INFLUENCE OF THE CAST IRON SURFACE TOPOGRAPHY ON PROPERTIES OF ZINC COATINGS

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Abstract

The paper describes the corrosion resistance comparison of hot-dip zinc galvanized cast iron with flake graphite in relations to bronze. The practical application of investigated cast iron is planned as a materials for fitting elements working in corroding medium of sea water. The surface of cast iron was prepared in different way: crude, turned, sandblasted and oxidized. Oxidation effect was evaluated by optical microscopic tests, surface roughness measurements and corrosion resistance potentio-dynamic tests. It was stated that oxidation process influence both on the level of surface development as well as the zinc coating structure and zinc diffusion depth in cast iron matrix. The observed influence causes the essential cast iron corrosion resistance increase which level reaches value characteristic to bronze. Structure of coating layers – alloyed and zinc and their thickness is in direct correlation with a kind of surface preparation and in consequence corrosion resistance. Examination presented in the elaboration confirmed the thesis that in analysed case high temperature oxidation is not a corrosion process but rather a kind of surface treatment that makes wider the cast iron application range.

Keywords: Cast iron, oxidation, surface preparation, corrosion resistance, zinc coating

INTRODUCTION

There are a million metal machinery parts and devices withdrawn from the use of every year because of wearing them out by oxidizing [1, 2]. The most susceptible to atmospheric corrosion (oxygen and humidity) are parts made of iron alloys. i.e. steel and cast iron. In industrial practice there are a lot of methods protecting against the corrosion. To the most popular belong: painting and varnishing, aluminizing, zinc coating or application of aluminium zinc alloys coating [3]. Zinc-coatings are the most effective and economic way of iron alloys protection against the corrosion. Apart from the high resistance to the atmospheric corrosion this kind of coating demonstrates also the high resistance to the tribologic wear, i.e. caused by the friction. Many machinery parts are exposed during the application to sliding friction, e.g. elements of industrial fittings. The coating protecting machinery parts surfaces against corrosion that are additionally exposed to the friction should possess very special properties. Therefore the zinc coating put on parts of fittings should be characterized by a small friction coefficient what makes easier the regulation of the working medium flow and reduce the consumption during the long-term using.

Although zinc-coatings are universally used for many years, these are still conducted the examinations to improve their properties [4-9]. The galvanizing process of the grey cast iron performed in industrial conditions is encountering difficulties, caused by subsurface graphite particles and the higher silicon content which is a main reason of zinc-coating defects [7-9]. Etching applied before steel galvanizing in the hydrochloric or sulphuric acid isn't such useful with reference to the cast-iron castings. Worsening of the quality of the created zinc coating is the a result of the acids reactions products precipitating in this process. The cleaning of the cast-iron casting surface before galvanizing is a very difficult treatment [7-9].

It follows from the above that universally technologies used normally in steel galvanizing process can’t be automatically transferred to cast iron castings and especially to the surfaces after mechanical working. The presented problems can be solved by surface decarburising of the cast iron in the process of high-temperature oxidation. The influence of high-temperature decarburising of the grey cast iron on properties of hot dip zinc coatings will be discussed in this article.

1. OWN RESEARCH

During the tests a grey cast iron GJL-250 was used with flake graphite and typical chemical composition determined in the PN-EN 1560: 2001 standard and B555 bronze with chemical composition according the EN573-1 standard (Table 1). Test samples were taken from parts applied for the production of checks valve, as one-way valves. They are used to protect pipelines and devices against the backward flow of the medium substance and are installed on pipelines and containers where we should prevent the stream withdrawal of the flowing medium. Checks valve are destined to flow of: water, steam, oil and other natural liquid and gases mediums and the work in sea conditions (Fig. 1).

Table 1 Chemical composition

	Chemical composition [%]									
Cast iron	C	Si	Mn	P	S	Mg	Ce	Ni	Cu	Al
	3.25	2.00	0.55	0.065	0.035	0	0	0	0	0
Bronze	Chemical composition [%]									
	Cu	Sn	Zn	Pb	Al	Fe	Mn	Si	P	Ni
	83-87	4-6	4-6	4-6	≤0,01	≤0,3	≤0,2	≤0,01	≤0,1	≤2

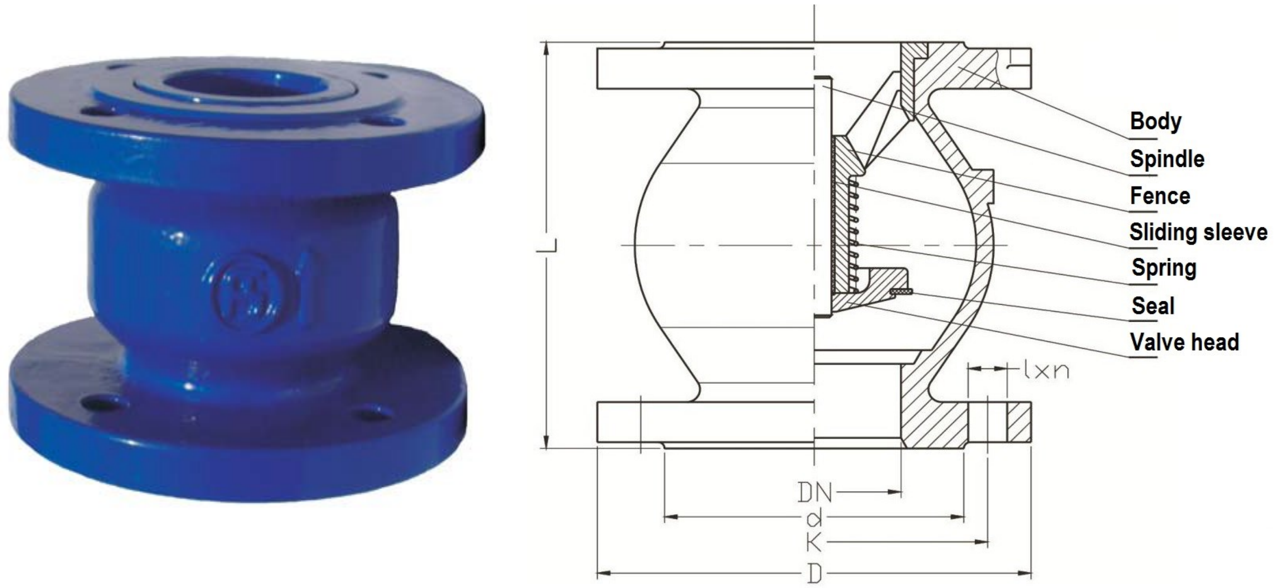
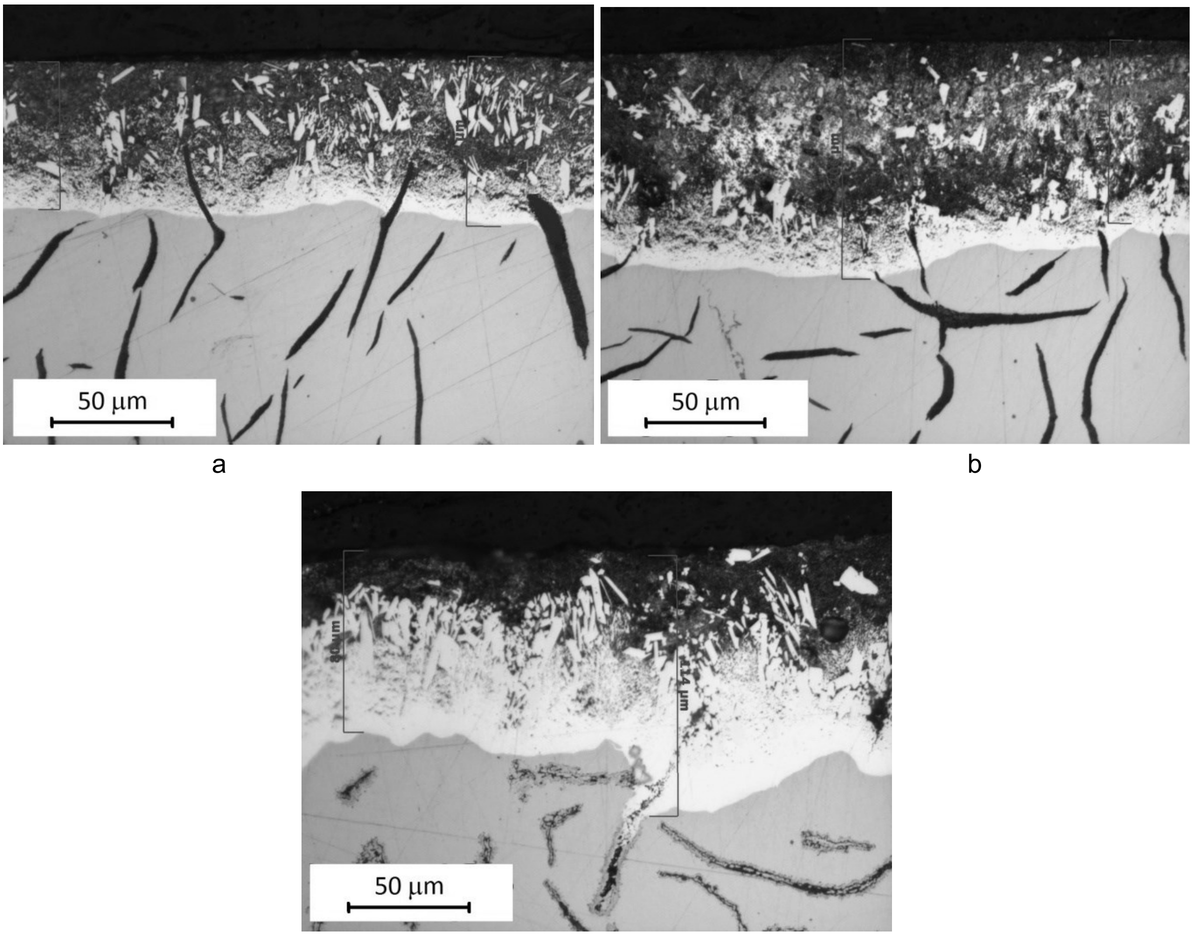


Fig. 1 Check valves

2. TEST RESULTS

To analyze the cross-sectional structure 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 Fig. 2.



a b

c

Fig. 2 The cross-section of zinc coating: a) the sandblasted surface, b) crude surface, c) the surface after oxidation.

Based on microscopic observation and results of roughness profiles measurements (3D) an influence of oxidizing on the cast iron microstructure and the state of the surface before galvanizing was determined. The average values of roughness measurements - the sRa parameter is presented in the form of graph (Fig. 3). Chosen roughness profiles of the studied materials surfaces are presented in Fig. 4-6.

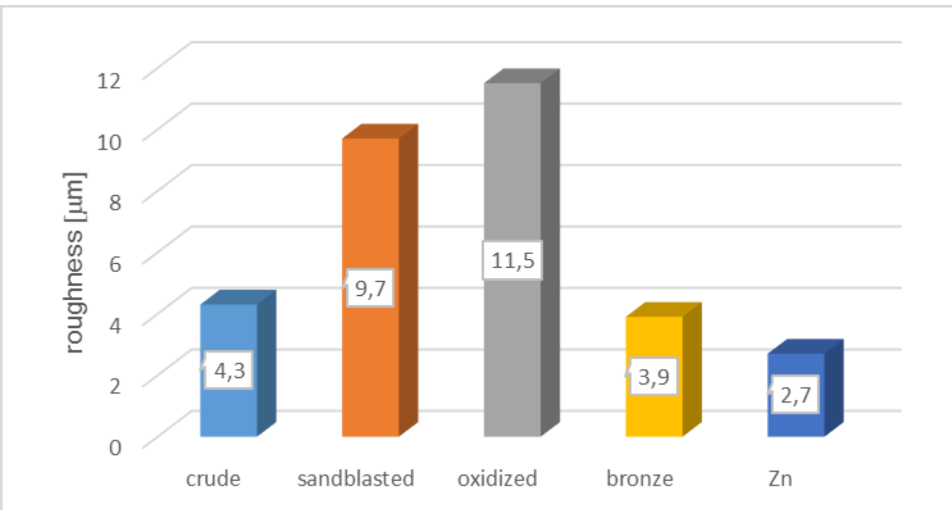


Fig. 3 The average values of measured roughness parameter sRa.

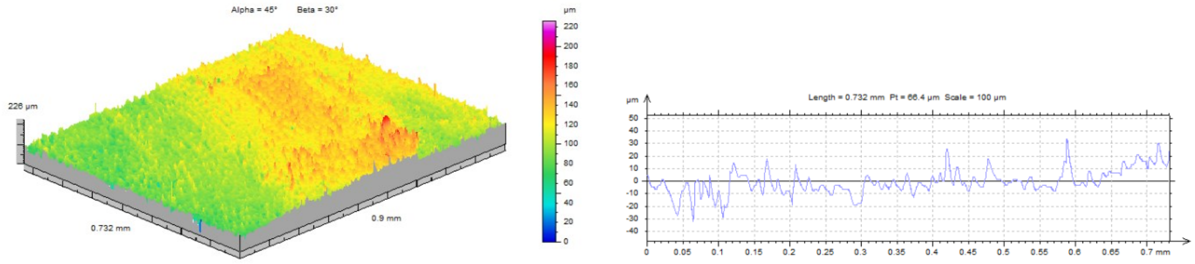


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Fig. 4 Isometric surface image and roughness profile after sandblasting 3D(a) i 2D (b)

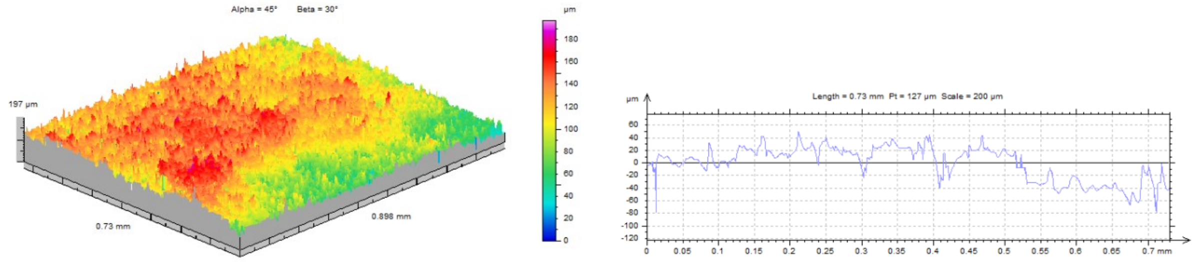

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Fig. 5 Isometric surface image and roughness profile after oxidation 3D(a) i 2D (b)

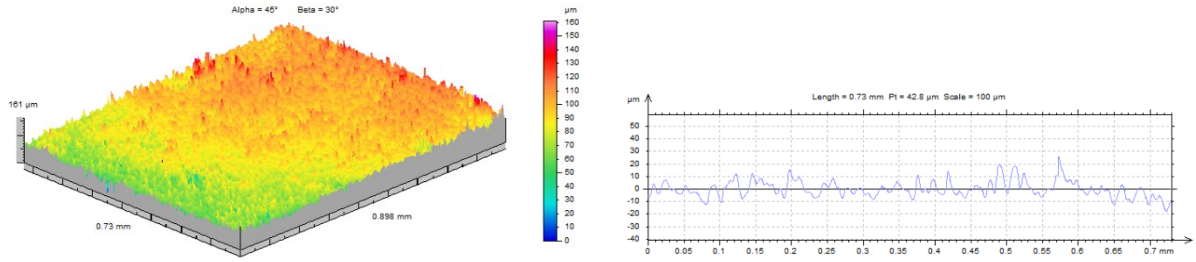

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Fig. 6 Isometric surface image and roughness profile after galvanizing 3D(a) i 2D (b)

To determine the corrosion resistance of the tested parts the potentiodynamic tests were performed in accordance with PN-76/H-04601 standard in the aerated solution simulating sea water of 3.5% NaCl. These studies were performed with application of a potentiostat Solartron SI 1286, and the measuring cell in the three-electrode system. The device was computer-controlled and equipped with modern control software (CorrWare, ZPlot) and software to results analyze (CorrView, Yawn), allowing conducting repeatable experiments with the elimination of interference. The test results are shown in Table 2 and Fig. 7. During the study the potential of anodic-cathodic transition $E_{K\text{-}A}$ and the corrosion current i_{kor} has been measured.

Table 2 The results of measurements of corrosion potential and corrosion current

Kind of surface	$E_{K–A}$ [mV]	i_{corr} [A/cm^2]	Corrosion rate [mm/year]
crude	–1255	1.34×10^{-5}	0.156
sandblasted	–698	8.28×10^{-6}	0.097
oxidized	–644	3.36×10^{-6}	0.039
bronze	–242	6.73×10^{-6}	0.079

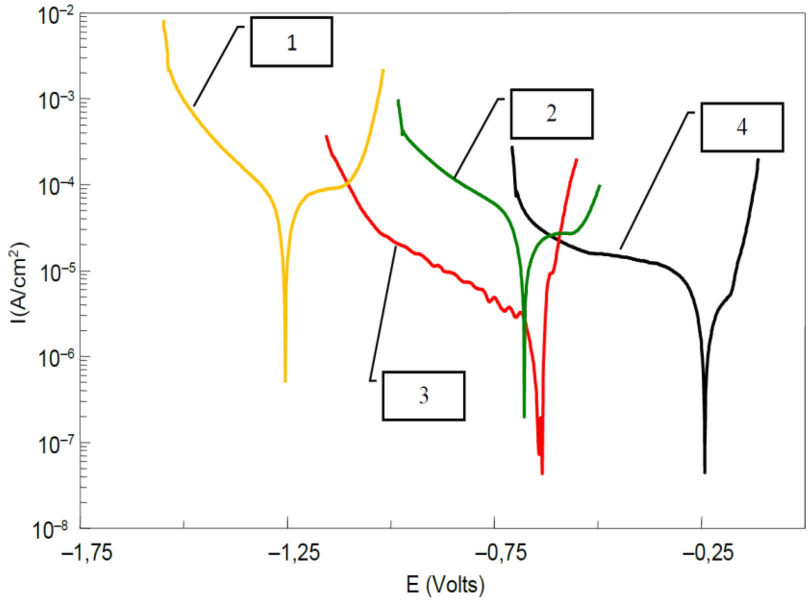

Fig. 7 Registered potentio-dynamic polarization curves - hot-dip zinc galvanized GJL-250 cast iron - 1) crude surface, 2) sand-blasted surface, 3) oxidized surface, 4) bronze

3. RESULTS ANALYSIS

Basing on the conducted tests it was stated that the corrosion resistance of the zinc coating put on the cast iron after the oxidation process was similar to this one which was determined on investigated bronze. It results among others from the fact that the structure of coatings created on cast iron the surfaces with high-temperature oxidation is similar to the model structure and is free from graphite precipitations decreasing coating tightness – Fig. 2. The coating created on oxidized base is composed of clearly visible diffusion layer and outside pure zinc layer. In internal layer it is possible to distinguish phases: Γ, δ_1 and ζ, however outside layer consists of phase η. After putting zinc coating on cast-iron surface which wasn't oxidised it was observed that graphite particles penetrate inside coating decreasing layer continuity. It proves that graphite particles could be the main reason of zinc coating anticorrosion properties decreasing. It results from coatings thickness measurements made by optical microscope application that the smallest thickness of the zinc coating - 60-65 μm was achieved on the crude cast iron surface. For the surface after sandblasting the thickness of the coating was in the range of 69-77 μm. The greatest coating thickness - 85-90 μm fulfilling the requirements of PN-EN-ISO 1461 standard was created on cast iron after high temperature oxidation.
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 (sRa = 4.3 μm, sRp = 19.9 μm, sRv = 24.8 μm) were determined for cast iron crude surface. After mechanical cleaning surface roughness increased to: sRa = 9.7 μm, sRp = 24.9 μm, sRv = 25.5 μm. After oxidation and the scale removal the average roughness values reached the level sRa = 11.5 μm, sRp = 21.9 μm, sRv = 18.6 μm. It was observed that the level of surface development influence on the thickness of internal zinc coating sublayers: alloyed layer and pure zinc layer thickness. Moreover, removal in the process of oxidation the graphite remains prevents theirs further diffusion deep into of zinc coating. On the other hand filling the post graphite emptiness with zinc can contribute to increase the corrosion resistance of earlier oxidised surfaces (Fig. 2c).
The results achieved in the form of polarizations curves/graphs can be divided to two fundamental parts: the cathodic and anodic polarization. From the point of view of conducted examinations the part describing the anodic polarization is more important. Observing of the anodic course it is possible to determine material's behaviour in corrosion environment. The most important points of the graph are corrosion potential E_{corr} and corrosion current i_{corr}. On the basis of potentio-dynamic measurements of polarization of the hot-dip

galvanized cast-iron electrode important differences were stated in the potential of zinc coatings. For the cast iron crude surface the potential was -1255 mV. The reduction of the potential by the half to the value -698 mV was recorded for the surface after sandblasting. Further potential decreasing to -644 mV was recorded for oxidised surfaces. Lowering the potential was combined with decreasing the corrosion current about one order of magnitude (3.36 × of 10^{-6} A/cm^2), and in the process with slowing down the corrosion. For parts made of bronze the corrosion potential was -242mV, and corrosion current 6.73 × of 10^{-6} A/cm ^{2}.

4. SUMMARY AND CONCLUSIONS

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

- The high temperature oxidation of cast iron surface exerts the influence in three directions: increases the level of surface development, eliminates graphite particles from the zinc coating structure and allows for deeper zinc diffusion inside the cast iron matrix.
- The achieved results confirm that the high temperature treatment (oxidation) of gray cast iron castings surface, allows for hot-dip zinc coatings creation with the correct structure and thickness.
- The zinc coating created on the surface after oxidation reveal the structure in accordance with Fe-Zn system.
- The enrichment of the metal matrix and "after graphite" voids in zinc may be the reason of the corrosion resistance increase of the materials previously oxidized.
- The corrosion resistance of oxidized and hot-dip zinc galvanized cast iron is similar to the bronze resistance tested in the same conditions.

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