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INFLUENCE OF PREVIOUS MACHINING ON CHARACTERISTICS OF GALVANIC COATINGS

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Abstract: *Galvanic coatings are applied to the base material surface in order to obtain some of the following characteristics: resistance to corrosion, chemical inertness, wear resistance, higher dimensions, lower coefficient of friction and a better aesthetic impression. Most studies of protective metal coatings focuses on the characterization of coatings and their links to the basic material, while very little is known about the effects of substrate on the characteristics of the coating. Surface finish has a great influence on determination of the physical and mechanical properties and structure of the surface layer. This paper presents the preliminary results of the surface topography changes depending on the thickness of Zn and Cr layer. The research was performed with samples of different hardness and different previous grinding.*

Keywords: *galvanic coatings, hardness, roughness, Zn coating, Cr coating*

1. INTRODUCTION

Creating metal coatings on the surface of another metal has a dual role, corrosion protection and changing characteristics of the metal surface, such as hardness, electrical conductivity, decoration and so on. Galvanic metal coatings have certain advantages over other coatings. They are resistant to mechanical damage, have good electrical and thermal conductivity and enable the connection of metal soldered together. But when the metal coatings are damaged, they can not simply be fixed, that makes them different from the organic coating.

The most important metal coatings, in terms of quantity in which they are applied, are the coatings of copper, nickel, zinc, chromium and tin. Coatings of precious metals (silver, cadmium, gold, rhodium, iridium, platinum and palladium) are used to a lesser extent but are important for special purposes.

Most studies in the field of galvanic coatings are focused on the characterization of coatings and their link with the basic material. The effect of processing procedure and conditions of pre-treatment and preparation of surfaces to which coatings are applied, technological heritage, is very little explored. Surface layers of machined surfaces obtained by different treatment processes and regimes may have a different structure, which only in the period of exploitation may be experienced. Therefore, it can be said that the characteristics of surface layers are formed as a result of different processing conditions in the technological chain of production of the finished part. The basic parameters that are inherited through the process of technological development can be divided into two groups. On the one hand there are parameters related to properties of materials: their composition, structure, stress state, etc.., while on the other hand are parameters related to macro and micro geometry of the surface (geometrical parameters). This indicates the complexity of the problem and the need for further studies.

Surface finish has a great influence on determining the physical - mechanical properties and structure of the surface layer. In this paper is investigation of the influence of the previous surface treatment and coating thickness on the changes of parameters of topography, in particular coating of chromium and zinc because they are most applicable to areas that are exposed to exploitation in extreme operating conditions, corrosive environment or high pressure and temperature.

2. GALVANIC COATING

Galvanic plating and metals are crystalline in nature. Therefore, the electrodeposition process is called crystallization. In the crystallization process - there are three independent processes:

1) formation of seeds (centers) or crystal nuclei,
2) crystal growth rate,
3) increase the speed of crystals on account of their merger.

These processes run in parallel. The creation and quality of metal coatings are influenced by many factors:

- concentration of metal ions,
- electrolyte composition,
- current density,
- mixing of the electrolyte,
- temperature of the electrolyte,
- state of the cathode surface, etc.

The concentration of ions significantly affects the quality of the coating, the composition of the electrolyte affect the properties and appearance of the coatings. Current density has a large impact on the formation rate of crystal nuclei, mixing is performed to maintain constant concentration of metal ions, the temperature plays a significant role in the speed of chemical reactions. Metals are polycrystalline particles, so the characteristics of the coating are affected by the structure of the substrate.

Electroplated coatings of zinc and chromium are most often changed, so in this work the attention is given to these coatings.

Zinc coatings are used for corrosion protection of machinery parts, steel plates, wire, etc.. located in different climate conditions, in closed environments with moderate humidity, at the polluted gases areas, flue gases area and in atmosphere containing sulfur vapor. These coatings are used to protect pipes, tanks and other parts, which are in contact with water at temperatures up to 70oC. Color of zinc coating is usually light gray, become dark during time, and therefore does not provide a decorative look. Zinc also protects the iron from corrosion when the coating is porous or damaged, because it forms a couple in which the iron is cathodically protected [3, 4].

Zinc belongs to the metals whose normal potential is more negative than the potential of iron, so zinc coating protects the iron not only mechanically but also electrochemically. The protective effect of the coating is interrupted only when the entire zinc layer is disrupted. Life of the protective effect of the coating depends on its thickness. For metal objects, which are used in relatively dry air in closed rooms, sufficient thickness of zinc coating of 10-15 μm. For items that are outside the room, in the air that is polluted by industrial gases, the thickness increases to 20 - 25 microns, and for articles intended for use in industrial environments, in terms of enhanced effects of moisture, sea water or water vapor, the thickness of zinc coating moving to 50 μm. Coating is more resistant if the zinc cleaner [1, 2, 3].

The hardness of metal coatings of zinc is 45 to 120 HB.

The thickness of coatings on parts of the weapon depends on the working conditions in which the part is used and usually is 5, 8, 12 to 25 microns, [SORS 2325]. Galvanic corrosion resistance of zinc coating can be improved by after-treatment - the application of phosphate or various types of chromate coatings: colorless – A, bluish – B, yellow - C, olives – D, and black - F coating. Chromate conversion coatings should not be applied to surfaces of elements that are in contact with flammable and explosive environments, [5, 6].

Requirements for quality zinc coatings are contained in the applicable standards and the most important are [5, 6, 7]:

The external appearance of galvanized zinc coating is defined by color that can be:

- Light-gray or silvery-white with blue gradient, shiny or matte,
- Silvery-gray or silvery-gray with blue or light-yellow hues,
- With olive olive of brown-green to dark green,
- With dark brown to black with green or blue-purple hue,
- With phosphate conversion coatings light-gray to dark gray.

Allowable defects of zinc coatings without post-processing are darker color of the coating on the inside surface elements, the presence of shiny and matte places on the same element, the absence of coating in blind holes, channels, and the like. at a depth of more than one diameter and in the openings that pass through the entire element at a depth greater than two diameters, slightly peeling in places of weld for molded parts, color change of coating after heating wit aim to the remove of hydrogen and the existence of traces of the inflow of water.

Unacceptable defects coatings without the occurrence of subsequent processing and dendrites and spongy coating, dark stripes on the edges of elements, (burned sites), uncovered places, except for points given to technical documentation, bubbles, layer removal and peeling of coating, appearance of grains and hard spots that interfere with the function of element, the black points and corrosion of zinc, traces of unwashed salts existence and mechanical damages of the coating.

The thickness of zinc coating is usually: 5, 8, 12 and 25 microns. Depending on the needs designer may define other values of thickness, allowing a greater thickness than the prescribed, if at the same time increasing the dimensions of the element does not affect its function. Smaller thickness of zinc coating is allowed on the inside surface, in holes and hollows, where the thickness of the coating must not be less than 60% of the prescribed level.

Adhesion. Galvanic zinc coatings shall not peel off of base metal and chromic or phosphate conversion coatings must not wash off from the zinc coating.

Corrosion resistance. Galvanic zinc coatings on steel must be corrosion resistant. When examining the chamber with a neutral salt fog 5% zinc coating without subsequent processing, does not allow the occurrence of red-brown dots (representing the corrosion of the base material) visible with the naked eye.

Chromium coatings in addition to zinc coatings are applied widely for galvanic coating of steel and its alloys [3].

Chromium is a very durable metal to various chemical agents. Soluble in hydrochloric and hot sulfuric acid. Unlike the nickel and silver, retains its color and shine. Change of the color of chromium occurs at temperatures above 500^{o}C.

Chromium coatings without a layer of copper and nickel under are used to increase surface hardness and resistance to mechanical wear of metals, to achieve the dimensions of parts, as well as anti-corrosive protection of wearing parts. Chromic coatings are commonly used in combination with a coating of nickel.

Chromic coatings with under layer of copper and nickel are used for protective-decorative coating and to increase the power of reflection of surface parts.

Electrolytic obtained chromium plating have specular gloss silver-steel color with bluish tint. Electrolytic chromium is possible to apply to almost all metals. Application of other metal parts on chromium parts can not be achieved, due to a high tendency towards passivity of chromium even in the air. Therefore, the potential of chromium plating in all known cases of is mere electrically positive than steel, so for iron and its alloys chromic coatings are only mechanical protectors.

Chromic coatings are void, even in thick areas, so plating for corrosion protection is done after the application of the under coatings on object surface of other metals, for example copper or nickel. Then the chromium layer protects only layer below it against mechanical damage and preserves the look of decorative items. The process of obtaining combined protective - decorative coatings, when the outer layer is of chromium, is called decorative chromium plating. It is widely used in protecting the outside of cars, measuring equipment and others. The thickness of the layer of chromium in this case does not exceed 1 μm, i.e. from 0.2 to 1.0 μm. To obtain a hard surface, often regenerated surfaces thickness range from 0.2 - 0.5 mm or more. Hard chromium coatings have potential in production of various tools, machine parts and printing rollers.

3. EXPERIMENTAL INVESTIGATIONS

The quality of metal coatings is major affected by the surface condition that it is applied to. Realized experiments in this paper had aim to determine the impact of previous treatment on the change of surface topography parameters of the deposition of electrolytic coatings of zinc and chromium.

For the purpose of testing the samples were made 15 x 6.3 x 10 mm (Figure 1). On samples from the front side were embedded serial numbers of the sample, and through lateral surfaces were drilled openings designed to mounting each sample individually for coating.

Samples are made of spring steel 67SiCr5 (Č4230). After the sample design, milling, heat treatment was done by improving the different hardness (Table 3).

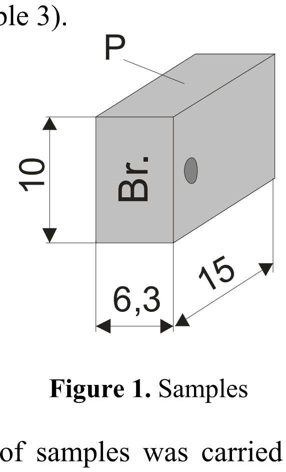


Figure 1. Samples

Grinding of samples was carried out with two regimes, A and B. Grinding of samples labeled A was performed with two passes with 0.02 mm depth and speed of 11 m/s and two passes with 0.01 mm and the speed of 22 m/s, and grinding of samples B was performed with two passes of depth 0.02 mm and speed 22 m/s. In this way they obtained different characteristics of the surface layer and the surface topography of various samples. Application of metal coatings was performed at the facility for electroplating factory "Zastava Arms", Kragujevac in production conditions, with different times in order to obtain different thicknesses of Zn (Table 1) and Cr (Table 2).

Zinc coating was carried out as follows:

I. alkaline degreasing without cyanides with industrial detergent,
II. rinse with water,
III. pickling in diluted hydrochloric acid in a 1:1 ratio,
IV. rinse with water,
V. electro-chemical coating of zinc,
VI. enlightening in 2% HNO3 for a period of 50 seconds,
VII. rinse with water,
VIII.blowing.
IX. temperature coating-room
X. strength of current I = 3 A/dm^2

Table 1. Terms of Zn application

Sample number	Thickness Zn, µm	Time, min	Power A/dm^2
2, 4, 11	< 6	8	3
10, 31, 34	6 - 10	16	3
5, 8, 13, 16, 22	10 - 15	25	3
6, 9, 17	>15	35	3

Chromium coatings are applied in the following way:

I. alkaline degreasing without cyanides with industrial detergent
II. rinse with water,
III. electro-chemical application of hard coating of chromium,
IV. enlightening in 2% HNO3 for a period of 50 seconds
V. rinse with water,
VI. coating temperature T = 55^{o}C
VII. strength of current I = 50 A/dm^2

Table 2. Terms of Cr application

Sample number	Thickness Cr, µm	Time, min	Power A/dm^2
15, 20, 25, 33, 24, 35	< 12	20	50
7, 18, 26, 28, 32, 36, 29, 37	> 12	30	50

Table 3 shows the data on the tested samples: marking of grinding, the hardness after heat treatment and obtained layer of Zn and Cr.

Coating thickness measurement was performed in a laboratory galvanizing area of factory "Zastava Arms" in Kragujevac. Samples with coatings of Zn in which the thickness were up to 4 µm were not further analyzed because it is the recommendation of the standard not to apply such thin zinc coatings.

Table 3. Hardness and thickness of Zn and Cr samples

Sample number	Grinding	Type coating	Hardness samples, HRC	Thickness µm
2	A	Zn	47,6	2
5	A	Zn	46,5	12
6	A	Zn	33	16
8	A	Zn	19,1	12
9	A	Zn	35,4	15
22	A	Zn	20,0	10
4	B	Zn	35,5	4
10	B	Zn	35,9	9
11	B	Zn	48,3	2
13	B	Zn	45,8	14
16	B	Zn	36,9	12.7
17	B	Zn	21,7	20
31	B	Zn	24,2	6.5
34	B	Zn	21,1	6
7	A	Cr	46,5	13.21
15	A	Cr	51,5	8.25
26	A	Cr	47,1	12,20
29	A	Cr	37,1	15.63
35	A	Cr	24,4	11.17
36	A	Cr	24,6	12.97
37	A	Cr	22,1	14.87
18	B	Cr	48,1	12.60
20	B	Cr	47,8	7.87
24	B	Cr	24,7	9.27
25	B	Cr	24,6	7.10
28	B	Cr	32,1	13.59
32	B	Cr	51,4	12.07
33	B	Cr	19,3	7.75

After grinding the samples, before applying the coatings, were measured hardness and surface topography parameters and the longitudinal and transverse direction. Measurements were taken at the surface of the sample P (Fig. 1). The appearance of ground surface of one of the samples before applying the coating is shown in figure 2. The value of the basic parameters of roughness in the longitudinal and transverse direction is approximately the same. Significant differences were observed in additional parameters, for example, uneven steps. Ra value ranges from 0.26 to 0.4 µm.

Realized tests were not possible to determine the dependence of the thickness of coatings of Zn and Cr from the previous grinding and the hardness of the samples. in order to establish the possible persistence of these depending on need extensive testing.

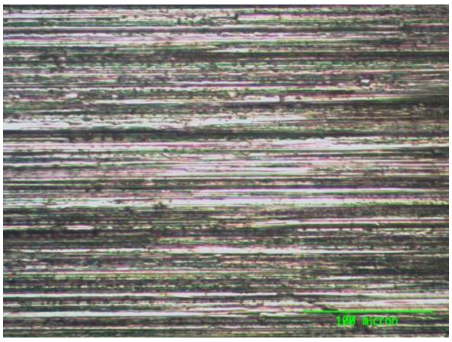
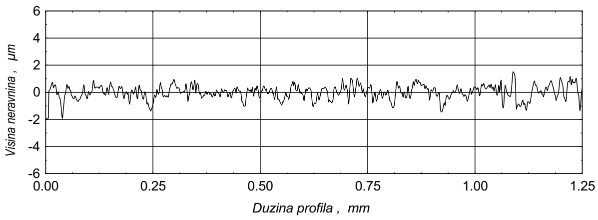


Figure 2. The appearance of ground surface of the sample before application of coatings

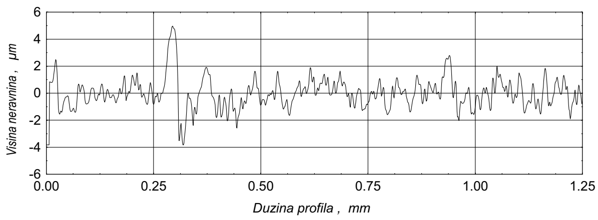
By measuring the parameters of the topography in the longitudinal and transverse direction it is shown that the coating changes the surface topography.

Applying Zn coatings leads to a deterioration of surface quality and roughness increases significantly. Class roughness of Zn coating can deteriorate for one, even for the two classes.

Figure 3 shows the topography of the sample surface 9 in the longitudinal direction before and after application of Zn. It can be concluded that the zinc coating thickness of 15 μm cause an increase of Ra twice.



a) Before applying the coating, Ra = 0.392 μ m



b) After application of Zn, Ra = 0.798 μ m

Figure 3. Profile of the sample 9

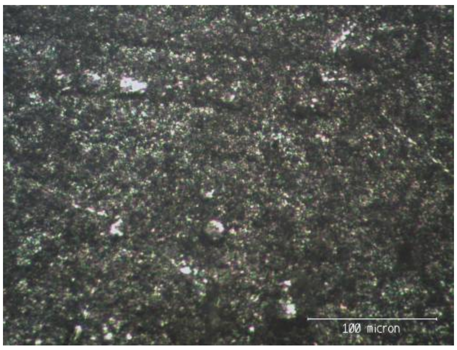
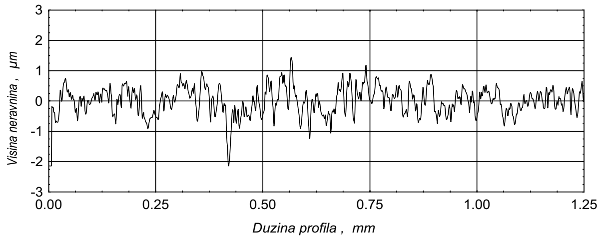
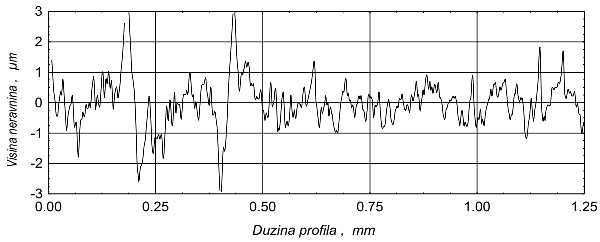


Figure 4. The appearance of the sample surface 9 after application of Zn

Realized testing did not determine dependence of coating thickness and surface topography changes. Figure 5 shows changes in the topography of the sample 31 with zinc coating thickness of 6.5 μm.



a) Before applying the coating, Ra=0,356 μm



b) After application of Zn, Ra=0,566 μm

Figure 5. Profile of the sample 31

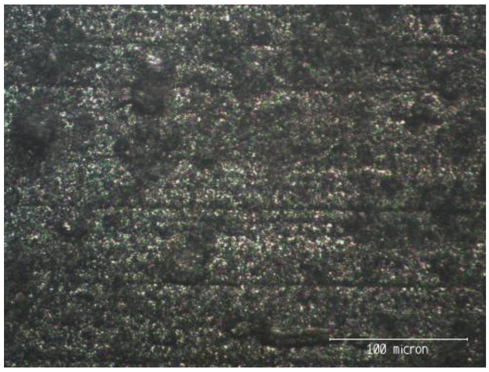


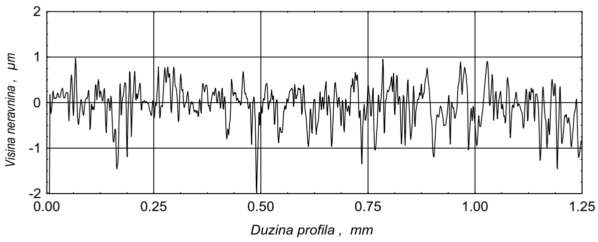
Figure 6. The appearance of the sample surface 31 after application of Zn

Table 4 shows the change in Ra due to the application of chrome plating.

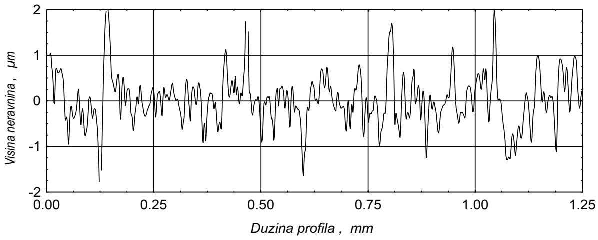
Table 4. Change parameters Ra

Sample number	Grinding	Hardness samples, HRC	Thickness μm	Ra before μm	Ra after μm
7	**A**	46,5	13.21	0.3	0.35
15	**A**	51,5	8.25	0.278	029
26	**A**	47,1	12,20	0.384	0.356
29	**A**	37,1	15.63	0.404	0.38
35	**A**	24,4	11.17	0.43	0.439
37	**A**	22,1	14.87	0.322	0.418
18	**B**	48,1	12.60	0.226	0.32
20	**B**	47,8	7.87	1.84	1.86
24	**B**	24,7	9.27	0.268	0.363
25	**B**	24,6	7.10	0.47	0.439
28	**B**	32,1	13.59	0.295	0.305
32	**B**	51,4	12.07	0.29	0.302
33	**B**	19,3	7.75	0.304	0.305

From table 4 it can be concluded that applying a coating of chromium leads to minor changes - an increase of the surface topography parameter Ra. In Figure 5 is shown the profile of the sample 37 before and after application of chrome plating. It can be seen that there was an increase of height roughness parameters, but also a significant increase in steps prominence.



a) Before applying the coating Cr, Ra=0,322 µm



b) After application of Cr, Ra=0,418 µm

Figure 7. Profile of the sample 37

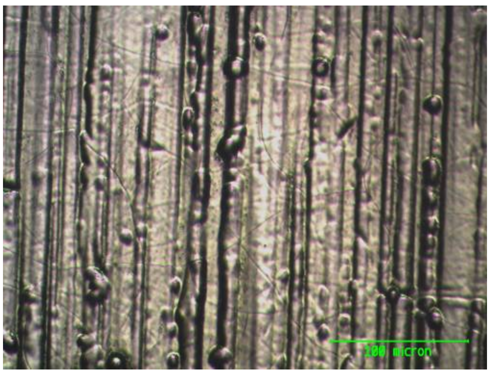


Figure 8. The appearance of the sample surface 37 after application of Cr (Ra=0,418 µm)

Figure 7 shows the surface appearance of the sample 33 on which is applied chrome coating thickness 7.75 µm. Comparing the appearance of this surface and the sample 37 with chrome coating thick 14.9µm it can be seen that sample 33 is clearly perceived the slightest traces of processing, while the sample 37 shallow bumps "flattening" - filled with chromium.

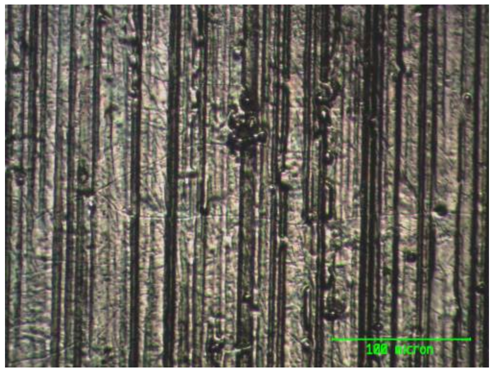


Figure 9. The appearance of the sample surface 33 after application of Cr (Ra=0,305 µm)

4. CONCLUSION

The main parameters that are inherited through the technological process of making the parameters related to properties of materials: their composition, structure, stress state, etc.., and parameters related to macro and mikrogeometry area (geometrical parameters).

Preliminary results of the surface topography changes depending on the type of Zn and Cr have shown that coating leads to significant changes in topography and that in order to establish the correlation very extensive research is required.

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