THE INFLUENCE OF PREPARATION OF THE SURFACE LAYER OF GREY CAST IRON PARTS ON THE MECHANICAL PROPERTIES OF THE ZINC COATING

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Abstract

The study determines the effect of different surface preparation method of grade cast iron GJL-250 on the mechanical properties of the hot-dip zinc coating. The samples for testing were taken from the parts used in the construction of power overhead lines. Mechanical properties and wear intensity of the zinc coating was determined by tribological tests in conditions of dry friction, that were performed using a tester T-11. Study allowed for determination of the coefficient of friction of the zinc coating with dependence on the surface preparation method. In order to supplement the test results nanohardness on the cross-section of the applied coatings were measured. Measurements were carried out of the maximum load 20 mN using a diamond indenter type Berkovitch. Additionally, in order to determine the mechanisms of the coating damage macroscopic and microscopic analysis and measurements of surface texture were carried out. On the basis of the results studies, the differentiation in the degree of the coatings wear deposited after different method of surface preparation were evaluated. The research showed that the use of high-temperature oxidation as a way of surface preparation of the cast iron may decide on the tribological properties of the hot-dip zinc coating.

Keywords: Cast iron, zinc coatings, surface wear, dry friction, oxidation

1. INTRODUCTION

Spare parts for power grids (handles, couplings) in atmospheric conditions corrode by reaction with the surrounding environment [1]. Destruction of corrosive materials can be effectively curtailed by its skilful prevention, mainly through the use of corrosion protection methods and the proper selection of materials. In the basic version, the grips and connectors of the power grids are made of aluminum or zinc-coated steel. However, practical and economic considerations lead to the attempt to use grey cast iron in the manufacture of network equipment [2, 3]. All metal coatings manufactured on an industrial scale may be damaged during transportation or use. The result of the parts interaction is tribological wear - the process of destroying and removing material from the surface of solids by friction, resulting in constant change of dimensions and shapes of defective parts. Fretting is a phenomenon of surface damage that involves the formation of local material emptiness in vibration parts or slight slippage as a result of cyclical impact and intense corrosion. The common characteristic of these interactions are strongly corrosive influence that accompany all stages of the destruction [4]. Corrosive wear products are metal oxides that act as abrasives. In addition, it can be observed that rough surfaces corrode faster than polished smooth surfaces. The reason for this phenomenon is to increase the rough surface area, which maintains more moisture, which in turn accelerates the corrosion and oxidation process [5, 6]. The tribological wear is most affected by the topography of the surface and the roughness of the surface. The surface with large number of unevenness is wearing out faster because the apexes participate in abrasive wear. [6, 7]. The study determines the influence of different surface preparation method of grade cast iron GJL-250 on the mechanical properties of the hot-dip zinc coating.

2. OWN RESEARCH

In the study the cast iron grade GJL-250 with flake graphite and typical chemical composition specified in PN-EN 1560:2001 was used. Test specimens were taken from the commercial parts used for the manufacture of network equipment - NK 2421 screw-and-cable clamping plates for closing the loops on the braces and connecting the two wires. Cover plates are made of cast iron secured additionally by zinc coating. Traditional cover plates surface preparation results in cracked and laminated zinc coating where in places of discontinuity corrosion arise (**Figure 1**).

Figure 1 The appearance of overlay with visible corrosion focal points

The research material was divided into three groups and subjected to surface treatment shown in **Table 1**. Sandblasting was performed using a pneumatic cleaning cabin with a cylindrical jet made of boron carbide. The angle of inclination of the cleaning nozzle to treated surface was approximately 45° at an operating pressure of 0.4 MPa. Sandblasting was performed using typical A95 corundum with a grain size of 1-2 mm and a hardness of 1355 HV. Shot-blasting was carried out in the cleaning chamber using the high carbon steel grit - chevron (broken) - GL 40. To clean the surface the grains in the shot broken size of 0.425 mm and a hardness of 600-700 HV were used. The process of high-temperature oxidation was carried out in ambient air in a furnace chamber, with electronic temperature controller PSK 600/25 VEB - Lokomotivbau Elektrotechnische Werke Company (temperature 850 °C; time 4h).

Table 1 The method of surface preparation prior to galvanizing

Series No.	Surface treatment	Method of surface preparation
I	CRUDE SURFACE	Pickling in HCl (12%; 35gFe/dm^3) Fluxing (pH = 4.80; 28°Be; 1,4gFe/dm^3)
II	SANDBLASTING	Blasting with electro-corundum 95A Pickling in HCl (12%; 35gFe/dm^3) Fluxing (pH = 4.80; 28°Be; 1,4gFe/dm^3)
III	SHOT-BLASTING	Shot-blasting with steel shot Pickling in HCl (12%; 35gFe/dm^3) Fluxing (pH = 4.80; 28°Be; 1,4gFe/dm^3)
IV	HIGH TEMPERATURE OXIDATION	Pickling in HCl (12%; 35gFe/dm^3) Fluxing (pH = 4.80; 28°Be; 1.4gFe/dm^3)

3. TEST RESULTS

After surface preparation according to the methodology presented in **Table 1**, the surface geometry which can significantly influence the final quality effect of the protective coating have been analysed. Stereometric studies were conducted in 3D using the Perthometer Concept (MAHR) profilometer. Examples of surface isometric images are shown in **Figures 2** and **3**. The average values of measured roughness parameters Sa are shown in **Figure 4**.

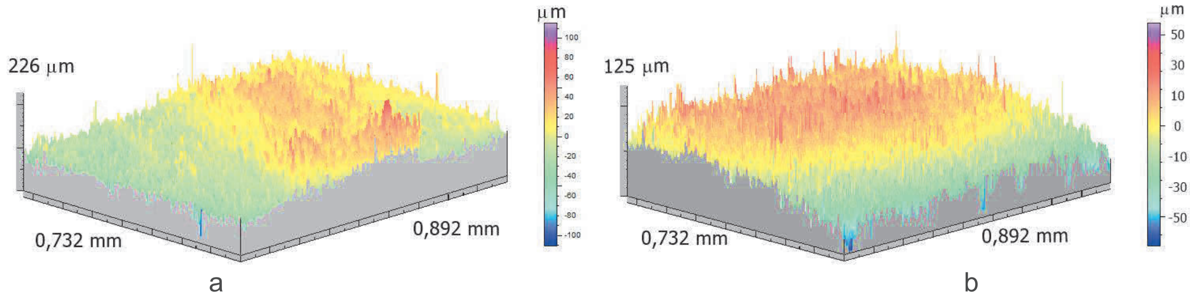


Figure 2 Isometric surface image and roughness profile a) crude surface, b) after sandblasting

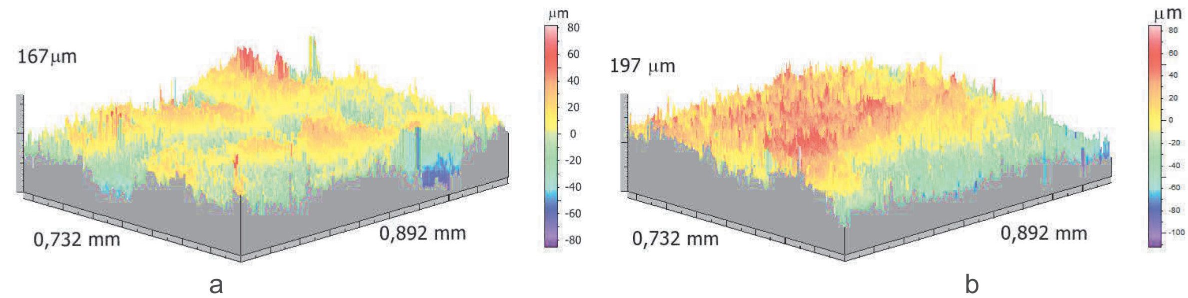


Figure 3 Isometric surface image and roughness profile a) after shot-blasting, b) after oxidation

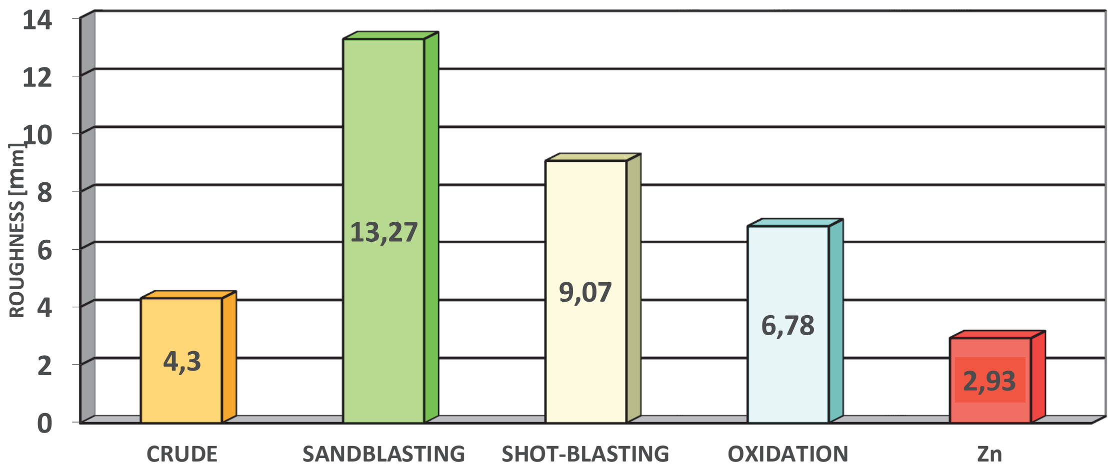
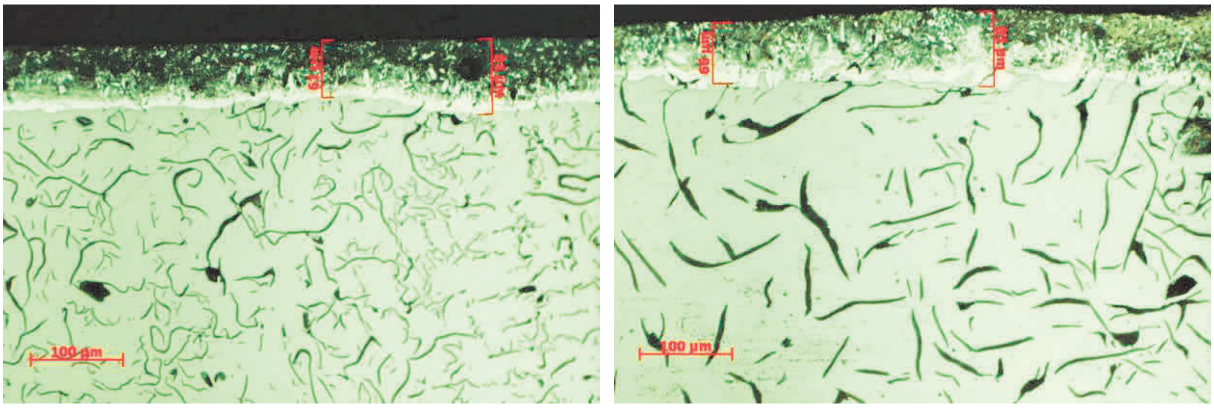


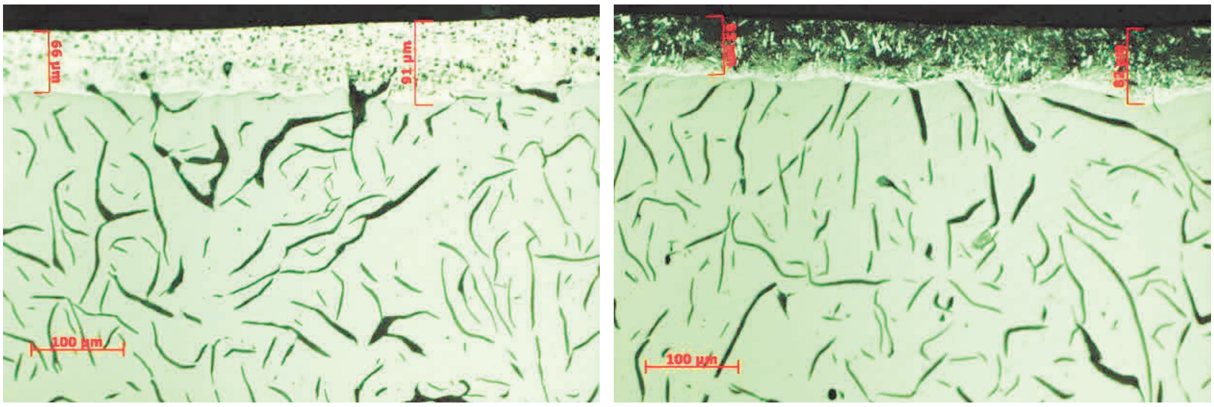
Figure 4 The average values of measured roughness parameter Sa

To analyse the structure existing on the cross-section of the created zinc coating the metallographic specimens were prepared. For metallographic observation an optical microscope Axiovert A - 100 and scanning microscope Joel - J7 were used. Results of samples observations are shown in **Figures 5** and **6**.



a b

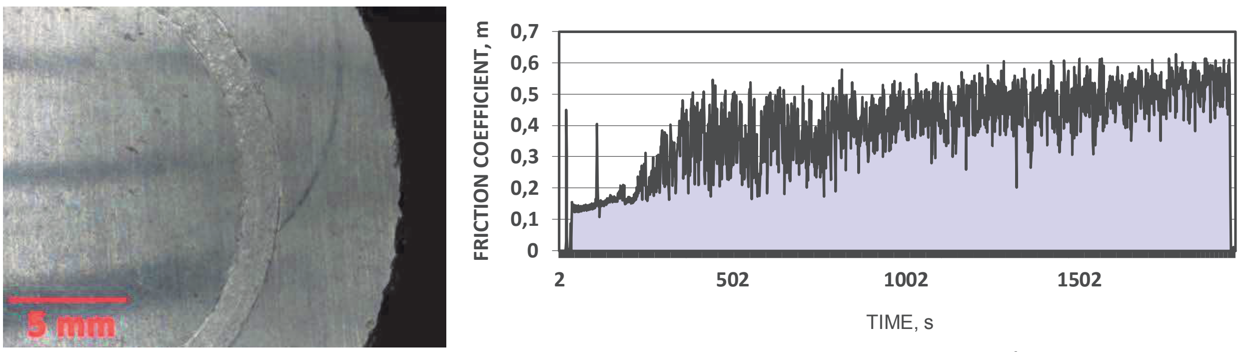
Figure 5 The structure visible at the cross-section of zinc coating: a) crude surface b) the sandblasted surface



a b

Figure 6 The structure visible at the cross-section of zinc coating: a) the shot-blasting surface, b) the surface after oxidation

The determination of friction characteristics were performed on a T-11 stand according to a fixed testing program. During test the following parameters were recorded continuously: friction force, temperature and time. Examples of test results are shown in **Figures 7** and **8**.



a b

Figure 7 Area after the friction test (a), graph of the friction coefficient as a function of time (b)

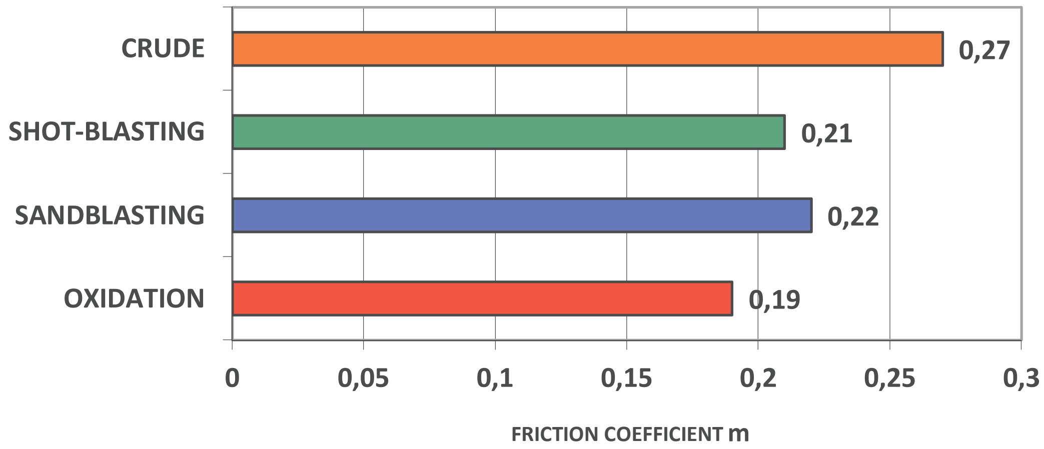


Figure 8 Average value of friction coefficient determined for the tested surfaces

4. RESULTS ANALYSIS

As a result of hot-dip zinc galvanizing process of tested samples in the described conditions a uniform and continuous coating were created - **Figure 2**. On the basis of conducted own research and literature data it was found that the structure and metallic phases composition of coatings created on the samples after high-temperature oxidation corresponds to the coating structure after classical surface preparation. Typical coating structure consists of a clearly visible diffusive - alloy layer and the outer layer. The diffusive layer can be divided in the following phases: Γ, ζ and δ the outer layer is formed of a η phase. In the case where the surface of cast iron was prepared traditionally the graphite penetration inside the zinc coating was observed (**Figure 2a**) causing the discontinuity. The results of the microscopic measurement of coating thickness confirmed that the lowest thickness of about 61-81 microns was achieved on the crude casting surface. For the shot-blasted and sand-blasted surface coating thickness was 63-82 microns. For cast iron, where the high temperature oxidation was used as a way of surface preparation the coating thickness had the highest value - 66-91 microns. So, it means that the coatings thickness fulfils the requirements of PN- EN- ISO 1461.

The reason of such the coating thickness differentiation could be the surface roughness - level of surface development - before zinc galvanizing. The smallest measured roughness values - Sa = 4.3 μm - were determined for cast iron crude surface. After mechanical cleaning surface roughness increased to: Sa = 9.07 μm for shot-blasting and Sa = 13.27 for sandblasting. After oxidation and the scale removal the average roughness values reached the level Sa = 6.78 μm.

Due to the penetration of graphite into the zinc coating, the highest values of friction coefficient were measured for coatings without pre-oxidation. The coefficient of friction for the zinc coating deposited on the crude surface created after casting was 0.27. Lower coefficients of friction were obtained for the hot-dip coating obtained on previously mechanically cleaned surfaces. The coefficient of friction was 0.21 for shot blasting and 0.22 for sand blasting. The highest friction wear resistance was determined for zinc coatings deposited on surfaces previously subjected to oxidation. The arithmetic average coefficient of friction was here 0.19.

As a investigation - tribological tests complement coatings hardness measurements with application of Anton Paar NHT2 device were conducted. Hardness tests were performed on the surface of each sample taking the 15 measurements in accordance with the standard. In the case of hot-dip zinc coating additional measurements on the cross-section were made. The average depth of penetration of the indenter was equal to 0.8 microns on the surface. On the cross-section these values varied from 1.2 μm outside the coating to 0.8 μm inside, where the iron content in the coating was greater.

5. SUMMARY AND CONCLUSIONS

On the basis of conducted tests the following conclusions can be formulated:

- The penetration of graphite into the hot-dip zinc coating may be the reason of increasing the value of the friction coefficient measured for the coatings deposited on cast iron.
- The achieved results confirm that the high temperature treatment (oxidation) of grey cast iron castings surface, allows for hot-dip zinc coatings creation with the correct structure and thickness.
- The zinc coating created on the cast iron surface after oxidation reveals the structure in accordance with Fe-Zn system.
- Penetration of graphite into zinc can reduces the coating mechanical properties.

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