ensure statistical stability and detect possible changes in the profiles, a number of methods have been proposed using classical Shewhart control charts as well as CUSUM, EWMA, MCUSUM, MEWMA and charts based on T^2 statistic [3]. The choice of a particular diagram depends on the type of profile being monitored.

3. WELD SEAMS QUALITY ASSESSMENT

The data for the proposed use of the profile monitoring in this paper originates from a company supplying components to the automotive industry. One of the important manufacturing processes of this company is welding, which creates permanent joints between steel components of the final product. The final product is highly safety relevant thus the extensive testing of each production equipment set up and batch is required.

The quality of weld seams of product are assessed in regular intervals by destructive methods, a metallographic cross cut, to evaluate weld seams on material level. The metallographic evaluation is carried out at regular intervals:

- at the start of production: on the first piece produced from a new batch,
- during production: when the specified number of pieces produced in a given batch is reached,
- after an interruption of production on a given welding machine of more than 8 hours,
- at the end of production: on the last piece produced of a batch.

The weld seams quality assessment by evaluation of metallographic cross cut begins with the identification of the sample and marking of the individual welds on it. Then sample is cut in the metallographic laboratory. The cut parts of the sample are grinded, polished and etched with nitric acid. As a result of the chemical reaction, the welds darken. The welds are then magnified under an optical microscope and photographed. Afterwards the quality characteristics of each weld seam are assessed by the metallographic laboratory staff. The main quality characteristics of weld are:

- position of weld seam,
- width of weld seam,
- weld penetration into the base material.

These characteristics are generally evaluated according to the required minimum value, maximum value, or both of them. The measured values are automatically recorded in a database. According to the values of quality characteristics, authorised personnel decide whether the evaluated weld seam meet the defined requirements and the welding process may continue under the existing conditions.

If the evaluated characteristics do not meet the required values, a report with a non-conforming result is issued and corrective actions are taken. These actions may be:

- inspection of input parts,
- checking and cleaning of zero points, clamps and clamping devices on welding fixtures,
- adjustment of welding parameters.

In addition to the evaluation of the partial quality characteristics and the overall quality assessment of each weld seam, it is also necessary to monitor the process stability in the long term. For long term monitoring of the variability of individual quality characteristics, the quality characteristics of each weld are monitored individually and the control chart may be used. However the interrelationships between welds on the same product may remain hidden. For this reason, a method using profile monitoring is proposed to monitor the dependencies between weld seam quality characteristics occurring on the same product.

4. PROPOSAL FOR THE USE OF PROFILE MONITORING IN WELD SEAMS QUALITY ASSESSMENT

The proposed use of profile monitoring is focused on monitoring of individual quality characteristic across weld seams on the same product. It is based on these steps:

- Choosing one quality characteristic to monitor.
- Plotting the quality characteristic values of all welds of one product on the single graph.
- Determining the shape of the relationship between plotted values.
- Describing this profile by a corresponding model.
- Finding the appropriate profile model for the selected quality characteristic on each product.
- Monitoring the slope, the intercept and the mean squared error of the profiles by proper control charts.

Figure 1 shows the example of the profile monitoring method on product, where total of three weld seams are assessed. From the quality characteristics of weld seam, the width of weld seam (Sn) and the penetration to the base material (z1) are plotted on a graph. Due to the position of the plotted values, the most suitable shape of profile is linear.

The linear profile may be described by the model shown in the graph. In this case, the best fitting model was found by the method of least squares. The coefficient of determination shows that 91,05 % of variability is explained by a model of profile. The next step would be plotting the values of same quality characteristic of other products to individual graphs and determining the model of profile for each profile. Assuming a statistically stable process, the slope, the intercept and the mean squared error of the profiles may be then compared and monitor over time by three individual control charts.

The proposed use of profile monitoring allows to detect not only the changes in individual weld values, but also to evaluate the changes in the profile formed by the values of all weld seams on product.

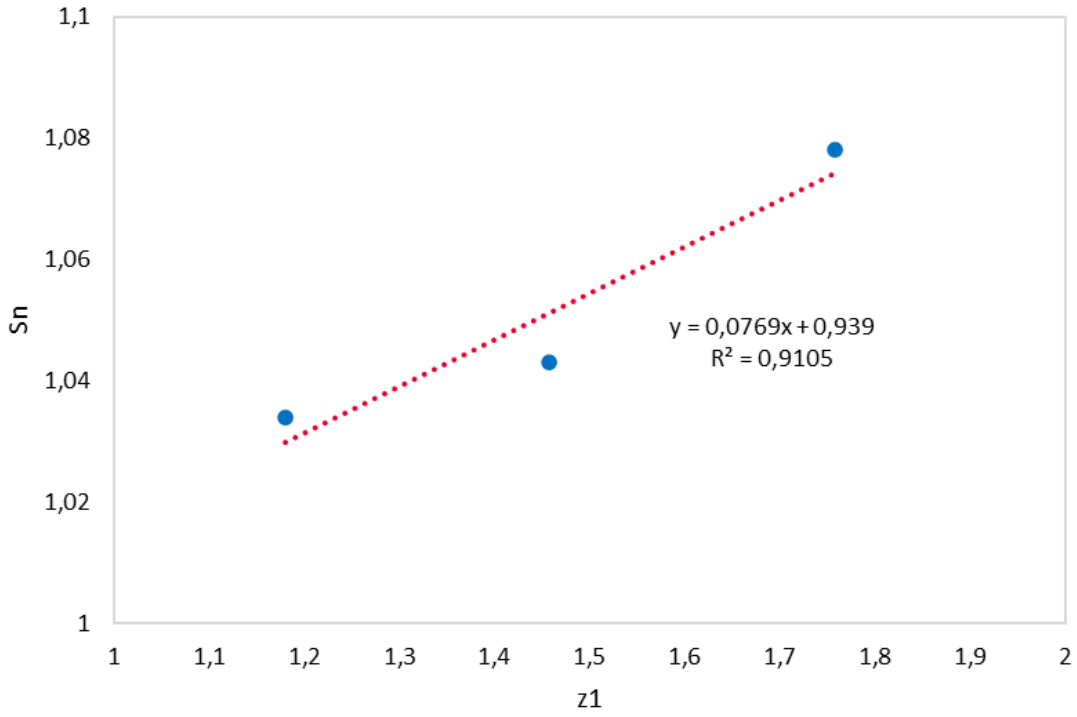

Figure 1 Linear profile. Source: (own)

5. CONCLUSION

The paper presents profile monitoring as a possible method for weld seams quality assessment. Compared to the long term evaluation of each characteristic individually, profile monitoring also provides the possibility to monitor the interrelationships between values of quality characteristic on individual welds. Further research will be focused on the practical application and verification of proposed use of profile monitoring in weld seams quality assessment on real data and evaluating the benefits of profile monitoring.

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PRODUCT QUALITY PLANNING IN THE CONDITIONS OF THE DIGITALIZATION

PLÁNOVANIE KVALITY PRODUKTU V PODMIENKACH DIGITALIZÁCIE

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Abstract

The article deals with quality planning using the possibilities that come with digitalization. It mainly aims at the possibilities of more efficient use of inputs and outputs of individual quality planning processes. It describes how to ensure that some inputs and outputs can be more accessible and used more effectively in quality planning processes and other product life cycle processes with the adoption of digital technologies.

Key words:

Quality planning, digitalization, Quality 4.0, pre-production stages.

1. INTRODUCTION

The Latin word ‘qualis’, from which the term ‘quality’ is derived, can be translated as ‘thing as it really is’ [1]. The ISO 9000:2015 standard defines quality as a ‘degree to which a set of inherent characteristics of an object fulfils requirements’ [2]. This definition is not the only one generally accepted definition [1].

Quality planning deals with quality management during the design and development of the product and process. According to Juran´s triology of quality, quality planning, together with quality control and quality improvement, is the essence of quality management. Quality planning is a structured process for the development of products and services that aims to ensure that the final product meets the customer’s requirements [3].

The opinion from the past that the quality of the product is determined by its production has been replaced by the current generally accepted view that the quality of the final product is up to 80 % affected during the pre-production stages, i.e., during product quality planning. Similarly, the costs incurred to eliminate non-conformities in the initial stages of the product life cycle are much lower than the costs incurred to eliminate non-conformities in the later stages [4].

Much information flows into quality processes, and a lot of information also comes from them. These inputs and outputs are also connected to other processes implemented during the product life cycle. The possibility of more efficient flow and sharing of this information is supported by digitalization, which was brought about by Industry 4.0.

The Industry 4.0 concept was the impetus for the development of the Quality 4.0 concept, which aligns quality management with Industry 4.0 to support efficiency, innovation and organizational performance [6].

Although Quality 4.0 may seem like the future of quality, the most successful organizations are already actively involved in the digital transformation of quality management processes [5]. Product quality planning should not be left out of the digital transformation. Therefore, it is a pity that the current quality planning methodological procedures still do not take into account possibilities connected to Industry 4.0, resp. Quality 4.0.

2. QUALITY PLANNING PROCESSES

Quality planning depends on other processes in the organization that provide input data to it and streamline work. On the contrary, many of the outputs of quality planning are useful for other

processes. These processes include, for example, risk management, production preparation and management, innovation and improvement, or problem and complaint solving. Quality planning can be broken down into the following processes:

- Product requirements identification,
- transformation of product requirements into product quality characteristics,
- product design and development,
- product design optimization in terms of possible defects risks,
- product design review,
- process design and development,
- process design optimization in terms of possible defects risks,
- process design review,
- pre-launch and process capability verification,
- gathering and assessing feedback.

3. POSSIBILITIES OF DIGITALIZATION APPLICATION IN QUALITY PLANNING

One of the characteristics of Industry 4.0 processes is their digitization. Digitization uses digital information technologies to transform data and processes. Each organization has a different level of digital maturity, with top-level organizations able to connect the online and offline worlds into one fully integrated and cost-effective entity [7].

The term digitization describes the conversion of existing data and documents from analogue to digital format. For example, scanning a document into a computer. Unlike digitalization, this activity does not seek to optimize processes or data, although it may partially streamline processes through better data accessibility [8].

From this it can be concluded that digitalization depends on the digitization of data and therefore for any process, including product quality planning processes, it is necessary to ensure first and foremost that the data and information with which the processes work is digitized.

Requirements

Different requirements are a key input for quality planning. Product requirements include not only customer requirements, but also requirements of legislation, the manufacturer, and other stakeholders. Requirements from all stakeholders, including legislative requirements, should be in one place, properly updated, archived, and accessible, as they are used in many phases of quality planning as well as in other product life cycle processes. Requirements tend to change often, so it is necessary to monitor these changes as well.

All kinds of requirements should be associated with the product throughout its life. They should also be easy to integrate into the various tools, documents, and processes that work with the requirements. Typically, this includes product and process design risk analysis, complaint management, control plans, technological procedures, work instructions, etc. Several available software offers these options.

Tracking and storing requirements of various natures (e.g., technical drawings, 3D models from CAD / CAM) and tracking their changes are greatly facilitated by software for QMS and Product Life-Cycle management. This software has the advantage of being able to integrate and share information with other enterprise software applications [6].

If an organization wants to be one step ahead of competitors, it must also consider future requirements. Understanding future requirements is the foundation for many innovations and continuous improvement in organizations. Industry 4.0 advanced analytical methods can currently be used to determine future requirements. For example, the Horizon scanning method allows the search for emerging trends that may affect the achievement of company goals and objectives [6].

Information about development trends and competitors of an organization

Information about the competitors of an organization is important for comparing an organization with the competitors, and trend information is not only needed to design and develop a product that meets expectations and assumptions, but can be important to capture innovations and trends around the world before they are caught by competitors.

As appropriate support for competitive intelligence can serve the Crunchbase Web tool, which is a database of various competing companies, their financial activities, and industry trends [9].

Various relevant news and current topics on the Internet, including social networks, can be followed thanks to an online monitoring service called Talkwalker Alerts. It browses the Internet based on user-entered terms and sends an e-mail notification with a link whenever this topic appears on the

Internet. It also offers an analysis of the frequency with which terms appear on the Internet over certain periods of time [10].

Feedback

Feedback from customers, employees, and production should be included in all individual quality planning processes. The goal of the organization, and especially the quality planning team, should be to provide continuous feedback from its products and from its customers using those products.

Sensors and measuring devices connected to information systems can be used to obtain feedback from production [7]. It is desirable that the quality planning team always has an up-to-date overview of the status of the verification and series production of the products it has planned, so that it can re-evaluate the effectiveness of quality planning processes, respond immediately to suggestions and adjust its proposals accordingly. Production data are also important for product validation, measurement system analysis, and preliminary capability analysis of the process.

In the case of obtaining feedback from products, the possibilities of the Internet of Things could be used, and sensors could be installed on the products, which will regularly send information about the status of the product through the Internet to competent employees of the organization [7].

Finally, it is important to realize that not all data needs to be known. Edge computing can be used to capture only the necessary data, in which data analysis is performed directly on or near industrial Internet of Things facilities and only useful data are sent to data centres or repositories [6].

In the case of products that currently have artificial intelligence built in and can be connected to the Internet or some intelligent devices and thus communicate with the organization (e.g., mobile phones, watches, cars, home appliances, lighting, etc.), these products may obtain information from customers and monitor their satisfaction with these products, for example, through the application of the product in a mobile phone.

Lessons-learned database

The lessons-learned database is an excellent tool for making effective use of the lessons learned throughout the product life cycle, whether the experience is negative or positive.

Some suggestions to the Lessons-learned database could be collected and recorded automatically, and the person responsible for the lessons-learned database or the owner of the process would be informed, for example, by automatically sent e-mail, SMS message or notification from the application.

Suggestions that could be automatically recorded are any form of feedback from production facilities (e.g., exceeding control limits, nonconformal product detected by sensor, production line overload, etc.), feedback reports from employees from connected software, feedback from customers, analysis of complaints (for example from 8D reports), new results of risk analysis, Pareto analysis and various other methods and tools associated with the product.

Control plan

The control plan is a description of the procedures and systems for the control of components and processes covering the prototype, pre-launch and production [11].

The control plan is largely based on the technical specifications of the product and the product drawings. A good example of how to streamline the creation of this document may be that technical drawings could be automatically projected into the control plan. If they were in paper form, optical character recognition could be used to scan the specifications of the drawing. The characteristics of quality in the technical drawings and in the 3D models in digital form could be recognized by the software and uploaded in the control plan.

The transfer of data from technical drawings in the CAD (Computer Aided Design) program to the control plan is enabled by the IQS software. This software also enables the scanning of paper drawings and their subsequent projection into the control plan, thanks to the optical characteristic recognition function. Furthermore, the control plan is linked to the results of the FMEA method and is automatically updated as a result of the adjustments and updating of the FMEA. This feature ensures that the control plan remains a living document [12].

Product design and process risk analysis

Product design and process risk analysis often refers to FMEA. FMEA should be initialized in the very first stages of the product and process design. The FMEA should be continuously updated because new risks can be identified anytime. Any problems that arise during the product life cycle are an incentive to consider a new risk. Therefore, the FMEA should be linked to all problem solving tools like 8D reports, Pareto analysis, Cause and effect diagram, the Five whys method, etc.

Suggestions to FMEA update and consider a new risk, based on analysis of the mentioned tools and methods digital results, may come to the relevant persons automatically as notifications from mobile applications.

Ensuring that all newly arisen problems, from complaints to manufacturing errors, are stored in the FMEA's possible defects catalogue, which is always up-to-date, can be offered by the IQS software. When new errors occur, the person responsible for the FMEA is informed and the FMEA is automatically updated [12].

The FMEA analysis should be assigned to each product and process and should be easy to find according to the relevant product and process. Because of this, it can be easily used as an input for quality planning of similar products in the future.

The FMEA module in the IQS software can ensure the detection of the similarity of products and components and create the so-called product families. As a result, it is not necessary to identify which products are similar, and all FMEA analyses are available in one place for a family of products and components [12].

4. CONCLUSION

This article dealt with the possibilities of more efficient acquisition and sharing of some inputs and outputs of quality planning processes, thanks to digitalization. Inputs and outputs that the author decided to address were product requirements, information about development trends and competition, feedback, lessons learned database, control plan and product design and process risk analyses. According to the author, these inputs and outputs have the greatest potential to be shared and acquired more efficiently thanks to digitalization.

Organizations should begin to look at the opportunities that arise from digital technologies. The solution may be the investment in robust software. Many of the useful software tools that an organization can use are available at affordable prices. The basis and first step in the digital transformation of the organization is the commitment to the transition from paper documentation to digital documents.

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IMPLEMENTATION OF SDGS INTO THE CORPORATION SOCIAL RESPONSIBILITY REPORTS: CURRENT STATUS IN AUTOMOTIVE INDUSTRY

IMPLEMENTACE SDG DO ZPRÁV SOCIÁLNÍ ZODPOVĚDNOSTI FIREM: SOUČASNÝ STAV V AUTOMOBILOVÉM PRŮMYSLU

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Abstract

In September 2015, the United Nation adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals at its core. However, after the outbreak of COVID-19 in 2020, the global economy was severely impacted and the process of implementing sustainable development was weakened. Especially in the automotive industry, global car production in 2020 is already below 2010 level. Therefore, the aim of this article is to analyze the current status of SDGs in different automotive corporations. After analyzing the CSR reports of 20 automotive corporations, this article focuses on the status quo of the SDGs disclosed in the CSR reports of these automotive corporations from 2015 to 2020. The results show that different automotive corporations disclose SDGs in their CSR reports at different times and choose different SDGs. Most automotive corporations in the CSR report correlate SDGs with the social responsibilities they perform, which leads to different SDGs selected in the annual CSR report. However, in recent years, seven auto companies have determined their Priority SDGs or Mid-to-Long-term SDGs by combining their development strategies, industrial environment, and climate environment.

Key words

SDGs, CSR, Automotive corporation.

1. INTRODUCTION

In September 2015, leaders of 193 countries around the world jointly adopted the "Transforming our World: The 2030 Agenda for Sustainable Development" at the United Nations Sustainable Development Summit and established a sustainable development goals (SDGs) system consisting of 17 goals and 169 sub-goals [1]. SDGs are a binding target index system formulated by the United Nations after MDGs, which is expected to completely solve the development problems of the three dimensions of society, economy and environment [2]. But since 2018, with the rise of trade protectionism, economic globalization is encountering more and more resistance. Especially the outbreak of COVID-19 in early 2020 further disrupted the pace of global economic recovery. The supply chain crisis, chip crisis and commodity price surge after 2020 have weakened the process of implementing SDGs for countries and industries.

In this context, the development of the global automobile industry has also suffered a certain impact. According to statistics from OICA, global automobile production in 2020 fell by 16 % to just under 78 million, which is equivalent to 2010. As an important part of the global economy, the automobile industry has become the object of general concern of all stakeholders for its economic, social and environmental responsibilities. Currently, the world's well-known automotive corporations all put forward carbon-neutral goals, and actively promote EV development. According to the survey, many automotive corporations are working hard to implement SDGs [4]

In recent years, academia mainly studies the internal index planning and coping strategies of SDGs from the perspectives of economy, politics, ecology, land space and environment, while the research on the interaction between SDGs and industries or corporations is less [3]. Therefore, the research aim of this article is to study the current situation of SDGs in the automotive industry by analyzing the content of CSR reports of selected automotive corporations.

2. SAMPLE SELECTION

This article obtains the top 20 automotive corporations by querying the production data of different automotive corporations on the OICA official website from 2006 to 2020 and calculating the weighted average of the production of different automotive corporations. Then, obtain the CSR reports of these 20 automotive corporations. Then, eliminated 5 Chinese automotive corporations whose report content did not include SDGs. Finally, this study obtained a total of 124 CSR reports from 15 automotive corporations. Because the UN SDGs system was released in September 2015, so, this article analyzes the CSRs issued by these 15 automotive corporations from 2015 to 2021 as a key sample.

3. ANALYSIS OF PRESENT SITUATION OF INFORMATION DISCLOSURE OF SDGS IN CSR REPORTS OF AUTOMOTIVE COMPANIES

Existing studies on CSR have not reached a unified conclusion on whether a corporation can form value creation effects by a corporation‘s fulfilment of social responsibility. Studies on the relationship between social responsibility and corporate value include positive correlation, negative correlation, irrelevant correlation, U-shaped curve relationship and synergy relationship [5]. According to the report released by KPMG in 2017, 95 % of the 250 large companies in the world report their social responsibility activities [6]. Through the analysis of CSR reports of automotive corporations selected in this article, it can be seen that these automotive corporations have been insisting on fulfilling their social responsibilities. However, there is no unified definition of corporate social responsibility, which leads to different corporate social responsibility terms, the different titles of corporate social responsibility reports, different content structures of the reports, different reference standards, different government requirements, different referenced guidelines [7].

Global Reporting Initiative (GRI) is the most complete and best structured global standard for reporting on sustainability practices [8]. By analyzing the historical CSR reports of these 15 automotive corporations, this article finds that, except GEELY, other automotive corporations take the GRI standard as the core standard.

Table 1 The year in which SDGs were first cited in the CSR report and the name of CSR reports. Source: (CSR reports issued by automotive corporations)

Automotive corporation	The year in which SDGs were first cited in the reports	Name of CSR report
TOYOTA	2017	Sustainability Data Book
VOLKSWAGEN	2017	Sustainability Report
HYUNDAI	2017	Sustainability Report
G.M	2016	Sustainability Report
FORD	2016	Sustainability Report
NISSAN	2018	Sustainability Report
HONDA	2020	Sustainability Report
FCA	2017	Sustainability Report
PSA	2017	Corporate Social Responsibility Report
SUZUKI	2018	CSR & Environmental Report
DAIMLER	2016	Sustainability Report
B.M.W.	2016	Sustainable Value Report
GEELY	2020	Corporate Social Responsibility Report
MAZDA	2017	Sustainability Report
MITSUBISHI	2018	Sustainability Report Corporate Social Responsibility Report

As shown in Table 1, the years in which automotive companies reported integrating their CSR practices with the SDGs are different, G.M, FORD, DAIMLER, and B.M.W disclosed SDGs in their CSR reports in 2016. Geely and Honda disclosed SDGs in 2020. The SDGs selected by different automotive companies in different years are not the same. Most automotive companies disclose their

corresponding SDGs by evaluating their activities. It means that companies will change their annual SDGs in the report due to different activities in fulfilling social responsibility activities in different years. Such as G.M, FORD, SUZUKI, etc. Among the 15 automotive corporations, 7 of them have analyzed their respective value chains and regional boundaries, combined with their development strategies. At the same time, they have chosen a more stable model based on The SDG Compass Guide issued by the United Nations in 2015. The priority SDGs, or mid-and long-term SDGs, are shown in Table 2.

The remaining 8 automotive corporations did not explicitly mention priority SDGs or mid-to-long-term SDGs in all reports, but only linked their corporate governance, corporate culture, social and environmental activities with SDGs. This is prone to companies' selective implementation of SDGs, leading to corporation's SDGs change every year [9], or "Greenwashing" phenomenon appears [10].

Table 2 Automotive corporations that disclose priority SDGs or Mid-to-Long-term SDGs.
Source: (CSR reports issued by automotive corporations)

Automoitve corporation	Year	Priority SDGs and Mid-to-Long-term SDGs
TOYOTA	2020	3, 4, 5, 8, 9, 10, 11, 12, 13, 15, 17
VOLKSWAGEN	2020	7, 8, 9, 11, 12, 13
HYUNDAI	2020	4,5, 7, 8, 9, 10, 11, 12, 13, 17
NISSAN	2018	1.2, 2.1, 3.6, 3.9, 4.2, 4.3, 4.7, 5.1, 5.5, 6.4, 7.2, 7.3, 8.1, 8.2, 8.5, 8.7, 8.8, 9.4. 10.2, 11.1, 11.2, 12.4, 12.5, 12.6, 13.1, 14.1, 15.5, 16.3, 16.4, 16.5, 17.16
DAIMLER	2018	8, 9, 11, 12, 13
B.M.W.	2016	11, 12, 13
MAZDA	2020	3.6, 3.9, 6.3, 7.2, 7.3, 7.a, 8.2, 8.4, 8.5, 8.10, 9.1, 9.4, 9.5, 11.2, 11.6, 11.a, 12.4, 12.5, 12.6, 13.2, 17.16, 17.17

Each number in Table 2 refers to a different SDG. There are 5 automotive corporations that only set main goals, while NISSAN and MAZDA set specific sub-goals.

From Table 2 we can see that SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable), SDG 12 (Ensure sustainable consumption and production patterns) and SDG 13 (Take urgent action to combat climate change and its impacts) are the priority SDGs or mid-to-long-term SDGs for these seven automotive corporations common goals. These three SDGs are also in line with the core strategic interests of each automotive corporation. Such as automotive corporations achieve SDG 11 by using technology to improve the safety of vehicle driving, achieve SDG 12 by using more energy-efficient and environmentally friendly production methods, and achieve SDG 13 by using green technologies to reduce the impact of products on air pollution, etc.

Among them, B.M.W first disclosed its Priority SDGs in its CSR report in 2016. NISSAN and MAZDA have proposed more specific Mid-to-Long-term SDGs than other auto companies. Among them, NISSAN has disclosed 31 specific targets in its CSR report in 2018. Until now, it will focus on these 31 each year in 2021. The target discloses the relevant activities that the company has practised and evaluates the progress of the activities.

4. CONCLUSION

By analyzing the CSR reports of these automotive corporations, it is not difficult to find that they have been persisting in fulfilling their respective TBL-based CSRs. However, due to the time of proposing SDGs and the complexity and comprehensiveness of their target systems, the timing of SDGs as CSR targets for automotive corporations is inconsistent.

And based on these automotive corporations' sustainable development strategies and the geographical environment, economic environment, and social environment in which the company is located, the SDG selected is also different. However, SDGs are goals pursued by companies in fulfilling CSR, not an explanation of their CSR activities. The research in this paper also found that some automotive corporations have organically combined their corporate strategies with the stable implementation of SDGs strategies.

The limitation of this study is that it only analyzes the status quo of information disclosure of SDGs in the CSR reports of various automotive corporations, but does not specifically analyze the theories and logic of each automotive corporation choosing their own SDGs. And need more in-depth

discussion of SDGs between traditional automotive corporations and new energy automotive corporations in the future for comparative research. At the same time, it should conduct in-depth research on the SDGs of auto companies based on regional differences.

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FLEXIBLE SYSTEM OF THE UNDER-RUN AGV

FLEXIBILNÍ LOGISTICKÝ SYSTÉM PODJEZDOVÝCH AGV

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Abstract

This work presents the use of a new logistics system for loading the production line, with the help of the use of AGV. The aim is to get acquainted with a new project, which is closely connected with automation in production logistics. By presenting the advantages of a flexible logistics underpass AGV, we want to move both in the quality of the entire process and in the use of the new potentials of the production line loading method.

Key words:

Logistics, industry, AGV.

1. INTRODUCTION

Thanks to the fast developing logistics as a whole, it is important to react quickly and accordingly. In today's world the market is wide and there is a lot of a potential companies among which the company can choose. In advanced company it is important to use modern solution for logistic activity. The trend in current world is to use trucks powered by fossil fuels and mainly automatization. Furthermore in course is use of autonomous technology, which is considered to be future of logistic, but not only there. Already in today's world we can find the existence of automated warehouses, where AGV distributes material to allocated places. It is important to say, that this whole process is without any touch of humans. The research of autonomous logistics is lately on a rise and some years later the autonomous LKW was introduced to the world.

What exactly is the AGV? This abbreviation stands for „Automatic Guided Vehicle". Simply put, we can describe AGV as a machine which can, without any human intervention, drive through designated course around the warehouse. It can be programmed, so it can go faster in specific section and in other go slower or even stop for certain period of time [1].

Huge demand is on a rise at market with AGV, and that is why it is possible to wait for the order up to many months. Companies which operate in production of AGV are very busy. There are some specialized companies, which offer their own product and their own software for controlling. The whole potential of autonomous vehicles is at replacing human resources. Main idea is that the work designated for AGV is simple and easy to complete. Replaced workers will be used to do more difficult and harder jobs than carrying material from one place to other. Future potential is to extend autonomous vehicles to basic tasks. Humans would then work on more important jobs, which the AGV could not complete [2].

AGV is divided into groups according to several parameters, from which the most basic is how the AGV moves in space. Simple division is according to technology of navigation: cable type, guide type, laser type, gyroscope and spatial vision [3].

2. UNDER-RUN AGV

Under-run AGV, made by company Asseco CEIT is easily integrated mobile robot, which is designed for continuous service, it is programmable to large extension and that is offering flexibility and scalability. These vehicles are compatible for intern logistics, but also for completed production lines. There is many types that company Asseco CEIT produces and they are divided for example by max load or by type of load, which they can carry. AGVs from Asseco CEIT are spatially guided, that

means by using a scanner the space is scanned and then the map is created, where the AGV will be operating [4].

For said project the model 1200F was chosen, as you can see on the figure 1. It represents efficient, fast and intelligent platform of under-run section of AGV from company Asseco CEIT. This AGV can go under sequential trolley, where it locks specific load or sequential palette and carries it on itself. Robot of this type has bilateral movement, it can carry up to 1200 kg and it can be charged under the sequential palette. As a result of this way of distribution and charging there will be more free space on the roads, because the AGV will be hidden under the sequential trolley. Bilateral movement will allow automatic change of sequential pallets without touch of the human.

1200F represents new line of under-run AGVs which offer flexibility, scalability, 360° security and protection. It is available with contour navigation without additional costs for other navigation elements. AGV is equipped with contactless induction and maintenance-free charging with quick start, quick initialization thanks to optic communication and short charging times. Because of maximal load up to 1200 kg it has wide range of uses. However the turning radius is only 0,7 m, The AGV can make a turn on a relatively small space. It can carry pallets, regals, trolleys or specifically made regals in speed up to 4,7 km/h. Its touch screen is allowing easy operating and furthermore it can be connected to notebook, tablet or mobile phone [5].

Figure 1 Under-run AGV 1200F. Source: [5]

2.1. FLEXIBLE SYSTEM OF THE UNDER-RUN AGV

This type of AGV (1200F) is put in service. Specifically was chosen space, part of assembly line, where sequential picked pallets are loaded. Said part of assembly line is ideal place where we can test logistic of “everything drives everything”.

That means, the closest available AGV is taking needed trolley with parts and is taking it to assembly line. Thanks to systematic layout of chargers, huge part of assembly line will be covered so, all chargers are in close range of sequential work places. This is concession from traditional concept, where one AGV has specific course and it carries specific material.

3. PILOT DEPLOYMENT OF FLEXIBLE UNDER-RUN AGV

In this part I would like to introduce new, flexible solution for suppling specific part of assembly line. On said section is carried material from 8 different sequences. These sequences are in close range of assembly line.

3.1. OLD CONDITION

Before there was 8 sequential workplaces supported by 3 traction AGVs and 5 sequences supported by hand. Supporting by AGV means that, vehicle has designated sequence and it is doing one cycle again and again. On sequence the worker has to unhook empty trolly and hook up new, which is filled with material. Similar situation is on assembly line, where worker unhooks new filled sequential trolley and changes it for empty one. The workers activates AGV by pressing the button and robot is on its way. If the AGV does not carry material to the assembly line, then the material is carried by man operated trolleys with similar type of change.

3.2. New condition

In case of flexible loading of the line assembly line, many things will be easier. The length of the set of under-run AGVs is only 1.5 meters and therefore takes up much less space in the street. Another advantage is that the charging stations are in the material zone area directly on the assembley line, so the AGV does not have to drive off the required route to charge. This will save a lot of time and also reduces the frequency of traffic on certain streets. The AGV is able to charge continuously while waiting for an instruction to deliver the line. Due to the fact that the used AGVs will increase from 3 to 6, which will increase the loading efficiency of the line.

The utilization of used under-run AGVs is estimated at 84.3 % according to the dynamic simulation of Asseco CEIT (see Figure 2).

You will need 10 charging stations to charge 6 AGVs. With 10 charging stations, which are intelligently placed in the area where the AGV moves, gives us great flexibility. Therefore, it can use any charger that is closest and does not have to travel to a specific charging station. In the event of a failure of the sequence will not have to be loaded manually

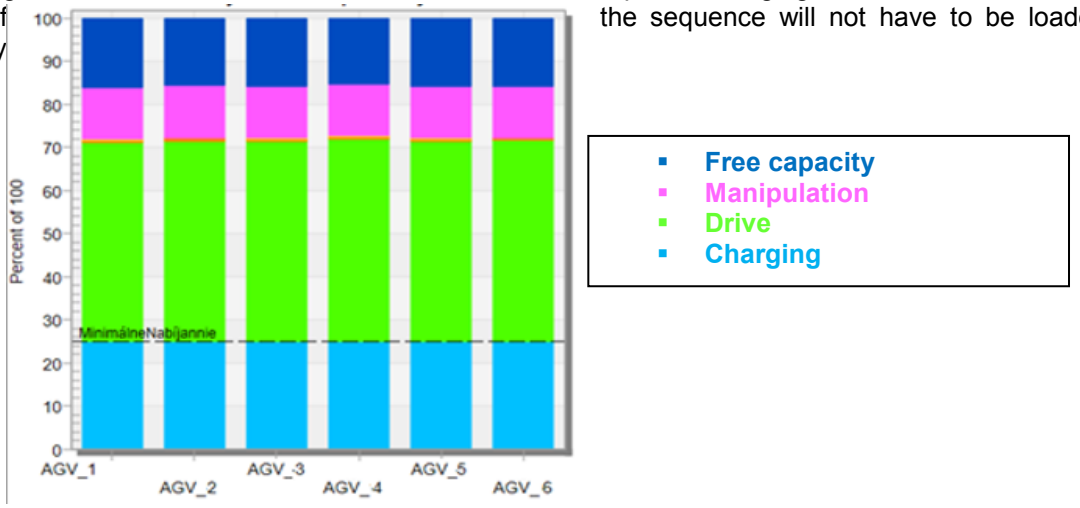

Figure 2 Utilization of the under-run AGV. Source: (own)

4. CONCLUSION

The aim of this work was to present a flexible system of under-run AGVs. The pilot deployment of the new technology on parts of the assembly line, has resulted in better passability of congested streets, easier loading of material and, above all, simplification of the entire process. Charging stations that are not on the street but in the material zone will also contribute to overall throughput. This project will also help the company look to the future. It will be possible to think about whether to use the technology of under-run AGVs in larger quantities like more sequential workplaces.

The advantage is also compatibility between individual robots. When in the event of a failure of one of them, the rest can easily cope with the delivery of the line and it will not be necessary to load the goods manually.

If 8 tractor robots were used to transport a given part of the assembly line, each with its own specific fixed path, while the length of the set is 6.5 meters, these sets would create an obstacle in the loaded street. And that is why the biggest benefit of under-run AGVs is that they do not have a fixed

route and can help each other. This use of AGVs will bring more efficient of AGV in the area. The number of robots will also be reduced by 2 and the operation will be smoother.

Finally, I will reiterate the benefits of deploying a flexible under-run AGV system.

1) Improving road traffic
2) Eliminate waiting
3) More space for charging
4) Improving work safety
5) Sequential Exchange automatization

I see the greatest benefit of this study in automating the whole process of loading material on the assembley line, but also in improving the passability of the streets.

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MOTIVATION AS A MAIN TOOL FOR THE COMPETITIVENESS OF EMPLOYERS IN THE LABOR MARKET

MOTIVACE JAKO HLAVNÍ NÁSTROJ KONKURENCESCHOPNOSTI ZAMĚSTNAVATELŮ NA TRHU PRÁCE

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Abstract

If the company wants to be successful, people are fundamental to achieve goals. It is because people are the engine that creates value. The company's human resources are closely related to how the company can respond to the constantly evolving market. Employers realize that they need to offer more added value to their employees than just their salary. They provide a number of benefits that not only keep employees in the company, but also motivate them to perform better and to be more satisfied. The main goal of this article is to decipher what are the current trends of companies in the motivation of their employees and in the offered benefits.

Key words:

Motivation, trends, benefits, productivity, employee.

1. INTRODUCTION

In today's dynamically developing market, it is primarily employees who contribute to the company's prosperity and are one of most valuable assets of the company. The fight for employees in companies has not finished yet even after the second year of the pandemic. HR professionals and team leaders are figuring out how to keep the employees they have [1].

A prerequisite for effective employee performance is, among other things, work motivation. Work motivation is sometimes called the holy grail of organizational issues [2].

In applying the incentive strategy, each company should pay particular attention to the structure and effectiveness of the remuneration system, including employee benefits. Remuneration and benefits, or employee benefits, must always sensitively reflect the specifics of work organization and work performance in the company. Benefits are the rewards that employers provide to employees in connection with their employment. In some cases, their position, length of employment in the company or merit may be taken into account in connection with their provision. Like financial rewards, they should be both motivating and stabilizing in nature and lead employees to better performance in the work process, job satisfaction and reduction of turnover [3, 4, 5]. The benefit can be, for example, adjusted working hours, the possibility of qualification growth, services paid for by the company, a discount on business services and products, social care by companies [4].

The article focuses on trends in remuneration and benefits at a time when there is a critical shortage of qualified employees in the market.

2. METHODOLOGY OF THE RESEARCH

Research was employed to see what are the trends in employee remuneration and benefits and how companies can hire new talents and reduce turnover. Part of this paper is focused on the question why is employee motivation so important in 2021.

Outputs of the research are listed in the following parts of the paper:

1. Methods to hire and keep employees?
2. Which benefits motivate the most for better work performance?
3. Why is motivation key in 2021?

3. RESULTS AND DISCUSION

This part of the paper presents the most important outputs of the research.

3.1. Methods to hire and keep employees

Looking back on the years after the crisis of 2007, it can be seen, that in the situation at the time, employers were the ones who chose employees and devised any attractive incentive programs. This trend is opposite compare to last situation. Experts from Stanton Chase, a company that seeks top managers, say that employees are the ones who choose a company, and employers without a good and strong brand (employer branding) have a difficult position in the labor market [6]. Stanton Chase analyzed insights from top executives who ran companies in China. Using this analysis, they identified several ways and tactics to succeed in the battle for talent as part of acquiring or retaining them. The resulting findings are as follows:

- *Understand how much they want us* - it is important to understand the true public reputation of a company or brand among customers and potential employees. It is necessary to find out how much people want to work for us, what attracts (or repels) them in our society.
- *Improve the company's reputation through branding* - to gain talent, you need to be able to sell your company brand publicly. As with product marketing, you need to sell your brand to both existing and, most importantly, potential employees, and their expectations must be exceeded.
- *Strengthening internal talent recruitment* - It is important to cultivate talent internally in the company and thus reduce the recruitment of new employees from outside. Employees are leaving company less if the company invests in their personal development and allows them to advance in the career ladder. For the best rated companies, internal candidates accounted for up to 80 % of recruitment. The remaining fifth of the candidates were recruited from the outside, ensuring fresh blood in the company.
- *Predict and be able to respond to changes in the labor market* - companies must be able to go along with how the labor market develops. The biggest role is to be able to determine the amount and structure of remuneration, types of rewards, long-term and short-term bonuses. Furthermore, investment in talent development [6].

3.2. Benefits that motivate the most for better work performance

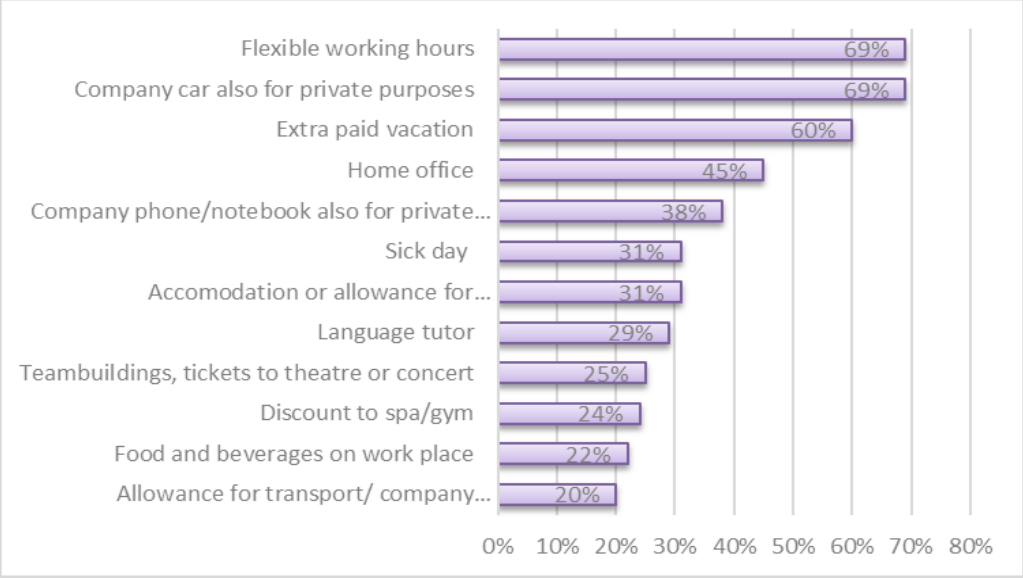

Figure 1 Preferred employee benefits. Source: [7]

In a paper called Employee benefits as one of the factors of work motivation [7], a survey was conducted in February 2017 trying to identify preferred employee benefits. The survey included 100 students of the University of Žilina. 43 % of respondents were male and 57 % female. The survey found that the most preferred benefits are flexible working hours 69 %, a company car for private purposes 69 % and an extra week of vacation 60 %. All these preferred benefits can be seen in the Figure 1 [7].

Given that the COVID-19 pandemic has affected business, employee bonuses in the form of company stocks can be a very good tool to increase their work motivation and retain key talent. This will motivate employees to work hard for the company as soon as they own a certain share, so there is a greater chance that the employee will take on more responsibility and work harder. It will also lead to prioritizing the company's goals over their own and will be more willing to work to make their share more valuable [8, 9].

3.3. Why is motivation key in 2021

Workplace motivation has always been a complex equation. For example, the correlation between motivation and salary may be weaker than you think. Young people suffer from a severe lack of work motivation due to the COVID-19 pandemic. A survey [10] of 1 000 UK employees showed that the performance of younger workers under the age of 35 is twice as likely to be affected by a lack of motivation 44 % as the performance of workers aged 45-54 by 30 %, and significantly more often affected by a lack of motivation than the average of all age groups. CEO Adrian Morhouse noted that young workers were some of the worst affected when it comes to vacations and loneliness, which affect motivation. The survey also showed that other factors affecting the performance of employees include domestic disruptive elements when working from home, 21 %, lack of connection or communication with colleagues 19 % [10, 11].

The paper How to increase motivation in the workplace in 2021 [11] shows that motivated employees are demonstrably more productive than the unmotivated part. A study in the UK and the EU found that resilient employees are more motivated, and that resilience can increase employee enthusiasm by 45 %, energy at work by 39 % and the ability to concentrate by 27 %. Resilience has physical aspects, mental and psychological principles such as safety, self-confidence, belonging and a sense of purpose are difficult to quantify [11].

In 2021, employees facing isolation and insecurity on many levels, investing in mental well-being and mental safety in the workplace is a necessity. When working from home, main responsibility is on managers, who must be able to communicate regularly, effectively and with the intention that employees remain engaged and motivated. Managers should inspire their employees and be more empathetic to them. If the manager manages to understand his employees well, it will lead to a better work performance.

Employee training and development is a great way to show employees that the company relying on them. It opens the way for inner motivation and the desire not only to learn new skills, but also to apply them at work [11].

Increasing remuneration has always been the simplest and most pleasant tactic for motivating employees. Unfortunately, this method is no longer as effective as it used to be. Research [12] shows that 9 out of 10 professionals are willing to work for less money, assuming they do meaningful work that entertains and motivates them. In 2021, when the organization is facing a financial crisis, turning away from financial compensation is more important than ever. Companies need to train and invest in the education of their employees, whose motivated approach will contribute to the company's business results [11, 12].

4. CONCLUSION

The main goal of the paper was to find out how companies today try to keep their employees and motivate them to achieve better results using various methods. Three basic questions which were identified were answered.

Today's situation is that people are more in a position to choose the companies in which to work for. Companies now have to use different tactics to attract new talent while retaining existing ones. Thanks to an analysis of top executives at Stanton Chase, we found that companies must first understand what is the interest about their company and that the strength of a company's brand plays a big role. Prioritizing investment in in-house talent development from outside recruitment has been

shown to help reduce staff turnover and increase employee motivation. Determining remuneration and bonus structures according to the evolving market is key for companies to motivate and retain employees.

A survey of university students revealed key expected job benefits. The most represented are flexible working hours 66 % and company car even for private use 66 %. In addition, 60 % of extra week of vacation and 45 % of respondents look for work from home. Remuneration of employees in the form of company shares is a very interesting motivational job benefit. This benefit is more widespread in Western countries. Employees are internally more motivated to work because they also own a small part of the company.

The year 2021 is a big test for employers and especially for young employees who, due to the COVID-19 pandemic, suffer from a great lack of work motivation. A survey of 1 000 British employees found that 44 % of workers under the age of 35 suffer from a severe lack of motivation. It is more than 45-50 year old workers who suffer from a lack of motivation in 30 %.

According to research conducted in the UK and the EU, employee resilience also plays a major role. Resilient employees can increase employee enthusiasm by 45 %, work energy by 39 % and increase concentration by 27 %.

In today's challenging times, managers must strive to be more empathetic and understand their employees, which has the positive effect of increasing work commitment.

A new interesting fact which was found is that 9 out of 10 professionals are able to prioritize a lower salary, if they enjoy the job they do and provides them a fulfilling feeling. You could say that money can't buy everything, and employee satisfaction is more important. Thanks to satisfied employees, companies can show excellent business results.

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