EVALUATION OF QUALITY OF TECHNOLOGICAL PROCESSES OF SURFACING OF PARTS OF RAILWAY ROLLING STOCK

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The factors influencing the quality of technological process of surfacing are considered. The results of analysis of the causes leading to appearance of defects and deviations from the required mechanical properties are presented. It is shown that one of the most important factors influencing the reliability of technological process of surfacing is its electrical mode, parameters of which depend not only on those established by surfacing operator, but also on the quality of supplied power. Influence of mode parameters on reliability of the process of multilayer surfacing is considered.

Keywords: *arc surfacing, parts of rail transport, quality of surfacing, reliability of technological process of surfacing, restoration*

The improvement in quality of technological processes of manufacture of different parts is actual and important problem for all spheres of industry. The deviations from the preset parameters of technological process beyond the admissible limits result in rejection of a part. This problem is especially urgent in repair production where it is not always possible to provide high quality of restored parts due to its complicated specifics.

The repair production includes a number of technologies, one of which is direct process of parts restoration. Nowadays surfacing technology is one of the most challenging technologies in restoration.

A great deal of works was devoted to investigation of surfacing processes, many of which concern the analysis of reasons for defects occurrence and give recommendations for their elimination [1–7]. However, in our opinion, no sufficient attention is paid to evaluation of influence of different components of technological process of surfacing on quality of part being surfaced as a whole.

The purpose of this work is evaluation of influence of separate stages of technological process of surfacing on quality of railway rolling stock parts being surfaced.

The optimal technological process of surfacing should provide the preset properties and quality of deposited layers, the defects in them should not exceed the limits restricted by regulation documents. The main factors influencing these characteristics of surfacing process (Figure 1) are quality of preliminary preparation of surfacing materials and surfaces of parts to be deposited; chemical composition of base and deposited metals; their weldability, physical-chemical properties and structure and also their changes during surfacing; surfacing modes; preliminary heating and heat treatment after surfacing; finishing treatment of as-surfaced parts.

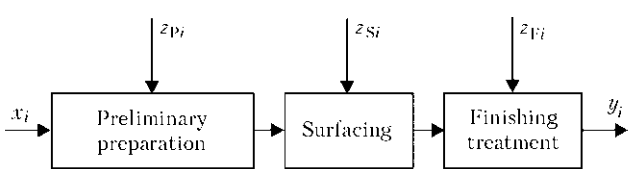

Figure 1. Structural scheme of surfacing process (x_i, y_i — input and output factors, respectively; z_{Pi}, z_{Si}, z_{Fi} — factors of preliminary preparation, surfacing and finishing treatment)

Let us consider the characteristics defining quality of surfaced parts more in detail. Hardness, wear resistance and fatigue strength are of special interest. The mentioned characteristics are selected, basing on the following considerations: mainly wear resistance and fatigue strength define service life of parts, and hardness is related to other mechanical properties and is very easily defined under industrial conditions. During optimal selection of surfacing materials these characteristics should meet the requirements of technical documentation. Otherwise they immediately pass to the category of inadmissible ones.

In accordance with GOST 30242–97 the defects of welding are divided into the following groups: cracks, pores (cavities), lacks of fusion and lacks of penetration, hard inclusions, violations of weld shape, etc.

It is a complicated task to obtain the perfect deposited layer without defects, however, it is necessary to minimize a number and sizes of defects, and also distinguish the admissible defects. As practice shows, in many cases defects arise due to deviations from the preset conditions of surfacing process. To determine the quality of surfacing process, let us systemize the reasons causing above-mentioned defects. According to [1–6] the main reasons, leading to defects in surfacing, are low-quality preparation of materials and surface of the part to be restored; incorrectly matched combinations of materials; violation of surfacing technology; improperly selected surfacing conditions.

The mentioned reasons of defects arising are mainly connected with skills and experience of designers, technologists and surfacing operators.

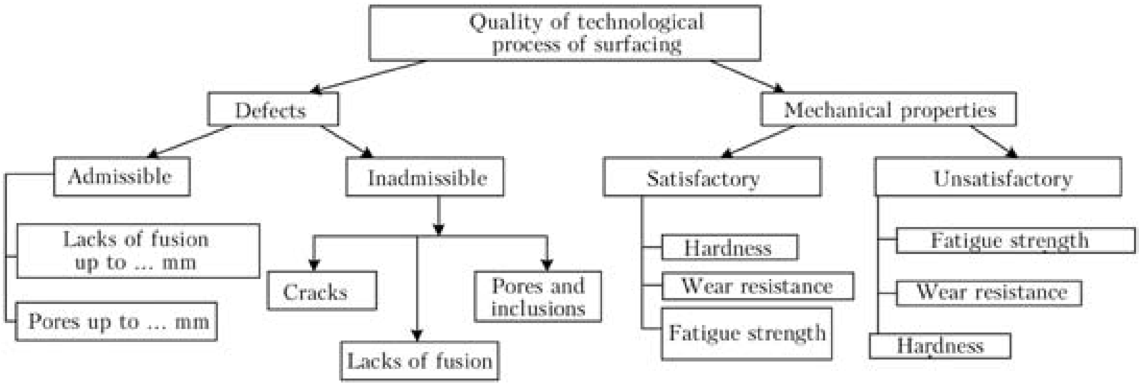

Figure 2. Structural scheme of evaluation of quality and reliability of technological process of surfacing

The electric conditions of surfacing have determinant influence on structure and properties of deposited layer and also defects occurrence. In the structural scheme, presented in Figure 2, no sizes of defects are mentioned in their admissible block, as far as they depend on conditions of service of the definite part and are specified in corresponding technical documentation. The basic reasons in the generalized form, leading to inadmissible defects, are formulated as follows: «unsatisfactory preparation of part surface», including characteristics of quality of cleaning and mechanical treatment during preparation of part surface for surfacing; «unsatisfactory preliminary heating before surfacing», i.e. insufficient or lack of heating of a part when such operation is required; «deviation from rational conditions of part surfacing», i.e. violation of conditions as to voltage, current and surfacing speed, reliability of supply of flux or shielding gases, keeping of surfacing run, electrode stickout, and also its shifting from zenith (the latter is observed in automatic surfacing of cylindrical parts).

In compliance with presented structural scheme of evaluation of quality of technological process of surfacing (Figure 2) and selected system of corresponding characteristics, the acquisition of data on quality of parts, deposited at the electric locomotive repair plant, locomotive depots with the volume of regular repair RR3 and car shops during one year was carried out. The parts of automatic coupler equipment, pivot unit of cargo cars, hinged units, cylindrical parts of the type «shaft» of braking linkage, leaf-spring suspension, etc. were subjected to analysis. In the volume of these observations the database for the further statistic analysis was created.

Mathematically, let us describe the object under investigation by the set of characteristics $\Omega = \{x_1, x_2, \ldots, x_N\}$, representing their information as a matrix of experimental values X:

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1N} \\ x_{21} & x_{22} & \ldots & x_{2N} \\ \ldots & \ldots & \ldots & \ldots \\ x_{M1} & x_{M2} & \ldots & x_{MN} \end{bmatrix},$$

where M is the number of lines corresponding to number of observations for the definite period of time; N is the number of columns corresponding to the number of characteristics; x_{ij} is the value of j-characteristic in the i-th observation (further we assume that $M > N$).

Let us study the basic moments of initial data analysis as far as this stage of modeling considerably influences further accuracy of quality evaluation of technological process.

In the processing of experimental data the certain difficulties were encountered, predetermined by different dimensions of selected characteristics, absence of some data, presence of suspicious values of characteristics being observed. The significant stage of analysis is verification of data for presence of «splashes» with their further processing. The censoring of data (elimination of splashes effect) is performed using either removal of these points from data, or application of methods of evaluation of parameters, sustainable to rough deviations (for example, method of the least modules).

Distribution of causes of occurrence of defects and deviations in mechanical properties in semi-automatic surfacing with flux-cored wire in CO_2

Causes of occurrence of defects and deviations in mechanical properties	Share, %	Variation factor, %
1. Unsatisfactory preparation of surfacing material and part to be surfaced	32	23
2. Unsatisfactory preheating or its absence	6	8
3. Deviation from conditions of cooling or heat treatment after surfacing	5	15
4. Deviation from rational conditions of surfacing	31	19
5. Non-quality cleaning from slag in multilayer surfacing	8	10
6. Deviation from rational conditions of finishing treatment of as-surfaced part	18	18

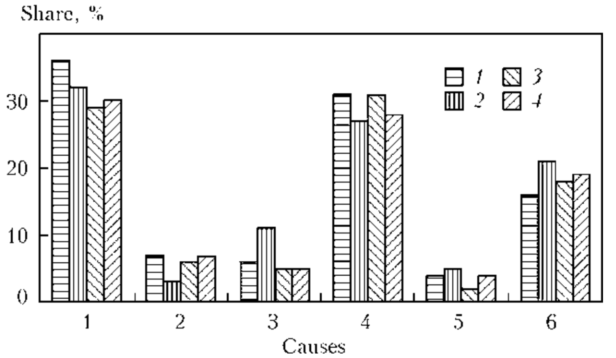

Figure 3. Distribution of causes (1–6 acc. to the Table) of occurrence of defects and deviations in mechanical properties depending on method of surfacing: *1* — semi-automatic surfacing in CO_2; *2* — automatic submerged arc surfacing; *3* — semi-automatic surfacing with flux-cored wires; *4* — manual arc surfacing

In capacity of censoring procedures, the following ones are used [8]:

• visualization of data, when regularities completely non obvious among many values, are established using graphic representation of information;

• analysis of some numerical characteristics of values being investigated. For example, presence of splashes can be evidenced from comparison of such values as a mean value and mode, if these characteristics are significantly different for the selected indication (as far as it is known that the mean selected value is sensitive to splashes, and modal value of the investigated indication is characterized by the property of robustness);

• rule of «3σ», if the hypotheses about normal distribution of values x_i are confirmed, is

$$P\{\varepsilon_i < 3\sigma_i\} = 0.9973,$$

where $\varepsilon_i = x_i - \overline{x}_i$; $\overline{x}_i$ is the mean selected x_i.

It is obvious that the simplest method of data censoring is visualization, however at large amount of data, like in our case, it is impossible to apply it. The procedure of censoring with application of normal law is also low-efficient, as it requires unjustified time losses, moreover, the considered characteristics can have another law of distribution. Therefore, among mentioned procedures of splashes elimination the most acceptable was that, connected with analysis of numerical data and comparison of the mean selected value with the mode for each characteristic of quality.

After fulfillment of the above-mentioned procedures we obtain distribution of causes of arising defects and deviations of mechanical properties from the expected ones. The Table gives distribution of causes of defects occurrence in semi-automatic surfacing using flux-cored wire in CO_2, and Figure 3 shows the same during main methods of arc surfacing.

As was expected, the statistic analysis confirmed that the most stable and high quality of restored parts is provided by automatic submerged arc surfacing. The worst characteristics on probability of arising defects of different type refer to manual arc surfacing with rod electrodes. The intermediate position is occupied by semi-automatic surfacing in shielding gases and open-arc surfacing with self-shielding flux-cored wires.

For all methods of surfacing the most significant characteristics influencing its quality are preliminary preparation of parts to be surfaced and surfacing materials, and also conditions of surfacing.

Influence of these factors is almost equal. Very significant is also influence of machining of surfaced parts on quality. It can be possibly connected with the fact that mechanical treatment of deposited surfaces is performed often in depot using manual grinding tool.

For all methods of arc surfacing, used in railway repair manufacturing, the mentioned causes of defects occurrence are dominating, though they have some different fractions of effect. Thus, to increase the quality and reliability of the surfacing process, they themselves should be subjected to the primary study and elimination.

CONCLUSIONS

1. The statistic analysis shows that automatic surfacing guarantees the higher quality characteristics of repaired parts then semi-automatic shielded-gas surfacing and open-arc surfacing with self-shielding wires, whereas lower characteristics are provided by manual surfacing with rod electrodes.

2. The ranging of causes, leading to the occurrence of defects and deterioration of quality of surfaced part, shows that the effect of non-quality preparation of parts to surfacing and surfacing materials, as well as deviations from surfacing conditions have the most essential effect on these characteristics.

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