The influence of galvanic coatings as a chemical pretreatment of the surface on the microgeometry of steel materials

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Abstract: *In the contribution, the surface quality of the steel substrate is analyzed from the point of view of its microgeometry as a set of quantities capturing the differences of individual surface changes. The subject of investigation are the surfaces of steel substrates, i.e. the base material, degreased surface, standard galvanized surface, surface after galvanizing and subsequent chromating, surface after phosphating and surface after phosphating and application of RAL coating.*
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1. Introduction

The development of other technologies, such as mechanical pre-treatment of the surface, degreasing and other preparatory operations as well as intermediate and finishing operations - rinsing, chromating, phosphating and others - is closely related to the development of electroplating. [1 - 5]

It is generally known that even with the best and most effective coating system, it is not possible to achieve satisfactory results (adhesion, durability, etc.) if this protective coating is not applied to a suitably pre-treated and cleaned surface. The surface layer is decisive in terms of the strength of the entire component under cyclic stress. From a physical point of view, the properties on the surface are significantly different from those in the volume - this transition is smooth, the properties do not change abruptly. The significance of the change is conditioned by the chemical composition, relief and structure of the material. Technological and functional conditions of material processing significantly affect the physical and chemical properties of the metal surface. [6 - 9]

From the point of view of the component's function, in many cases the geometric properties of the surface are very important (e.g. in conditions of friction and wear). Therefore, it is necessary to place sufficient emphasis on the assessment of the geometry of the surfaces and the determination of deviations of the profile from the defined plane.

Among the whole range of surface properties, its microgeometry plays a very important role. In order to assess the microgeometric condition of the surface, a surface evaluation and measurement system is built. [10 - 15]

Measurement with touch profilometers is one of the most sophisticated methods of assessing surface roughness with a larger range of measured characteristics, which can be used in laboratory as well as operational conditions. The basic source of information is the surface profile.

Quantities standardized in STN EN ISO 21920 are used to assess the surface structure. The surface structure is characterized by the following geometric parameters in the mentioned standard:

- P parameter – parameter calculated from the primary profile,
- R parameter - parameter calculated from the roughness profile,
- W parameter - parameter calculated from the waviness profile.

The basic source of information is the surface profile, which is created by cutting the real surface with a defined area.

Primary profile (P – profile) – a profile that results from a section of the measured surface by a plane that is perpendicular to this surface. It represents the basis for the numerical processing of the profile using profile filters and for the calculation of profile parameters.

Roughness profile (R – profile) – a profile that is derived from a primary profile by suppressing long wavelength components with a profile filter. It is the basis for determining the parameters of the roughness profile.

Wave profile (W – profile) - a profile that is derived from the primary profile using profile filters. It is the basis for determining the waviness parameters of the profile.

The calculation system for evaluating the parameters of the surface profile, which is used in the mentioned EN ISO, is based on the system of the middle line of the profile of roughness, waviness and the middle line of the primary profile.

From the point of view of worldwide technical practice, the most widespread evaluation parameter of roughness is the mean arithmetic deviation of the considered profile Ra - an integral quantity that is often confused with the general term roughness. It should be noted here that this parameter has only informative value. It does not allow the resolution of sharpness or roundness of protrusions of profile irregularities, is significantly distorted by cracks and other random surface defects. Therefore, when evaluating the microgeometry of various types of surfaces, it is necessary to use a selected set of roughness parameters from the ISO 21920 standard, which will sufficiently accurately capture the specifics of the assessed surface.

2. Materials and methods

2.1 Basic material

Unalloyed structural steel of usual quality S235JR was used as the basic material. It is used for fusion-welded, statically and dynamically stressed parts of constructions and machines of medium thickness. Furthermore, for components made from sheet metal, longitudinally welded hollow profiles and forged components for thermal power equipment and pressure vessels operating with limited excess pressure and temperature up to 300°C.

The chemical composition of the materials is in Table 1.

Table 1. *Chemical composition of used steel SľšťJR*

Material	C	P	S	N
S235JR	0,17%	0,045%	0,045%	0,009%

2.2 Pre-treatment of the surface

The surface of the test samples of S235JR steels was without any surface treatments. The tested samples of both materials were classified into following categories:

1. Surfaces without further treatment – a steel sample is used for testing in the state in which it was delivered from the manufacturer (designation: Sample no. 1).

2. Surface after degreasing - used bath AKTIGAL FB 5-6%, immersion at temperature 65^{o}C, pH11, immersion time 5min. (designation: Sample no. 2).
3. The surface is galvanized - after degreasing, the sample was immersed in the HELIOSTAR zinc bath of the company ENTONE OMI at a temperature of 18^{o}C, pH 4.9, immersion time 20 min. (designation: Sample no. 3).
4. Surface galvanized and chromated - after degreasing, the sample was immersed in a zinc bath and subsequently chromated in an IMMUNOX 3K bath from ENTONE OMI at a temperature of 18^{o}C, pH 2, immersion time 35 min. (designation: Sample no. 4).
5. After degreasing, the surface was phosphated in a DURIDIN 3822 IT bath from the HENKEL company at a temperature of 40^{o}C, pH 5.8, by spraying for 3 min. (designation: Sample no. 5).
6. A RAL 9016.5020/0661 coating was electrostatically applied to the surface after degreasing and phosphating with a NORDSON type gun, 65 kV (designation: Sample no. 6).

2.3 Roughness measurement methodology

Surface roughness of the produced samples was evaluated according to ISO 21920 by the contact method using a stylus profilometer Surftest SJ-201, Mitutoyo, Tokyo, Japan. This standard defines roughness parameters based on the deviation from the mean line for the primary profile. The measurement parameters used were as follows:

- a measured profile: R, filter: GAUSS, a sampling length λc = 0,8 mm, a number of sampling lengths N = 5,
- an evaluation length ln = 4 mm,

In order to obtain as much information as possible about the produced surfaces in individual positions, the surface roughness was evaluated using a set of several parameters:

- the arithmetical mean deviation of the assessed profile (Ra),
- the maximum height of profile on the basic length (Rz),
- the total height parameter (Rt),
- the mean width of the profile element on the length (RSm),
- the mean number of peaks per centimeter (RPc),

3. Results

By measuring the selected roughness parameters on the basic and pre-treatment material, the values shown in Table 2 were achieved. For surface samples no. 5 and 6, it was not possible to measure the RPc and RSm values, as they did not show the necessary number of protrusions for evaluation.

***Table 2**. The mean of roughness parameters*

Sample	Measured values of roughness parameters				
	Ra [µm]	Rz [µm]	Rt [µm]	RPc [-/mm]	RSm [µm]
1	0,96	5,17	6,22	148,1	67,75
2	0,79	4,81	6,09	197,8	52,06
3	0,79	4,42	5,47	186,2	54,53
4	0,67	4,13	5,52	221,0	45,70
5	0,83	4,63	5,64	153,2	66,03
6	0,13	2,29	3,62	-	-

Profilograms and Abbott Firestone curves of individual surfaces were also realized Fig. 1a-1f where we recorded a change in the surface roughness of the tested materials.

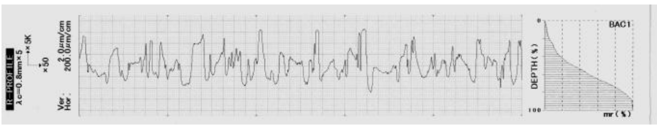

***Fig. 1a** Profilogram and Abbott Firestone curve for the sample no. 1*

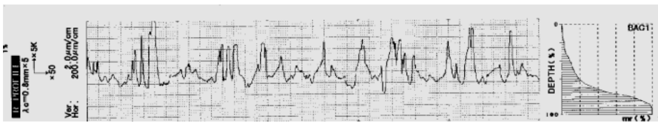

***Fig. 1b** Profilogram and Abbott Firestone curve for the sample no. 2*

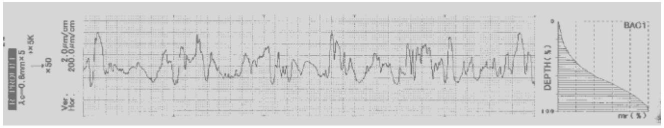

***Fig. 1c** Profilogram and Abbott Firestone curve for the sample no. 3*

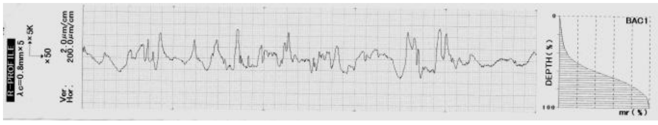

***Fig. 1d** Profilogram and Abbott Firestone curve for the sample no. 4*

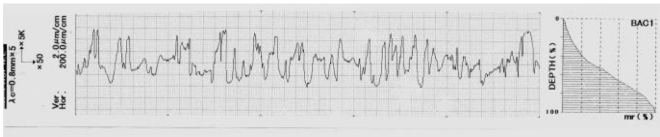

***Fig. 1e** Profilogram and Abbott Firestone curve for the sample no. 5*

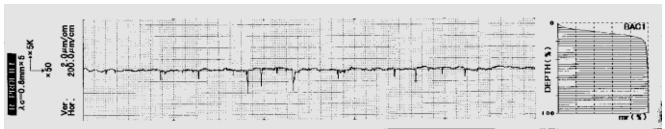

***Fig. 1f** Profilogram and Abbott Firestone curve for the sample no. 6*

By comparing the measured values with each other, it can be concluded that the surface morphology in the process of pretreatment and subsequent surface treatment by galvanization remains basically the same. This fact is also confirmed by the profilograms of the surfaces shown in Fig. 1, which document the relief of the degreased surface and the surface after degreasing and subsequent galvanizing.

From a quantitative point of view, it can be stated that after galvanizing, or after galvanizing and chromating, there is a very slight decrease in the roughness characteristics, evaluating the surface in the vertical direction, Fig. 2a-2e, while at the same time the number of profile protrusions per unit length RPc increases slightly, which logically results from a slight decrease in the spacing of protrusions RSm. This phenomenon occurs due to the in-house technology of surface formation by galvanization. This fact was most evident in surfaces after galvanizing and subsequent chromating.

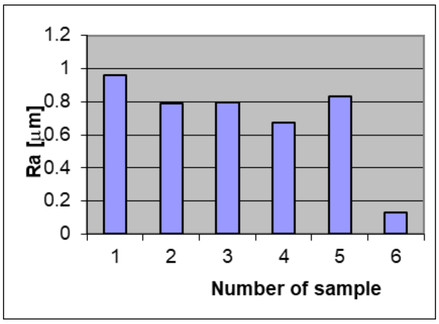

Fig. 2a *Graph of measured Ra values*

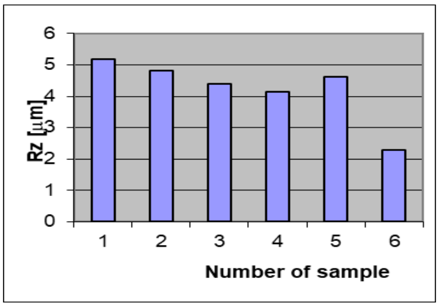

Fig. 2b *Graph of measured Rz values*

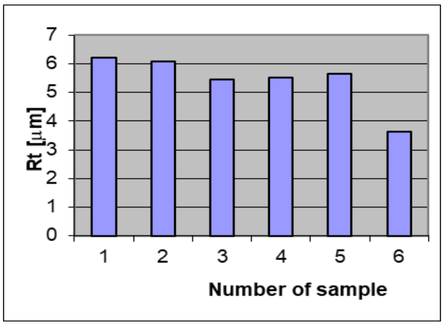

Fig. 2c *Graph of measured Rt values*

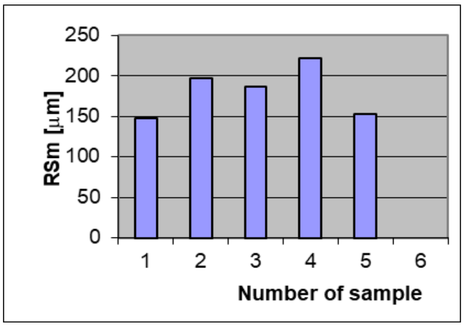

Fig. 2d *Graph of measured RSm values*

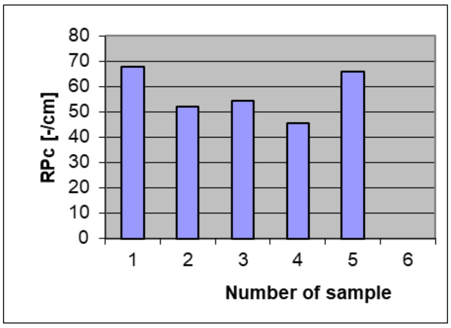

Fig. 2e *Graph of measured RPc values*

Due to the complexity of the assessment, a plastic surface (RAL) was also included in the evaluation, which was applied to the surface after degreasing and subsequent phosphating. The production technology as well as the hardening nature of the plastic material used ensured the creation of an almost smooth surface with a roughness Ra of approximately 0,13 µm, while the maximum height of irregularities on the evaluated relief Rz was 2,29 µm. From the point of view of the thickness of the applied coating, which was greater than 50 µm, it is clear that the original surface relief could not be copied.

4. Conclusions

Based on the experimental measurements, it can be concluded that:

- the morphology of the surface in the process of pre-treatment and subsequent surface treatment by galvanization remains basically the same,

- after galvanizing, or after galvanizing and chromating, there is a very slight decrease in the roughness characteristics, evaluating the surface in the vertical direction. This fact was most evident in surfaces after galvanizing and subsequent chromating,

- the production technology as well as the curing nature of the RAL coating ensured the creation of an almost smooth surface, and since the thickness of the applied coating was 50 µm, there was no copying of the original surface relief.

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