THE COMPARISON OF SURFACE STATE EVALUATION ACCURACY OF ZINC COATED ELEMENTS BY APPLICATION OF DIFFERENT METHODS

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Abstract

Research were focused to different zinc coatings quality put on iron alloys (cast iron, steel). In the paper the galvanic, hot-dip and lamellar zinc coatings were compared. The complex investigation method consisted in proper coating preparation (in industrial conditions) on specially prepared samples and evaluation of surface state/topography that has essential influence on other coatings specific properties, like corrosion resistance, wear resistance, resistance to mechanical damage, etc. Additionally also mechanical, tribological and anticorrosion properties were determined (in other paper). For surface/topography state evaluation three different methods were used: contact profile recording instrument Perthometer Concept (MAHR) with 3D software, PhaseView optical assembly for 3D surface scanning and MarSurf WS 1 - the high-precision, non-contact measurement of surface texture using the principle of white-light interferometry. During tests the basic parameters describing roughness and waviness together with isometric surface image were determined. Advantages and disadvantages of each method were compared. It was stated that although the most precise results are achieved by contact profilometer application also using the ZeeScan system enable the reliable surface evaluation but in much shorter time.

Keywords: Zinc coatings, surface topography, hot-dip zinc coating, galvanizing, lamellar zinc

1. INTRODUCTION

Zinc coatings are still the best and the most effective anticorrosion protection of Fe-C alloys [1]. The most important advantage of zinc as the steel and cast iron rustproofing is its protection mechanism that consist in providing on one hand a tight barrier on the other the cathodic protection for the underlying Fe-C alloy. The effectiveness of this cathodic protection is dependent on the type of coating, its structure and thickness and kind of the underlying alloy, as well as on the area of damage. Because the galvanized elements of constructions and machines very often undergo mechanical damages both during the assembly, as well as the operation apart from anticorrosion also tribological properties of coatings are very important. The most often parameters being characteristic for wear resistance zinc-coatings are friction coefficient and hardness [1]. Also surface state/topography exerts essential influence on coatings specific properties, like corrosion resistance, wear resistance, resistance to mechanical damage, etc. There is practically four zinc coating methods used in industrial conditions: the hot-dip zinc galvanizing, zinc electro-galvanizing; lamellar technique, sherardizing (thermo-diffusion) [2]. The essential difference between these coating regards lamellar zinc coating which does not demonstrate of cathodic protection, unlike the other three coatings, and behaves similarly to powder coating, where breaking the protective layer continuousness leads to quick occurrence of corrosion point. Moreover, the smoothest surface is usually created on the electro-galvanized materials that can be applied in the next step for a high quality paint finish - **Fig. 1**. Despite the fact that the above methods are applied for many years a research on its' technique improving and more precise describing the mechanism is still being conducted [3-5].

a) b) c)

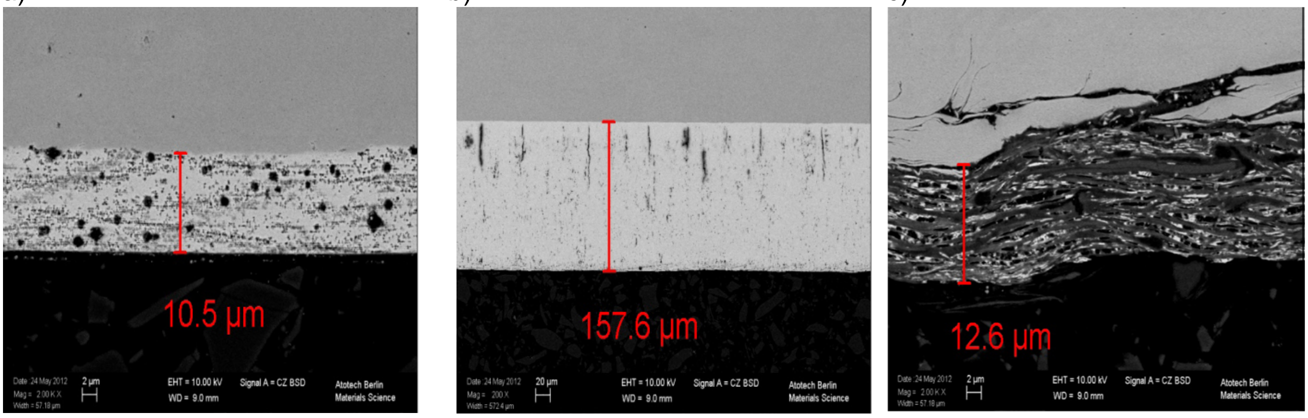


Fig. 1 The cross section of different Zn coatings (scanning microscope): a - galvanic, b - hot-dip, c - lamellar (own investigation)

Various instruments are available for the roughness measurement. Generally, the measurement technique can be divided into two broad categories: a contact type in which during measurement a component of the measurement instrument actually contacts the surface to be measured; and a noncontact type [6]. For surface/topography state evaluation of coatings investigated in presented paper three different methods were used: contact profile recording instrument Perthometer Concept (MAHR) with 3D software, PhaseView ZeeScan optical assembly for 3D surface scanning and MarSurf WS 1 - the high-precision, non-contact measurement of surface texture using the principle of white-light interferometry. Mahr's Perthometer Concept is a popular measuring system for contact measuring surface roughness, waviness and form measurements [7]. ZeeScan device is advanced attachment to optical microscopes for fast and precise 3D acquisition. ZeeScan uses a proprietary PhaseView optical assembly for 3D scanning, integrating the advances of digital lens technology for accurate and highly repea**Table 3**D acquisition. ZeeScan is supplied with GUI software GetPhase [8] that enables 2D/3D acquisition: 2D, Z-stack, 3D roughness, 3D shape. Multiple display modes: 3D, phase contrast, DIC, darkfield, image fusion (extended depth of field) 2D/3D analysis tools : profiles, step height, roughness, etc. 3D roughness measurement**:** relies on proprietary wave-front technique, for measuring surface topography in reflection. The algorithm processes a set of 2 or more images acquired within objective depth of field. This method is particularly useful for measuring small surface variations, when sample features are all in-focus, within depth of field of the selected objective. The 3D reconstruction is determined by the maximum slope constraint; samples with steep slopes require high objective magnification as related to objective numerical aperture (NA). 3D Shape Measurement: relies on detecting local contrast on Z image series for measuring depth map of an object. The algorithm processes Z-stack images acquired beyond the objective depth of field. This method is well adapted to samples having surface variations beyond objective depth of field. 3D reconstruction is performed when samples exhibit some texture along the Z image planes.

MarSurf WS 1 is recommended by producer because of the following advantages: short measuring times of only a few seconds, compact and simple design, accurate results achieved thanks to 0.1 nm vertical resolution, possibility of application both in the workshop and laboratory [7]. The design is similar to that of a traditional interferometer, but uses interferograms at various scan depths white light instead of coherent light. White light has a short coherence length and therefore shows excellent properties for measuring surface topographies. In contrast to traditional interferometry, height information can be clearly assigned in the case of height steps in the test specimen [7].

The aim of presented investigation was to verify if the Phase View (Zee Scan) system can be used for roughness and waviness measurement of different zinc coatings.

2. EXPERIMENTAL

2.1. Investigation methodology

The methodology of zinc coatings investigation applied in the investigation is presented in **Fig. 2**, i.e. roughness parameters are measured twice: after base steel/cast iron surface preparation and after zinc coating creation.

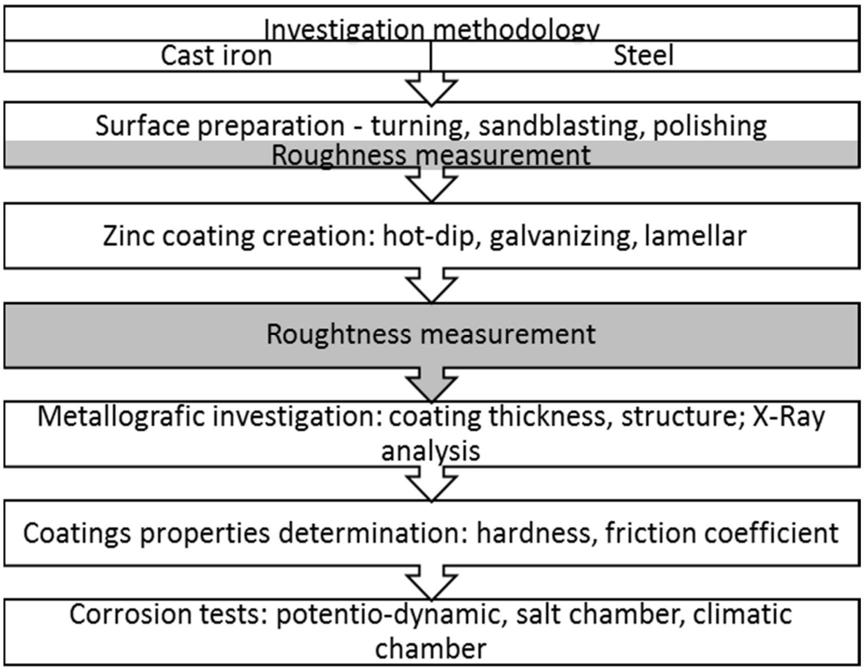


Fig. 2 The methodology of zinc coating investigations

2.2. Samples preparation technique

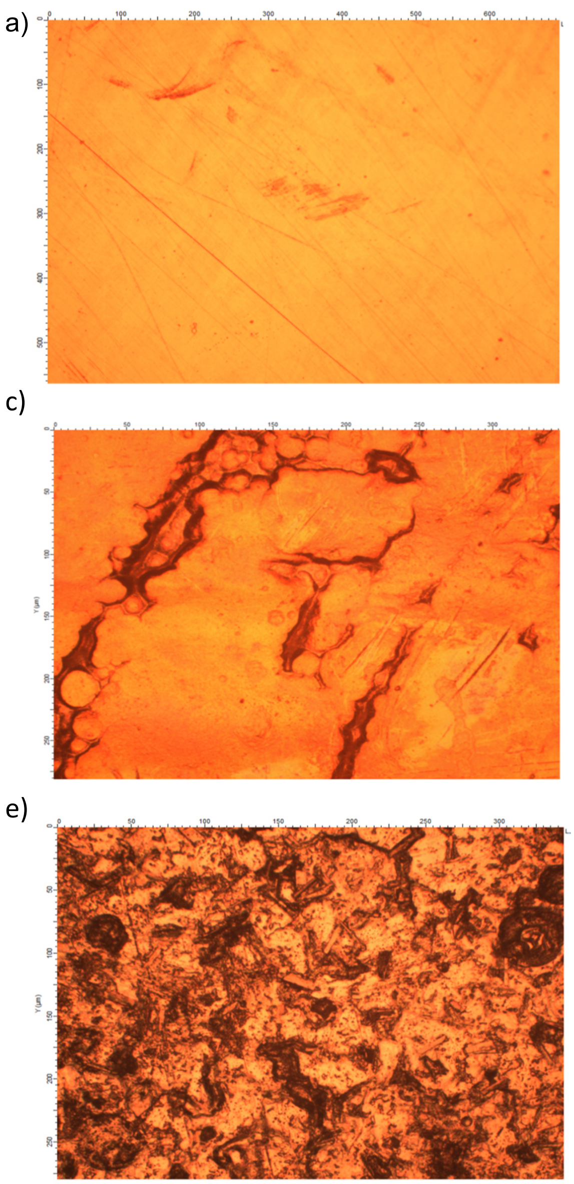
The experiment regarded the grey cast iron grade EN-GJL-250 (3.28 %C, 1.72 %Si, 0.62 %Mn, 0.06 %P, 0.05 %S) and DC01 steel (0.075 %C, 0.030 %P, 0.036 %S, 0.50 %Mn, 0.030 %Al, 0.055 %Si, 0.056 %Cu, 0.010 %Cr, 0.028 %Ni, Fe - the rest). Samples were divided in three groups and directed to the galvanizing process (thick chromate coating was used), hot dip and lamellar. Zinc coating was conducted in industrial conditions. Electro-galvanizing acc. PN-EN ISO 4042 [9] - chemical degreasing, temp. 60 °C, etching in 18 % HCl and 10 % H_2SO_4 with inhibitors, degreasing and electro-polishing, temp. 60 °C, 1000 A, galvanization in the weak acid chlorine Zn bath, temp. 35 °C, pH 5.1; deposition of conversion coating - jons Cr^{3+}, Co^{2+}, NO_{3-}, temp. 45 °C, pH 1.9; Hot-dip acc. PN-EN ISO 10684 [10] - etching in 12 % HCl, fluxing, galvanizing in the bath: Zn with additions Al, Bi, Ni; temp. 460 °C, time 1.5 min, cooling in water. Lamellar acc. PN-EN ISO 10683 [11] - shotblasting 0.4 mm, triple painting (95 %Zn, 5 %Al), temperature holding in 120 °C, cooling to temp. 25 °C - air jet. Zinc plated samples were subjected to the following investigations: roughness measurement - the topography after coating creation (three different methods: contact profile recording instrument Perthometer Concept (MAHR) with 3D software, PhaseView ZeeScan optical assembly for 3D surface scanning and MarSurf WS 1); microscopic observations - optical microscope Axiovert 100A.

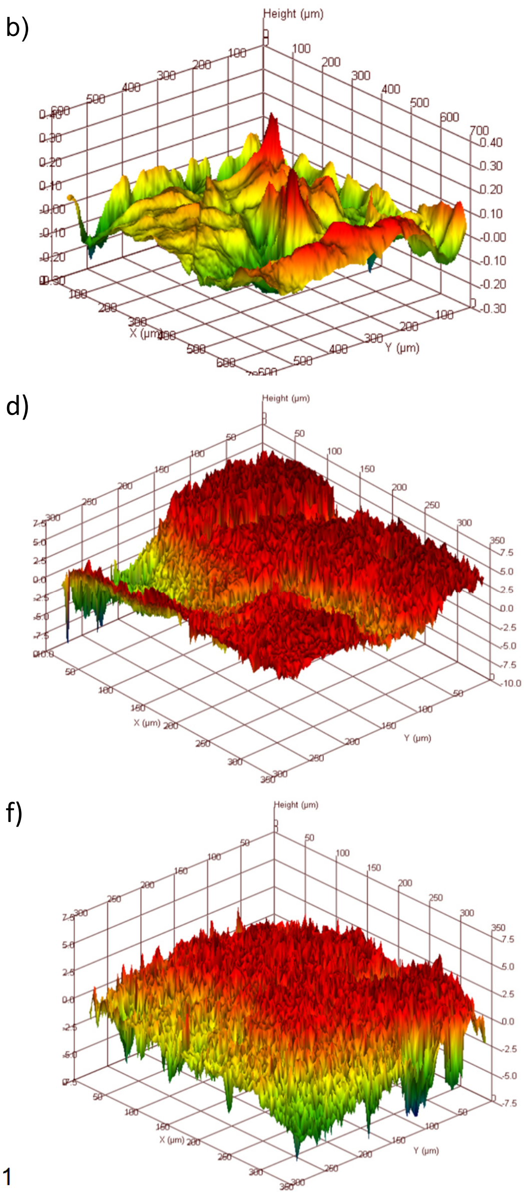
3. ANALYSIS OF RESULTS

Every three applied methods enable complex surface description/characterization by the parameters regarding both profile (R_a, R_q, R_{sk}, R_{kv}, R_v, R_p, R_t, R_z) as well as isometric surface image (S_x). Beside this ZeeScan system offer image acquisition in bright and dark field, phase contrast, DIC, step height, and histogram. The equipment possibilities are a function of applied objectives - see **Table 1**. For other magnification and adapter parameters (standard magnification. is 1x), the following formulas can be applied: Z Range = 16mm / (ObjM • adaptM)^2, Z Resolution = Objective depth of field / 4 (ObjM = Objective magnification; adaptM - adapter magnification. An examples of recorded images and surface topography are presented in **Fig. 3**. Tested samples - steel after polishing and cast iron after turning reveals wide range of roughness values - 0,05- 4,89 µm - **Fig. 4**, **Table 2**.

Table 1 The optical parameters range of ZeeScan system

Measurement parameters range, µm	Objective magnification/numerical aperture				
	5x/0.15	10x/0.30	20x/0.50	50x/0.75	100x/0.9
X axis	1398	699	350	140	70
Y axis	1136	568	284	114	57
Z axis	728	182	45	7.3	1.8
Min. Z interval	0.364	0.091	0.023	0.004	0.001
Depth of field	35.43	7.47	3.08	1.27	0.84





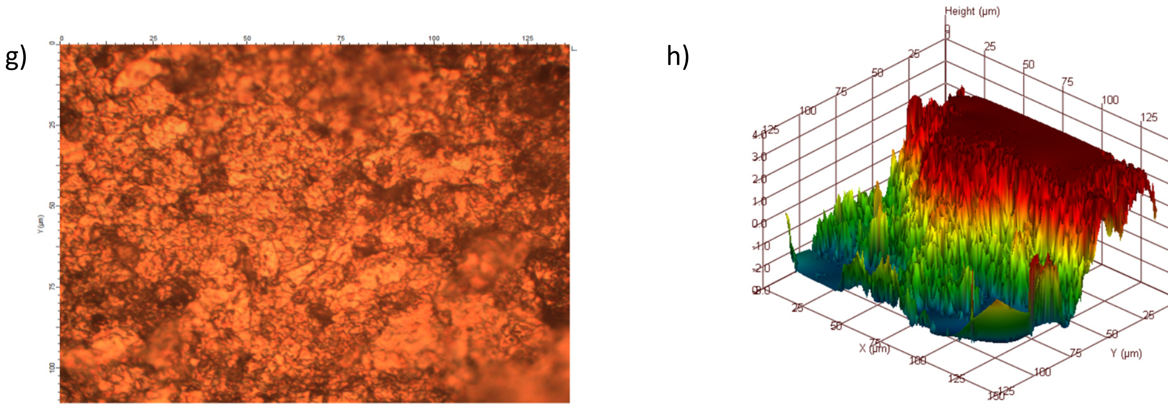


Fig. 3 The view of surface and isometric image of investigated coatings acquired by ZeeScan system: a, b - Zn galvanized steel; c, d - Zn galvanized cast iron; e, f - Zn hot-dip galvanized cast iron; g, h - lamellar Zn coating on cast iron

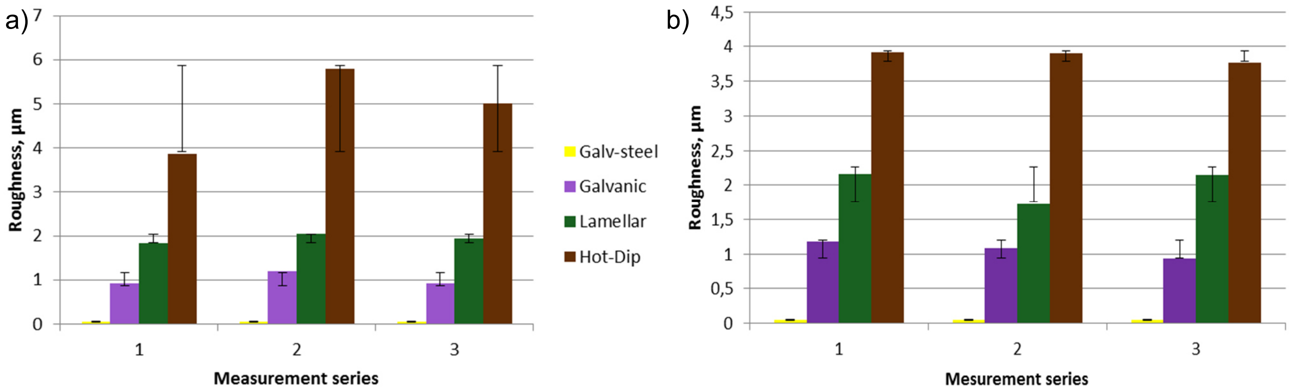


Fig. 4 Roughness values comparison measured on different Zn surfaces by different methods: a - Perthometer Conc., b - ZeeScan

Table 2 The average roughness values determined during tests

Method of measuring	Average surface roughness Ra, µm			
	Galvanic - steel	Galvanic (CI)	Lamellar (CI)	Hot-dip (CI)
Perthometer Conc.	0.05	1.02	1.94	4.89
ZeeScan	0.05	1.07	2.01	3.86
MarSurf WS 1	0.06	n.d.	n.d	n.d

CI - means cast iron; n.d. - not determined

The achieved results that describe/characterize surface state are an appendix/supplement to complex analysis of different zinc coatings: galvanizing, lamellar, hot-dip and thermo-diffusion (investigation in progress). The tested optical system is very sensitive and reproduces in details even small scratches visible on the Zn galvanized surface (see **Fig. 3a, b**). Moreover the combination of microscopic observation with topography evaluation enables the proper coating characterization especially when on the surface exist traces of previous mechanical treatment, like turning - **Fig. 3c, d**. The R_a value measured for the entire surface of galvanized cast iron (1.02-1.07μm) is here much higher than typical value for galvanic coating because of the influence of the base cast iron surface quality and especially deep grooves and valleys remaining after turning. R_a values measured in right top corner of **Fig. 3c** is about 0,5μm whereas roughness measured across grooves reaches value 2.5 μm. So, it means that although the contact profilometer gives appropriate information about surface quality in some cases such characterization is not adequate to coating parameters. There is no such problems regarding hot-dip Zn coating because the analyzed surface is more homogeneous - all the after-turning scratches and grooves are filled with Zn - **Fig. 3e, f**. The application of optical systems for surface evaluation requires the proper parameter fitting. If the objective focus depth is too small, the higher parts of valleys and peaks will be cut and the measured parameters will be charged by the relatively high error - **Fig. 3g, h** - lamellar coating, objective 50x, Ra = 1.4µm (instead of 2.01µm). The average roughness values presented in **Table 2** confirms that using optical system we can achieve reliable results regarding coatings surface topography. Roughness values are practically on the same level. A small differences can results from surface diversity. According to the supplier/producer specification ZeeScan system offers the following measuring possibilities: R_a, R_q range: 0.01-500 µm; measuring accuracy: ±10 %; repeatability: less than or equal to 6 % [7]. Roughness values presented in **Fig. 4** and **Table 2** confirms that the determined deviation is on the similar level. Moreover, a contact-type instrument may damage soft surfaces when a sharp stylus tip is used. On the other hand non-contact measurement of surface texture using the principle of white-light interferometry can be used mainly to very smooth surfaces and also in this case the measurement deviation is about 10 %.

4. CONCLUSIONS

1) The Zee Scan system enables getting the reliable results regarding the roughness and waviness of different zinc coating put on steel. At the correctly selected optical system parameters deviation from roughness values measured by contact profilometer is slight and doesn't exceed 10%.
2) The research possibilities of the Zee Scan system are limited by properties of applied optical systems, from the other side the recorded image enlarge research possibilities (image acquisition in bright and dark field, phase contrast, DIC, step height, and histogram).
3) Additional advantage of the system is achieving the focused image in the whole range of depth of focus depending on the objective kind and illumination intensity.
4) A next attribute of the system is the possibility of its adaptation to other kind of microscopes - e. g. stereoscopic, that essentially increase its application.
5) The non-contact measurement of surface texture using the principle of white-light interferometry can be used mainly to very smooth surfaces and even in such case relatively high measure deviation is possible.

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