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FACTORS INFLUENCING THE REQUIREMENTS FULFILMENT IN THE ZINC COATING PROCESSES

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The aim of the analysis was the assessment of the zinc coating process with application of the authorial methodology which allows in the highest degree to reflect the threats occurring in this process. Findings of the analysis are as follows: factors influencing the requirements fulfilment in the zinc coating process are not only the significance and the probability of occurrence of the incompatibilities and the possibility of process supervision, but also the influence of the technological parameters realization on ensuring the specific requirements and technical difficulty of parameters realization.

Key words: zinc, coating, quality, environmental protection, integrated requirements

INTRODUCTION

Organizations realizing processes of surface treatment of metals using chemical methods are mostly small and medium enterprises with limited technical resources [1]. The traditional technology of hot dip zinc coating includes chemical pretreatment of the steel surface and immersing the steel element in the molten zinc [2]. This kind of process creates not only a lot of defects [3], but it is also highly dangerous for the environment [4].

It means for those organizations the development of the realized processes, however, not only in the context of the particular products or in the sustainable meaning, but also with taking into consideration other criteria [5,6]. It results in the necessity of applying the new tools and methods facilitating the effective assessment.

Currently, for assessment of the technological processes and the technology are applying various quantity and quality methods, depending on the undertaken by the particular organization methodology [7].

So-far, however, rarely applied method, apart from its wide possibilities of application within the following scope: definition of issues, impact identification, effected environment description, impact prediction and impact assessment, is the risk assessment [8]. The mentioned method can be effectively applied within the integrated range of quality, environment and the occupational safety on the level of assessment of the processes' influences [9-10].

One should verify if the results obtained by applying such a risk assessment are sufficiently complex to be the base for taking up the decisions aiming at optimization of hot dip zinc coating processes.

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METHODOLOGY

In the analysed zinc coating processes the developed assessment methodology covers the identification of the process risk, its analysis and assessment. The method is based on defining the values of the integrated risk ratio (IRR). The mentioned ratio may be of the simplified character (IRR_1, IRR_2) or may take into consideration, in a complex way, all potential factors deciding on the level of the risk within the zinc coating process (IRR_3) – Figure 1.

The integrated assessment, taking into consideration potentially all factors having influence on the process (IRR_3) covers the following:

- influence of the technological parameters realization on the ensuring of the requirements by defining the significance of the technological parameters for effective realization of the integrated aims (S),
- technical difficulty of realizing the technological parameters of the process by appointing the difficulty ratio of realizing the technological parameters (D),
- risk of the integrated quality (QRR), environmental (ERR) and occupational incompatibilities (ORR) arising from both significance (PRS) and probability (PRO) of occurrence of the defects, environmental influences and the results of the occupational threats, and the possibility of the supervision over the realized process (PRC).

The influence of the technological parameters on ensuring the specific requirements has been defined by the ratio of the processes' parameters significance (S). It allows for defining the dependence between the requirements of the process and its parameters. The mentioned dependence for each of the technological parameters (Si) is defined by the sum of the product of the importance of

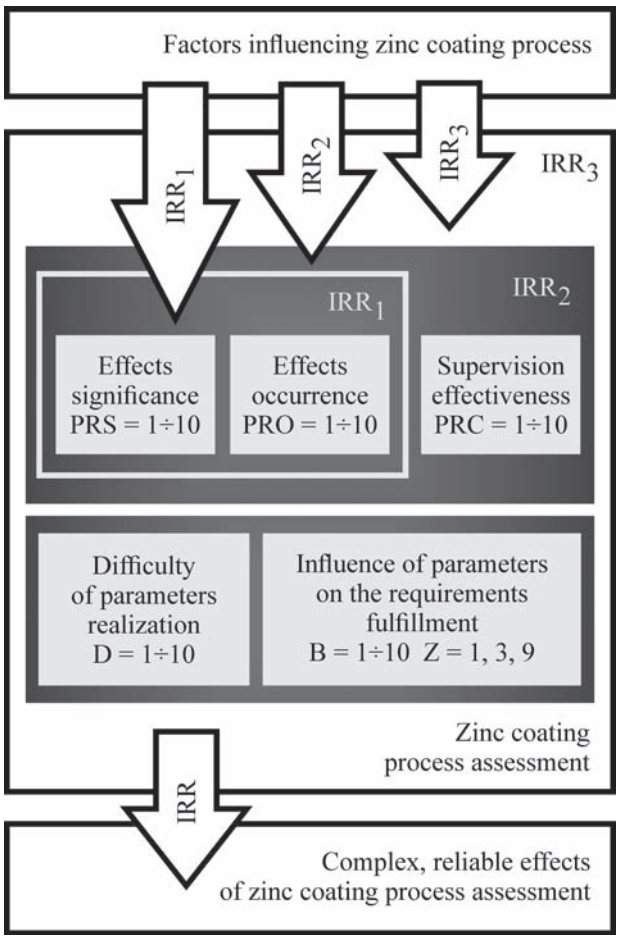

Figure 1 Scheme of zinc coating process assessment with consideration of different influencing factors

particular requirement within the range of: quality, environment and workplace safety (B) as well as their level of support (Z) with this technological parameter.

The level of support (Z) defines the force of influence of technological parameter realization on the fulfilment of the integrated requirements. It was described as: poor, medium or strong and one has assigned the following values: 1, 3 and 9. Defining the dependence represents the base for the assessment estimating in what level the realization of the particular technological parameter influences on obtaining the highest amount of the optimal features.

Representing the significance ratio in percent allows for defining the technological parameters having the highest influence on the complex of quality, environmental and occupational features.

Importance of the particular requirements (B) has been defined by the experts based on the 1 - 10 value scale.

The cumulative ratio of the technological processes significance (S) represents the sum of the unitary ratios of the importance concerning all of the technological parameters influencing on achieving the established aims.

The difficulty of performance has been characterized as the expert ratio of difficulty of realizing the technological parameters (D), which takes the values from 1 to 5. Realization of the technological parameter with the highest ratio value can be accompanied by the highest number of problems and the particular parameter requires a specific attention during the realization of the process.

While choosing the integrated risk ratio, one should keep in mind that the more factors influencing on the course of the process and deciding about the fulfilment of the requirements are considered in the risk ratio, the better the ratio reflects the real conditions of realizing the particular process, however, it requires from the organization definitely much more involvement in the estimation of ratio's value. To estimate the potential possibilities of applying each of the described factors of the integrated risk, one has prepared the scale of its assessment, which takes into consideration the following:

- factors influencing the requirements' fulfilment (F = 1 ÷ 3; where 3 means the broadest one),
- time-consumption and the involvement of experts into the assessment (C = 1 ÷ 3; where 3 means the smallest ones),
- feeling of the experts concerning the effectiveness (E = 1 ÷ 3; where 3 means the most effective ones).

Each of the elements (F, C, and E) was described by the quotient of sum of points assigned by the experts and amount of the experts participating the survey. The highest value of the sum (P) concerning the listed elements proves, due to the experts' opinion, the most functional assessment method.

ZINC COATING PROCESS – ASSESSMENT RESULTS

The subject of the analysis, with the application of the developed methodology of the process assessment, was process of the hot dip zinc coating of the steel elements. The process covered the following operations: etching in the hydrochloric acid solution, washing, fluxing with the zinc chloride and ammonium as well as glycerine, drying and hot dep immersing in zinc solution.

Acting in accordance with the prepared methodology, firstly, one has identified the potential threats in the process as well as their effects, and one has also calculated connected with them values of the risk ratio within the range of the following: quality, environment and safety. It has been proved that the improper technological parameters of preparing the surface and applying the layer as well as the insufficient fineness of the applied zinc all have been accompanied by occurring the non-homogenous layer which is susceptible to the corrosion (ΣQRR = 617). The mentioned process is accompanied by the occurrence of: the wastewater and the falls of the physic-chemical character being especially dangerous for the waters and soil, and significant amounts of the zinc-covered steel scrap as well as the emission refraining from heating and evaporation of the hydrochloric acid and zinc (ΣERR = 1 122). The threats of the workplace safety refrain from the contact

with the hot surfaces, microclimate, possibility of slip and fall as well as from the overload of the musculoskeletal system and stress (ΣORR = 767).

Next, one has calculated the indexes values of the difficulty of realization the technological parameters as well as the indexes of their importance. The way of dealing with the zinc coating technological parameters assessment is presented in the Table 1.

Table 1 **Matrix of calculating the significance and difficulty of the chosen technological parameters of the zinc coating process**

Technological parameters of the processes and fulfilment of the requirements / Requirements	Importance of requirement (B)	Technological parameters: Hydrochloric acid concentration	Time of lasting in acid solution	Temperature of acid solution	$FeCl_2$ concentration	Rinsing time	Temperature of rising water	$ZnCl_2$ concentration in the flux	NH_4Cl concentration in the flux
Clean surface	10	9	9	9	9	9	9		
Lack of post-etching residues	4				3	1	1	3	1
Dry surface of flux	6								
Planned strength properties	10	3	3	3	3	3	3	9	9
Lack of emission to air	10	9							
Significance ratio (S)		270	110	110	192	124	124	102	94
		10,8 %	4,4 %	4,4 %	7,7 %	4,9 %	4,9 %	4,1 %	3,7 %
Difficulty ratio (D)		1	3	1	5	1	1	3	3

Values of the integrated risk ratios with both: taking into consideration the element of assessment of the realization difficulty and the significance of the technological parameters as well as without them, in the process of hot dip zinc coating, one has compared in the Table 2.

Table 2 **Comparison of the integrated risk ratio values for its various variants in the zinc coating process**

Sort of the ratio	ΣDi	ΣSi	ΣQRR	ΣERR	ΣORR	IRR
IRR_3	2 612	46	617	1 122	767	753
IRR_2	-	-	617	1 122	767	2 506
IRR_1	-	-	242	319	151	712

The experts have been asked to submit the estimation of each of the ratios, in accordance with the prepared guidance. The effects have been compared in Table 3.

All of the experts agreed that the IRR_3 in a full way reflects the factors influencing on the requirements' fulfilment (F = 3) and is also the most effective (E = 3). Simultaneously, it requires the highest involvement in the assessment (C = 1), which, however, does not burden to describe it as the most functional in the process of assessment.

Table 3 **Comparison of the results of the expert analysis of the ratio variants in the zinc coating process**

Sort of the ratio	F	C	E	P
IRR_3	3	1	3	7
IRR_2	2	2	2	6
IRR_1	1	3	1	5

CONCLUSIONS

Application of the developed methodology in the analysed process of hot dip zinc coating has confirmed that it represents especially huge threat in the integrated scope. The defects being described by the highest values of the qualitative ratio were the following: non homogeneity, too slam thickness and cracking as well as the insufficient adherence of the zinc layer. The highest values of the environmental risk ratio concerned the following: controlled and uncontrolled contamination of the waters and soils with the after-pickling wastewater and the slop as well as the effects of using the energy. On the other hand, the most significant results of the safety threats turned out to be: thermal burns, fractures of the limbs, body contusions and the head injuries as well as the afflictions and injuries of the musculoskeletal system.

The technological parameters, which are of the greatest significance for fulfilment of the integrated requirements were the following: HCl and $FeCl_2$ concentration in the solution. And the most difficult technological processes in the realization were the following: $FeCl_2$ concentration, Fe content in the flux and the presence of the hard zinc. The pointed requirements as well as the technological parameters should be treated as the key ones and be taken into consideration in the operational control process.

The conducted analysis are also the confirmation that the complex tool for analysing and developing the hot dip zinc coating process, in the aspect of ensuring quality, minimizing the negative influence on the environment as well as limiting the threats of the work safety must cover the following: probability of occurrence, significance of the defects, environmental influences and the effects of the safety threats, as well as way of supervising the process together with difficulty of the realization and significance of the particular parameters of this process for fulfilling the requirements. The experts are of the opinion that, apart from the required time and involvement, taking into the consideration of all those factors is essential in assessment of hot dip zinc coating processes.

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