Resistance of Components to Zinc Plated Against Corrosion

Zdenek Donoval, Robert Prochazka, Miroslav Pristavka, Vladimir Krocko, Plamen Kangalov

Abstract: *In the article we focused on the zinc coating by galvanic zinc coating on the surface of the material for its corrosion resistance. The introduction deals with theoretical knowledge such as material selection, processing, cleaning and surface protection. The next part is devoted to the measurement of the coating thickness using an X-ray machine and corrosion test methods. The article methodology deals about galvanic zinc technologies in the acid bath as well as the technological process itself, the coating thickness tests using the Fisherscope X-RAY XDL-B X-ray apparatus, the coating thickness measurement procedure and the salt spray corrosion test in the Liebisch Labortechnik SKB 1000 AT-R corrosion chamber. The results of the work show the table and the graph of the results of the coating thickness measurements and the evaluation of the corrosion test.*

Keywords: *galvanizing, corrosion, coating, surface protection*

INTRODUCTION

The corrosion requirements claimed on the most diverse machine parts are higher every year. Without surface treatments, it is now impossible to meet these high demands. One of the most widespread methods of surface treatment is galvanizing, which forms the majority of galvanically protected metals [1, 3]. The largest customer in the galvanic industry is the automotive industry, which is largely responsible for the development and innovation of galvanizing. The priority of the automotive industry is to protect components from corrosion under acceptable economic conditions. Just because of the economic reasons, the automotive industry was forced to move from the more expensive corrosion protection systems, with copper and chromium, to a cheaper galvanizing system, saving large sums of money [2]. The article emphasizes the quality of advance preparation of the surface of the components, closer analysis of the galvanic zinc technology, testing of the coating thickness application on the material surface and the tests in the corrosion chamber [5, 7].

MATERIALS AND METHODS

The aim of the article is to acquire new knowledge of the zinc coating application, to bring the zinc coating to the surface of the material by galvanizing and to check the thickness of the zinc layer using the X-RAY Fisherscope XDL-B X-ray unit whether it fulfill the demands of customer. Another objective is to determine the corrosion resistance of the deposited layer by performing a corrosion test in the Liebisch Labortechnik SKB 1000 A-TR corrosion chamber and to check the surface for compliance with the required corrosion resistance. The last part is an overall evaluation of the results of the control of the applied zinc layer thickness and the corrosion test.

Technological process of galvanic zinc coating

The surface of the components supplied for galvanizing is almost always unsuitable for direct coating. This is caused by stuck dirt on the surface, oil residues, corrosion and many other foreign substances and bodies. This surface impurity must be removed because it would make it impossible to produce a high-quality zinc coating with good adhesion to the base material. This is achieved by a sequence of several technological operations: coarse degreasing, pickling, electrolytic degreasing and subsequent surface activation [4].

Sometimes surface machining is also included before these operations. If a perfectly clean surface is not achieved, a high-quality and even zinc coating on the surface of the material cannot then occur. In this case, the coating will have poor adhesion, uneven thickness, appearance defects and reduced corrosion resistance. After the application of zinc on the surface of the material, further operations are performed to increase the corrosion resistance, i.e. passivation and painting.

The technological process itself starts with hanging the parts. The suspension is followed by a coarse chemical degreasing, which is the first stage of surface pretreatment. Coarse chemical degreasing has the task of removing all kinds of stuck impurities from the surface of the material such as substances bound to the surface by physical absorption (grease) and also by substances bound by adhesion forces such as e.g. dust, metal chips. An important feature is also the dissolution of heteropolar compounds (inorganic salts) which are poorly soluble in organic solvents. After gross degreasing, the two-stage cold rinse is followed by clean service water and then the pickling of the components is the next step. Pickling serves to remove impurities that are bound to the surface of components by chemical bonds [6].

Typical representatives of these impurities are hydrated oxides (rust). The action of these strong acids leads to a chemical reaction to form soluble salts (Fig. 1). Most often, the steel is pickled in sulfuric acid or hydrochloric acid. The next step is to re-create the two-stage cold rinse with service water. This is followed by electrolytic degreasing, which is responsible for the highest quality degreasing of the material, so it is placed at the end.

This step is followed by a cold rinse 35 and dripping to activate the material surface. It is the removal of the last impurities (oxidation layers) that have occurred in previous operations. The final step before galvanic plating is the cold one-stage rinse with water.

The actual electrolytic zinc process is carried out in an acid bath. The bath consists of an aqueous solution of potassium chloride and dissolved zinc. Another additive is boric acid to stabilize the pH of the bath. The acidity of the bath must be between pH 5 – 5.5. This operation is only followed by operations that provide a higher surface quality. One of them is a thick layer passivation, which aims to increase the corrosion resistance of the coating. The passivation is followed by rinsing with cold water and warm air drying. The last operation is the hanging from the hinges and the storage of the parts in the shipping pallets [6].

Fig. 1 Galvanizing line

X-ray coating thickness test

Zinc coating thickness tests were performed using a Fisherscope X-RAY XDL-B X-ray apparatus. Fisherscope X-RAY XDL-B is a versatile handheld or automatic layer thickness spectrometer for protective and decorative coatings of various components. It represents another major step in the development of the proven Fisherscope X-RAY XDL-B. The device is equipped with a standard X-ray and a fixed aperture, which is suitable for measurements on larger parts and contains a large number of filters that provide optimum conditions for various measuring applications. The device is particularly suitable for non-destructive thickness measurement and thin film analysis and for the measurement of mass-produced components. High speed of measurement is achieved by using a proportional counter that allows accurate and fast measurement.

The device can analyze a large range of elements, 38 up to 24 from chlorine to uranium. The X-RAY XDL-B spectrometer has excellent long-term stability, which has a major impact on less frequent instrument calibration [6].

Technological procedure for coating thickness measurement.

Prior to measuring the zinc coating thickness of the components, it was necessary to select 20 components that were subjected to surface layer thickness measurements. The components were surface treated with galvanic acid bath. The measurement is performed on a Fisherscope X-RAY XDL-B that is connected to the WinFTM program via pc. In WinFTM it is necessary to set the required measurement parameters, such as coating type, component designation and measurement time. My measurement time was 5 seconds. The next step is to place the component on the Fisherscope X-RAX XDL-B work surface. There is a red laser spot on the desktop that indicates the measurement location. The first measuring point was the center of the part and the second point of the bottom part (see Fig. XX). Subsequently, we started the measurement using a computer and after 5 seconds we saw on the screen the measured values of the coating thickness at the specified measuring points. We did this for all 20 parts. After measuring all of the components, the program printed a protocol in which all parameters of measurement and thickness were recorded [6].

Salt corrosion laboratory tests

The salt mist corrosion test is carried out according to STN EN ISO 9227 /2012 standard, which refers to corrosion tests in artificial atmospheres, namely salt fog tests. Standard STN EN ISO 9227: 2012 This International Standard specifies equipment, reagents and test procedures in neutral salt mist (NSS), in salt mist acidified with acetic acid (AASS) and in salt mist acidified with copper accelerated acetic acid (CASS) to assess corrosion resistance metallic materials with or without permanent corrosion protection. The test for neutral sodium chloride mist is used to:

- Metal and their alloys
- Metal coatings
- Conversion coatings
- Anodic oxidation coatings
- Organic coatings on metal substrates.

The corrosion test was carried out in the Liebisch Labortechnik SKB 1000 A-TR, which is produced of highly resistant laminate, thus it is resistant to all corrosive influences. Small components are made of plastic or stainless steel to ensure maximum equipment life. The chamber features an LCD, low maintenance and very low running costs, and is capable of 24-hour continuous operation 7 days a week [6].

RESULTS AND DISCUSSION

Coating Thickness Test Results

With galvanic plating the components with zinc, but also with other plating technologies, it is very difficult to achieve a uniform thickness of the metallized layer on a product of any shape. In practice, this is impossible, so tolerance aberrances are determined. In our case the customer has determined that the layer thickens should be between 11-22μm. Twenty samples were taken into the assay form two measurements using a Fisherscope X-RAY XDL-B X-ray apparatus. The first measurement point was in the enter of the component and the second point at the bottom of the components. In the table 1 we can see the measured values. The coating thickness test was fulfilled as all values were within tolerance [6].

Table 1 *Measured values*

Assay number	Measured value (point 1) / µm	Measured value (point 2) / µm
1	14.70	21.30
2	12.20	16.90
3	18.30	17.40
4	15.80	19.40
5	14.40	17.20
6	18.50	17.50
7	13.80	15.40
8	19.80	21.10
9	17.70	18.60
10	14.40	17.10
11	11.70	12.40
12	15.70	17.50
13	20.40	18.40
14	13.10	14.10
15	19.50	20.00
16	12.80	15.90
17	12.90	13.40
18	15.70	18.90
19	11.40	15.00
20	17.50	16.40

Corrosion tests results

The corrosion test was performed in the Liebisch Labortechnik corrosion chamber of the SKB 1000 A-TR type. The procedure of the corrosion test was made according to the standard STN EN ISO 9227, which talks about corrosion tests in artificial atmospheres and salt fog tests. Five random samples were tested for corrosion testing. The customer has determined the thickness of the coating and the corrosion resistance of the components. The zinc thickness of the components should be in the range of 11-22 µm, which all randomly selected samples met. The required corrosion resistance to white corrosion was given to customers for 240 hours.

Table 2 *Results evaluation according to STN EN ISO 10 289 standard*

Time	240 hours
White corrosion	**non**
Red corrosion	**---**
Evaluation of appearance change	**- 10/10**
Evaluation	**approved**

Fig. 2 Test samples after 240 hours

A corrosion test performed on five random samples, the results indicates that the required corrosion resistance to white corrosion which has been assigned by the customer. White corrosion was not observed on any test sample, so we can evaluate the galvanic zinc process to be successful.

CONCLUSION

The major problem with steel parts and structures is the damage to the base material by the chemical or physical action of the environment, causing corrosion. Applying a protective layer to the base surface of the material prevents corrosion.

In the present accession, we have questioned the resistance of Zn-coated parts against corrosion. In the first part of the measurements, we measured the thickness of the layer of twenty selected samples in the center of the component and at the bottom of the component. It was determined that the layer thickness should be in the range of 11 to 22 μm. We recorded the measured values in the table and then we constructed the graph.

Consequently, the coating thickness test of twenty measured samples was fulfilled as all values were within the tolerance. In the second part of the measurements, a corrosion test was performed on five randomly selected samples. Since the zinc deposited condition of 11 to 22 μm was met on all samples, the samples could undergo a corrosion test. Customers have been provided with the condition that the parts must remain in the corrosion chamber for 240 hours and white corrosion must not form on the surface of the component. Since there was no white corrosion on the five production samples during the 240-hour corrosion test, this means that the test condition was satisfactory.

In the future, it will be necessary to focus mainly on how to achieve the highest quality applied surface so that the applied layer is as corrosion resistant as possible. Great influence on the amount of applied layer has surface roughness. Optimum roughness values should be sought so that the consumption of zinc is as small as possible and at the same time to ensure the effectiveness of corrosion protection. In the random sample selection, we found an unevenness of the thickness of the applied layer, which was created by placing the parts in the galvanizing bath.

ACKNOWLEDGEMENT

This paper was created with financial support of the grant project Vega no. 1/0718/17 " Study about the effect of technological parameters of the surface coating in agricultural and forestry techniques for qualitative parameters, safety and environmental acceptability."

REFERENCE

[1] Bujna, M., Prístavka, M., Polák, P., Žitňanský, J., Prístavková, M., (2017). Application of fault tree analysis at selected process. In: Bezpečnosť – Kvalita – Spoľahlivosť. Košice. 2017. pp. 37-42 ISBN: 978-80-553-3115-7.

[2] ČSN EN ISO 2081. Kovové a jiné anorganické povlaky: Elektrolyticky vyloučené povlaky zinku s dodatečnou úpravou na železe nebo oceli. Praha: Úřad pro technickou normalizaci, metrologii a státní zkušebnictví, květen 2009.

[3] Hadzima, B. Elektrochemická korózia kovov a ich zliatin. [s.a.] [online] [cit. 2014-12-13].

[4] Kročko, V., Tomáš, J., Drlička, R. (2001). Strojárska technológia 2 (Návody na cvičenia). Nitra: SPU, 2001, ISBN 80-7137-930-1.

[5] Prístavka, M., Beloev, H., (2015). Engineering of Products Quality. 1. vyd., Ruse: Angel Kanchev University of Ruse, 2015. 186s . ISBN 978-954-712-655-8.

[6] Sliška, J., (2015). Odolnosť súčiastok pokovovaných zn proti korózií. [diplomová práca], Nitra, 2015.

[7] Švač, V., Kováč, J. (2009). Korózia kovov a protikorózna ochrana. 2009. [online] [cit. 2014-12-12].

CONTACTS

Zdenek Donoval, Department of Quality and Engineering technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovakia, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia

Róbert Procházka, Department of Quality and Engineering technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovakia, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia

Miroslav Prístavka, Department of Quality and Engineering technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovakia, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, e-mail: miroslav.pristavka@uniag.sk

Vladimir Krocko Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, e-mail: vladimir.krocko@uniag.sk

Plamen Kangalov, Department of Repair and Reliability, Agrarian and Industrial Faculty, University of Ruse, 8, Studentska Str., 7017 Ruse, Bulgaria, e-mail: kangalov@uni-ruse.bg