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INTEGRATED RISK ESTIMATION OF METAL INERT GAS (MIG) AND METAL ACTIVE GAS (MAG) WELDING PROCESSES

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Taking into account the technical characteristics of the welding processes, associated with the fulfilling clients' requirements, the assurance of safe and healthy working places as well as the environment protection the fundamental meaning belongs to the application of the appropriate methods of risk assessment of these processes. The paper presents the results of risk analysis, using an integrated risk indicator implemented into operation of the MIG and MAG welding processes in the practice. In the welding risk management one can decide about reduce the risk by avoiding the risky ventures, or as a result of the proper preventive actions' application.

Keywords: process of welding (MIG, MAG), quality, environment, occupational management, risk assessment

Integrirana procjena MIG (Metal inertni plin) i MAG (Metal aktivni plin) procesa zavarivanja. Uzimajući u obzir tehničke karakteristike postupaka zavarivanja, povezane sa ispunjenjem zahtjeva kupaca, osiguranja sigurnosti i zdravlja na radnim mjestima te zaštite okoliša, kao temeljni zahtjev pojavljuje se primjena odgovarajućih metoda procjene rizika tih procesa. U radu su dati rezultati provedene analize, korištenjem integriranog pokazatelja rizika u operacijama MIG i MAG zavarivanja u praksi. U upravljanju rizikom zavarivanja može se smanjiti rizik procesa ili izbjegavanjem rizičnih ulaganja u opremu ili kao rezultat uvođenja odgovarajućih preventivnih mjera.

Ključne riječi: proces zavarivanja (MIG, MAG), kvaliteta, zaštita okoliša, upravljanje radom, procjena rizika

INTRODUCTION

The recent years have proved that welding technologies are extremely developed and especially in the field of assessment of technical parameters. Simultaneously the presence of welding gases, due to their quantity and chemical quality, both state the threats for workers' health and have negative impact on the condition of work background and natural environment [1,2]. The raise of technical level of production, the boost of workers' qualifications, the aim at the production of products of the best quality with the simultaneous pollutions emission limit – all of them require from organizations the usage of method allowing for integrated design and assessment of welding processes. Each of the functioning area is is depicted by countless number of variables which are registered in the function of aims' achievement. Point of achievement of an objective can be crossed by the function or the function can pass it by, if there appear any unwanted accidents. As it was noticed there exist probabilities to systematize and even to normalize major accidents, which are unfavourable for realization of the goals of every process in any aspect. By applying various methods one can assess the hazard more and more accurately, considering almost all of the aspects of organizations' functioning [3-10].

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WELDING PROCESSES IN THE ASPECT OF INTEGRATED QUALITY CRITERION

The proposed methodology has been used in the estimation of process of MIG and MAG welding, which are a semi-automatic or automatic welding processes in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. Typical welding semi-automatic consists of: constant power source, ionizer being a generator of high frequency, welding gun, shielding gas supply as well as set of welding cables (Figure 1) [2].

MIG and MAG welding methods use metals usually in the form of a solid wire electrode fed through a welding gun. The filler metals are melted off continuously in an electric arc generated by the electric power source.

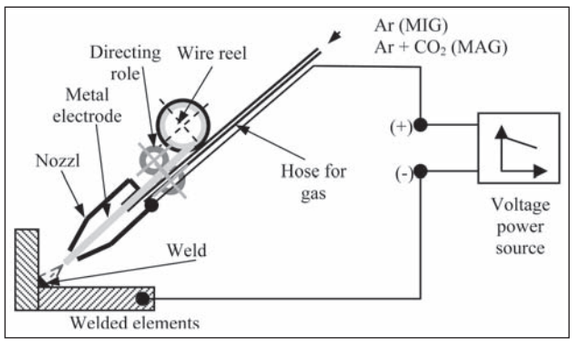

Figure 1 Draft of metal inert gas (MIG) and metal active gas (MAG) welding [2]

The arc and the molten weld pool are protected by a shielding gas which flows out of the gas nozzle located on the welding gun. Transferring metal from the electrode wire to the molten pool depends upon current, voltage and shielding gas composition. Dependently on the composition of the shielding gases, welding can be realized either in inert (MIG) or active conditions (MAG). During welding by metal inert gas method, the gas (e.g. argon and argon/helium mixture) doesn't react with the molten weld pool or the melting electrode. Metal active gas welding (e.g. argon/oxygen/carbon dioxide mixtures) ensures process stability and reliability. The effect of welding processes management based on quality criterion should be nowadays of high effectiveness in the realization of the assumed aims not only in the aspect of products quality, but also - in environmental and occupational ones. The assurance of efficiency of welding processes should be implemented by technology and technological processes management by elimination or minimization of the risk connected with potential nonconformities, environmental impacts and effects of occupational threats, which may occur in metal inert gas welding and metal active gas welding processes.

In the welding processes nonconformity can be defined as "non-fulfilment of a requirement" and defect means "non-fulfilment of a requirement related to an intended or specified use" [11], environmental impact can be characterized as "any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects" [12] and effect of occupational threats as the result of "the condition of the environment which might cause the accident or the illness" [13].

METHODOLOGY OF ESTIMATION OF WELDING PROCESSES

Dependently on the subject of threat as well as its consequences in the context of integrated management it can concern threat risk and can be classified as (Table 1): quality, occupational health and safety, environmental. That is why in the method of welding processes estimation the constant dependence between causes of nonconformities and nonconformities, environmental aspects and their impacts as well as between threats to occupational health and safety and their results can be accepted.

In the estimating the risk connected with presence of nonconformities, environmental impacts and results of threats to occupational health and safety as well as the undertaking the preventive and corrective actions one can accept the assessment algorithm including:

- identification of nonconformities, environmental aspects and after-effects of threats to occupational health and safety,
- analysing the risk connected with presence of nonconformities, environmental aspects and after-effects of threats to occupational health and safety,
- estimating the risk acceptability connected with presence of nonconformity, environmental aspects and after-effects of threats to occupational health and safety.

Risk in the analyzed ranges of integrated management system can be defined as function of:

- the probability of occurrence of cause of the nonconformity and the meaning of the nonconformity - nonconformity occurrence risk,
- the probability of occurrence of environmental aspect and the meaning of the environmental impact - environmental impact occurrence risk,
- the probability of occurrence of threats and the meaning of their results - threats to occupational health and safety occurrence risk.

In the estimation of the probability of appearance of both cause of nonconformity, environmental aspect, threat to occupational health and safety and in the opinion of the significance of nonconformity, environmental impact, result of threat to occupational health and safety tree-stage scale can be used and the estimating suggestions for assessment of the significance of incompatibilities have been shown in the Table 2. The pointed independent risk indicator, defined as a sum of products of probabilities of occurrence of "integrated" incompatibilities and the significance of their results, shows the risk of realization of the analyzed process in the integrated meaning. Method using matrix with "significance of incompatibilities" rows and "probability of occurrence" columns indicates the acceptability of nonconformities, environmental influences and results of threats to occupational safety.

APPLICATION OF INTEGRATED ESTIMATION IN WELDING PROCESS

For the analyzed process one has qualified the risk connected with occurrence of the incompatibilities, risk connected with occurrence of the environmental impacts as well as the risk connected with occurrence of the results of threats to occupational health and safety (Tables 3-5).

The level of acceptability of nonconformities, environmental influences and results of threats to occupational safety in the integrated area, according to the in-

Table 1 **Specification of the risk subject dependently on the range of management system**

Risk	Threat, source of risk	Subject of risk
quality	unfulfilling the technical and technological requirements	product, service, quality management system
occupational	undesirable event connected with performing work, usually influencing health	worker, occupational health and safety management system
environmental	unfavourably environmental aspect	natural environment, environmental management system

Table 2 **List of guidelines necessary in estimating the significance of nonconformities, environmental aspects, results of threats to occupational safety**

Meaning	Criterions of estimation
insignificant	welding nonconformities, dimensional and others, that don't influence client's satisfaction and are not in breach of an agreement, but can be important the comparison of organizations unfavorably environmental aspects that have minimal influence on the closest natural environment and having short-lasting character injuries and illnesses that don't cause long-lasting ailments and absences in work; temporary worsening of condition
moderate	welding nonconformities, dimensional and others that can be removed totally or partially; they influence client's satisfaction and are in breach of an agreement so they can be the reason of rejection of product as well as a loss of client unfavorably environmental aspects that can have long-lasting character and influence the closest natural environment or unfavorably environmental aspects that can have short-lasting character and influence the far-off natural environment injuries and illnesses that cause slight but long-lasting or periodically repeated ailments and connected absences in work
significant	welding nonconformities, dimensional and others, that fully disqualify product unfavorably environmental aspects that have long-lasting character and influence the far-off natural environment injuries and illnesses that cause severe and long-lasting permanent ailments and/or death connected absences in work

Table 3 **Specification of the chosen classical reasons of the nonconformities and the probability of their occurrence (P), their significance (I), and the connection of it with the risk (R) during welding by MIG and MAG welding**

Nonconformity	Nonconformity cause	Nonconformity effect	P	I	R
inclusions in the weld	contamination of the welded material, too high temperature of welding process	decrease of strength and plasticity, hot breaks inter-crystalline	2	3	6
inadequate joint penetration	inconsistent: welding parameters, preparation of the surface to the welding process, positioning of the electrode	susceptibility to brittle (during welding process) fatigue failures	2	3	6
gas cavity in the weld	inconsistent welding conditions, inconsistent welding technique	decrease of strength, fragile breaks of ferritic alloys	2	3	6

Table 4 **Specification of the chosen classical environmental aspects and probability of their occurrences (P), environmental impacts and their significance (I) together with the risk involved (R)**

Environmental impact	Environmental aspect	Environmental impact effect	P	I	R
fire, explosion	welding close to gas cylinder or flammable materials	pollution of air and site	1	3	3
emission of the welding smoke	welding process in open premises and open countries	filling the air with smoke in the neighbourhood of the welding shop, deposition of heavy particles, acid rains created by nitrogen oxides	1	1	1

Table 5 **Specification of the chosen classical threats to occupational health and safety together with their occurrences (P), environmental impacts and their significance (I) together with the risk involved (R)**

Effects of threats to occupational health and safety	Threat to occupational health and safety	Cause of threat to occupational health and safety	P	I	R
electric shock, electric burn, death	contact with electrical energy	use of devices fed by electrical energy	2	3	6
thermal burn of I and II degree	contact with hot surfaces	welded elements, melted alloys metal	2	3	6
irritation of eyes, redder eyelids, headaches	blue light	welding process – electric arc burning	1	1	1

Table 6 **Specification of the probabilities of the chosen occurrence of "integrated" incompatibilities, significance of their results as well as outcomes of acceptability assessment in the electric welding processes; A - acceptable risk (small), B - acceptable risk (moderate), C - unacceptable risk (high)**

		Importance of effects		
		insignificant	moderate	significant
probability	little	• blue light A • electromagnetic field A • caustic substances A	• hit, fall A • noise A • dangerous substances A	• pressing by falling objects B • fire, explosion B • ultraviolet radiation UV B • infrared radiation IR B • overloading the motion system B
		• emission of the welding smoke A	• fire, explosion A	
			• inclusions in the weld A • hot failures A • cold failures A • inadequate shape of weld A • damages of unwelded surfaces A	
	medium	• blow by the unmoving objects A • contact with sharp edge A • contact with rough surface A	• dustiness B • welding smoke B • toxic substances B • overloading the eyesight B	• contact with electrical energy C • contact with hot surfaces C
			• gas cavity in the weld B • lack of inter-run fusion B • inadequate joint penetration B	• deformation of welded element C

tegrated risk indicator method depends exclusively on the individual level of the process improvement. In the analyzed case it has been classified as acceptable. The acceptability of incompatibilities, according to the traditional method, has been indicated in the Table 6.

CONCLUSIONS

Up to now measurable and proved aims of the quality, environmental and occupational health and the safety policy in the welding procedures may be accomplished by application of the integrated method of technological processes' analyzes and opinion taking advantage of general algorithm of risk estimating connected with the presence of nonconformities in a wide meaning, which means: nonconformities, environmental impacts and effects of hazards to occupational health and protection.

The suggested integrated estimation method has been applied in the analysis of metal inert gas welding (MIG) and metal active gas welding (MAG) processes; risk indicator connected with the nonconformities appearance, peril of environmental impacts as well as risk of hazardous effects to occupational health and protection has been introduced into practice. One had qualified the risk connected with the nonconformities occurrence, environmental impacts as well as results of threat to occupational health and protection, and next the integrated risk coefficient for accomplished procedures has been calculated. At the same time regular method using matrix "significance of incompatibilities" and "probability of occurrence" to point out the acceptability of nonconformities, environmental influences and outcomes of occupational safety threats in the field of integrated system has been implemented into operation.

The hazard connected with the occurrence of environmental aspects and their impacts have been assessed as the ignoble ones. Unsuccessfully it has been pointed out that the risk connected with the appearance of occupational health and safety threats and their outcomes as well as hazard connected with the occurrence of nonconformities and their causes were comparatively significant and prominent.

Simultaneously the "integrated" incompatibilities have been presented as unaccepted due to the probabilities of their appearance or their importance, or both of them. Therefore the integrated unified estimation has specified both the most threatened component of integrated area and the factors being the most perilous for beneficial realization of the accomplished welding procedures.

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Note: The responsible translator for English language is Dominika Wnukowska, Katowice, Poland