INNOVATIVE TRENDS IN RAW MATERIALS HEAT TREATMENT

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Abstract

The purpose of research and development in the field of raw materials extraction and treatment, is a significant component of the Slovak economy, is economical, efficiency and sustainable use of available raw materials in compliance with principles of environmental protection. This complex problem involves a wide range of necessary activities from the exploration, extraction, processing to final utilization of mineral resources. Innovations of higher level based on scientific knowledge that lead to change of research focus from operational research on conceptual issues are desirable. Present research results show that qualitative innovations may ensure higher order improvement. In complex systems, such as the area of mineral resources, is necessary to find the complex optimum involving the entire value chain from research through mining, processing, primary and secondary (recycling) processing of raw materials to creation of new products and technologies. Environmentally friendly innovative and intelligent raw materials processing can only be achieved with the active support of information and communication technology (ICT), information and digitization of the processes and equipments and advanced automation - SMARTization of the processes and technological nodes. Thereby, it ensures the autonomy of these intelligent nodes and their functional verification under pilot and operating conditions. Thus, the substantiation of an advanced technology implementation into the mining companies practice can be shown.

Keywords: Innovative trends, heat treatment, raw materials

Introduction:

Heat treatment of raw materials is an important and often dominant part of most of the extractive and manufacturing industries. Due to large capital, energy and environmental intensity the thermal processes play a crucial role in higher production costs. Energy consumption used for their execution generally substantially exceeds their technological requirements. We can influence it by the technical-technological and operational measures. The basic thermal technological processes include heating, drying, thermal decomposition, sintering and smelting. An important part of the thermal process consists of heat treatment of lumpy, granular and dusty materials. Their heat treatment is carried out in shaft, rotary and multi-stage furnaces. Shaft furnaces are used for processing of lumpy and coarse-grained materials and rotary furnaces are used for the coarse-grained, fine-grained and dusty materials processing. Multi-stage furnaces are designed primarily for processing of dusty materials. The material thermal treatment in this apparatus is in the compact layer. Shafts furnaces operate in a thick co-current or counter-current permeable layer. Rotary furnaces work mostly with non-permeable thin layer. According to the layer dynamics it can be stationary or with internal mixing. Multi-stage furnaces work in mechanically mixed thin layer. Another group of the thermal apparatus is devoted to the fine-grained and dusty materials heat treatment in a fluidized layer, in which the processing is performed in a fluidized state.

1. Experimental materials and methods:

The technological development in the area of raw materials thermal treatment is analogically in other areas – according to the life cycle curves (S-curve). Each life cycle curve represents one stage. On the S curve (Fig. 1) are presented four characteristic stages: the creation, development, maturity and termination. Evolution is between and inside S curves. The transition to the new S curve is characterized by the revolutionary - qualitative development which is expressed by qualitative technical and technological changes. Qualitative changes create space for a new quantitative development. Changes within the S curve create opportunities for improvement by their optimization. The optimization provides the utilization of the created technical possibilities.

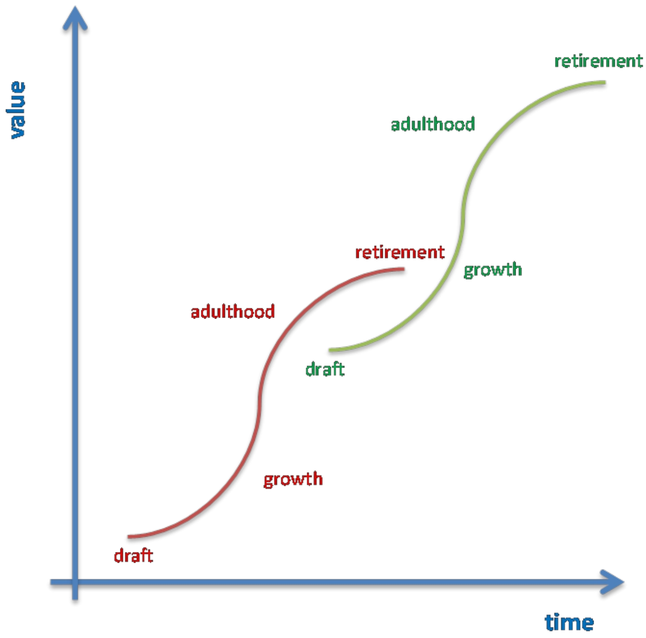

Fig. 1 Life cycle of innovations

Changes inside one S curve characterize development of the systems, equipments, technologies and processes that have a spiral shape. Their repetition is always on a higher level of spiral. By the transfer to the higher level, the possibilities of the system are created.

The technological requirements are basic requirements for innovation of raw materials extraction and treatment, i.e. efficiency and quality. Logistics requirements are focused on using of effective logistics principles, which are mostly based on the PULL philosophy.

The organizational requirements are focused on higher level of system organization. The role of the organization is to establish the organizational rules that create an order and give the instructions on how to proceed in the certain situations. These general rules will ensure not only the effective realization of tasks, but also modify the method to resolve conflicts that arise in the system and create ways for new ideas, for instance for the implementation of business process management. Energy requirements are aimed to reduce energy and mineral resource intensity based on the use of new technologies that minimize heat and materials losses.

The environmental requirements have a common goal - to realize thermal processes with minimal negative impact on the environment. The requirements include:

- minimization of noise and dustiness,
- minimization of gaseous emissions from the raw materials treatment,

- reduction of the energy intensity of the manufacturing process,
- reduction of the material consumption by complex treatment of extracted raw material.

In this regard, the allocation of the whole technological process in the underground would be an ideal solution. This would enable a radical reduction of negative environmental impacts. Underground placement of the process would ensure the total elimination of noise and dustiness. Economic requirements for innovation are closely connected with the issue of impact evaluation related to implementation into practice.

Existing methods for evaluation of benefits of innovation have just been focused on the area of economic efficiency, i.e. on the efforts to find the most quantifiable benefits arising from the introduction of the changes. In evaluating the effectiveness of innovative conceptual changes is necessary to proceed strategically and strive to trace all of the factors that this process brings. Therefore, the effectiveness of the innovation consists of two parts:

- economic efficiency,
- non-economic effects.

2. Results:

Each of period development is characterized by basic directions of development, which are determined by the existing conditions and requirements. Its early detection enables to achieve better position of the company in its sector. Automation of the production, biotechnology, nanotechnology, etc. are used as an example contributing to the increased productivity, quality of production and the costs reduction. The principal innovation activities should follow these directions. In the area of raw materials extraction and treatment the following preferred directions can be considered:

- technological logistics,
- informatization,
- virtual reality,
- digital factory.

2.1 Technological logistics

Technological logistics is a part of logistics focused on the technological processes. In a hierarchical scale technological logistics presents the lowest logistics level. Technological processes provide transformation processes and their optimal implementation. Therefore they include a basic innovation potential. As an example, the magnesite processes in the area of granular materials processing can be used. Magnesite processing includes the processes of drying, calcination and sintering. Logistic processes included flow and accumulation can be divided into rheological (material flow), hydro mechanical gas (medium flow) and thermodynamic (thermal flux) processes.

Rheological processes characterize the movement of granular material. Material layer thickness represents the accumulation component. Motion of a layer is transfer component. The movement may be vertical or horizontal and is carried out by gravitational forces, pressure forces and centrifugal forces. The layer thickness and a manner of the material movement in the layer appreciably affect transformation processes. Recently they have been the subject of significant innovation. It was designed a new type of thermal apparatus operating in a thin compact layer and also designed increase of layer thickness in rotary furnace has been regarded as a significant contribution.

Hydro-mechanical processes represent the motion of gaseous and liquid media through the compact layer or the flow processes in a fluidized layer. These principles were used for the design of microfluid and high-revolution rotary fluidized furnace. Thermodynamic processes involve the heat transfer and its accumulation. By increased heat transfer, the dimensions of the devices can be decreased or the effectiveness can be increased. As an example, can be used the high-revolution rotary furnace preheater.

The main benefit of technological logistics, where in comparison to the classical rotary furnaces the heat transfer intensity was by 25 tones increased, is that problems are solved directly on the basic physical level, executive area which is the essence of the process. The solutions at high hierarchical levels can be only optimized based on results from technological area. The benefits achieved from the solutions in the field of technological logistics can be presented up to several tens of percent of the process costs. It confirms that a great innovation potential of this layer depends primarily on the professionally dealing with the problem. Therefore, education experts and system research have to be regarded as decisive factors.

2.2 Informatization

Informatization of the processes is characterized by the information used for the implementation in the process. The basic information sources about the processes are operating measurements and physical and mathematical models. Operational measurements provide the posteriori information. For obtaining a priori information there are necessary the simulations - model experiments. The mathematical models have a principal advantage. Their main attributes is the adequacy of process modeling and simulation speed. To achieve these requirements, it is necessary to create the models based on a-priori knowledge and the simplified - substitute models. The structure of the model has to permit the simulation of the considered alternatives. Technologically optimal furnace is a reference object. The furnace included technologically feasible modifications that would allow the furnace to achieve the optimum value of the selected criteria (i.e. minimum fuel consumption, maximum productivity etc.).

The use of communication systems is a part of the informatization. As an example for progressive informatization technology is the RFID system. Its use will permit the precise identification of individual doses and subsequent automated control process.

2.3 Virtual reality

Visual communication it is the most effective means of people´ contact with the outside world. For virtual reality implementation it is necessary to generate not only the virtual object which contains the necessary information but also through appropriate modification to achieve their visibility. Another important requirement is to see the existing connections. The virtual reality best meets these attributes. Conceptual contribution of virtual reality is a 3D display and to enable dynamic communication with the virtual world. Visual support in the virtual reality environment is much wider and more efficient than in the traditional systems. The virtual reality development in terms of research processes of the raw materials extracting and processing should provide a conceptual and technical management of static and dynamic processes visualization. The first step is managing in a laboratory scale and subsequent operational validation. The use of virtual reality is developed to support the design and management support.

2.4 Digital factory

Digital factory is an image of the real factory in a virtual environment. Digital factory is used for imitation of the real factory mainly for design, planning, simulations, production and control. A process digitization allows their control by using a predictive approach based on mathematical models and virtual techniques. From a technological point of view, these processes mostly represent bottlenecks.

With a progressive feeding of the models of previous and following processes on the thermal processes models, their model and operational harmonization and integration will be carried out. The ultimate goal of digitization is to create a model of the whole technological process vertically linked with the superior model of the custom logistics integrated system. Thereby, the process enterprise integration is achieved.

3. Discussion:

Trends of advanced technologies can make a transition from automated devices with control system support to the highly intelligent autonomous self-controlling equipment. The critical amount of acquired knowledge will permit the processes and products smartization and the creation of new advanced technology capable of applying to the real operation of mining company. Thus, the goal of the scientific research activities is to build an integrated and smartization technology of complex raw materials processing. The technological scheme of complex magnesite processing technology is shown in Fig. 2.

For the design of a new advanced concept of raw materials extraction and treatment the following methods, concepts and approaches will be used:

- process and system approach to problems solving,
- modeling and simulation of processes (processes partial model, production processes complex balance model, processes hierarchical model),
- concept „Advanced process manipulation“ of technological logistics and processes optimization,
- informatization, digitization and use of virtual reality (digital factory),
- thermal apparatus development methodology.

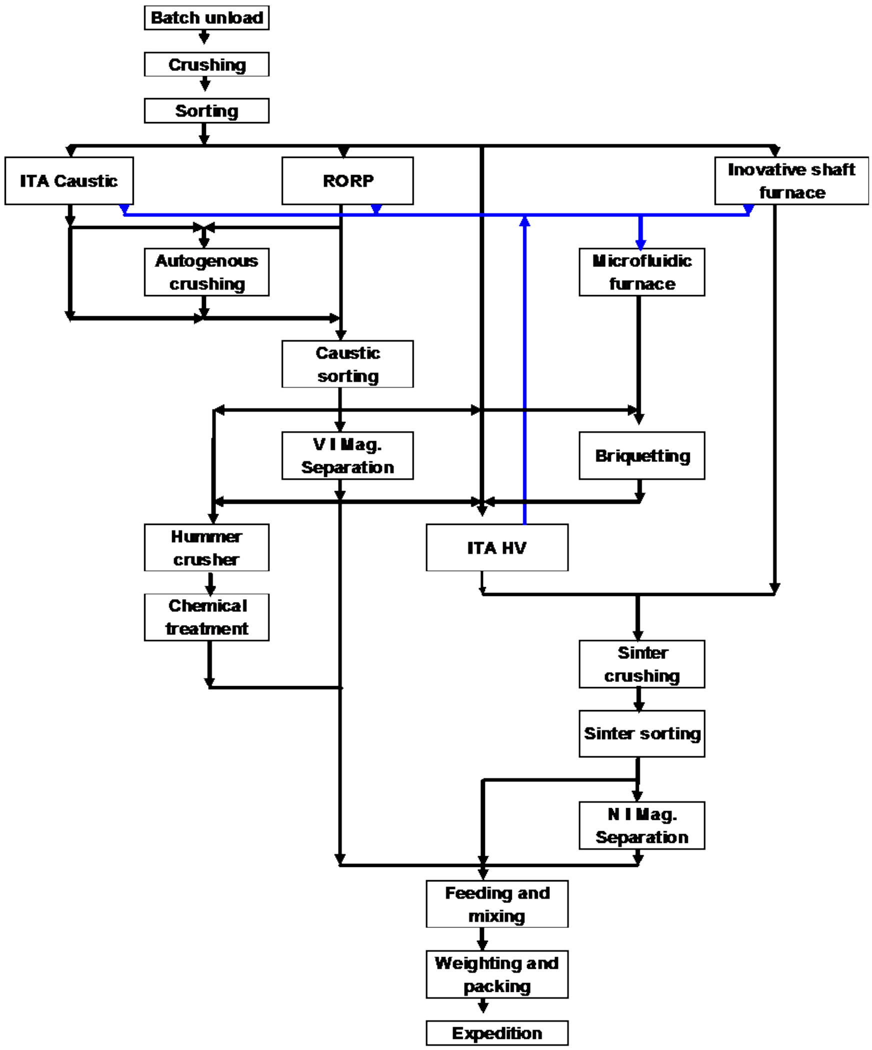

Fig. 2 Technological scheme of raw magnesite complex processing

Conclusion:

Achievement of the intended research results and application outcomes will have, in terms of implementation in practice, the multiplier effect. Research outcomes don't have a standard monothematic goal – they are not a single-purpose or specifically oriented methods, devices or products. The research in the field of granular material thermal processing was focused on their innovations with objectives to secure sustainable developments. The research results are multispectral – they can be applied in a wide range of the thermal treatment, in a variety of industries, in the innovative new products production. The realization and implementation in practice costs will, in comparison to their benefits, present only a tiny portion. Mentioned research results regarding innovation and smartization of technology of complex raw materials processing will bring a new and progressive knowledge and experience. Its utilization will enable a significant increase of the material, energy and environmental efficiency of the processes of raw materials extraction and processing and also will increase the level of completion and production of new products based on domestic raw materials. The impact of the implementation of research results will have a positive impact on increase in competitiveness of regional, Slovak and international businesses and ensure their long-term and sustainable development in all its three components - environmental, economic and social.

Acknowledgement:

This work was supported by the Slovak Research and Development Agency under the contract No. SUSPP-0005-09.

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