Journal of Metals, Materials and Minerals. Vol.17 No.2 pp.17-21, 2007

Zn Coatings for Temporary Protection Applied by Peening Technology

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Received Oct. 3, 2007
Accepted Nov. 12, 2007

Abstract

This paper presents actual investigation results of an experiment that aimed at verifying the possibility of applying zinc on steel surface by peening technology using zinc-coated cut wire. A suitable method for obtained zinc layers and evaluation of their corrosion resistance was determined. Accelerated laboratory tests with presence of SO_2 and long term working tests in atmospheric conditions were used. Creation of incoherent zinc coatings was established on the bases of metallographic and spectral analysis. The process of cold zinc by peening may serve as temporary anticorrosion protection of steel surface.

Key words : Zn coating, surface protection, peening technology

Introduction

The surface treatment, in most cases, requires the surface pre-treatment of basic material. The increasing demands on production quality require higher cleanness and quality of the surface for the final surface treatment. Almost all the materials succumb to deterioration due to the influence of the surrounding environment. This is caused by heterogeneous chemical and electrochemical reactions going on between the material surface and the surrounding aggressive environment. Corrosion can be defined as chemical destruction of a material. In the study of corrosion it is necessary to keep in mind various technical and other consequences.(1)

One of the frequently used mechanical pre-treatments of a surface before application of functional as well as protective paints is peening technology. Peening is a sort of mechanical treatment of the base surface where a peening device (hereafter PD) acts as a peening tool and brings about qualitative changes in the surface layers of substrate. This results in the characteristic surface morphology.(2) The peened surface has a high surface activity. In real conditions, its activity decreases very quickly due to chemical adsorption of atmospheric gases and oxidation.(3)

The activity of peened surfaces is influenced by the character of deformation of subsurface layer. Subsurface layer influenced by plastic deformation after peening has higher energetic level in comparison with non-influenced metal. Under the influence of deformation, the quantity of failures in crystal grating increases, and dislocation density rises which increases the ability of metal to react with the surrounding environment.

The deformation helps atoms of metal overcome the metal binding and it allows for them to leave the grate, i. e. it decreases the ion output work. This results in decrease of electrode potential of metal. According to further information, the deformation influences the electrode potential due to changes in absorption ability which is higher on the active places of a metal surface. The strengthened oxygen adsorption leads to the initial potential of anode dissolution and passivation potential.(4, 5, 6) From this, it is possible to be noted that the surface of peened parts is in a very active state. Due to this reason it is necessary to temporarily protect pre-treated surface in this way against corrosion before its coating. There are several possibilities of temporary metal protection, e.g. by passivating electron stream on the metal surface between the anodic and cathodic areas, by creating a physical hydrophobic layer which blocks the direct contact of moisture with the metal surface and thus enters between the metal and electrolyte, by regulation of pH value of the electrolyte, etc.(7)

Zinc coating is one of the metal coatings used for corrosion prevention. The reason why it is used is its higher corrosion resistance in water and its anodic character towards steel. In the primary stage zinc mainly works as sacrified metal and cathodically protects uncovered places of steel. More negative potential of zinc against iron and the majority of other metals enables its use as a protector in the cathodic protection system. Its resistance in atmospheric conditions is much higher than that of other metals. It causes a different mechanism of corrosion stimulators which make contact with metal surface. Moreover, the base material is protected electrochemically on the place of zinc coating failure.[8, 9, 10]

Zinc coatings have been applied by different technologies. Most often they are electro and hot-dip galvanizings. At present, mechanical deposition of zinc layer belongs to less investigated technologies. The works[11, 12] were dedicated to the research of the possibility of zinc coating creation by peening technology. This paper evaluates surface activity of zinc-coated surface and its protective effects in conditions of atmospheric corrosion.

Experimental Procedures

On the basis of the results of present research[4] the experiments aimed at verifying the possibility of applying zinc on steel surface by peening, as well as suggesting a suitable method of evaluation of the zinc coatings and determination of their corrosion resistance. Hot-rolled 3 mm thick low carbon steel sheet 11 375.11 with not pre-treated scaled surface was used as base material. The tested specimens were 150 x 100 x 3 mm. Mono-dispersive peening device (PD) was used for applying zinc coatings (zinc-coated cut wire of size d_{zSD} = 1,12 mm).

Peening was carried out on the mechanical laboratory wheel abrader type Di – 2.

Parameters of peening are:

1. distance of specimens from the throw wheel L = 200 mm.

2. shot velocity v_{TP} = 78,1 m.s^{-1}

3. impact angle of PM α = 30°, 45°, 75°.

The surface roughness after peening was evaluated on the surface analyser Surftest SJ – 301, fy. Mitutoyo, Japan. The average value was Ra = 16 μm. The surface of specimens was peened with a necessary quantity of PM q_{nR} and multiplied quantities for comparison. Destructive gravimetric method according to STN 03 8156 was applied for determination of average thickness of coating deposited on steel surface. The mass of zinc coatings was determined as the mass difference of examined specimens before and after dissolving of coating in the solution.[5] The average thickness of coating was calculated by the expression:

$$s = \frac{(m_1 - m_2).10^4}{A.\gamma} \qquad (1)$$

where m_1 – mass of specimen before dissolving of coating [g]

m_2 - mass of specimen after dissolving of coating [g]

A - surface of specimen with zinc coating [cm^2]

γ- specific mass of zinc [g.cm^{-3}].

The calculation does not consider the actual size of the surface and uniform distribution of zinc coating. A Hitachi S–450 scanning electron microscope (SEM) as well as JOEL JSM-35 CF energy-dispersive spectrometer LINK AN 10000 analyser were used to study the mechanism of creating zinc coating.

The activity of the surface after peening with zinc coated PD was evaluated on the basis of electrode potential changes. The tested specimens were exposed in the interior and the activity of specimen couple was measured as follows: immediately after peening, then after 2, 6, 24 and 48 hours. The resultant value was established as arithmetical mean of the specimen couple. Measurements of the potential were performed against saturated calomel electrode. The arrangement is shown in Figure 1. The specimen couples [3,4] was measured simultaneously; two circuits were switched by a switch.[8] The bridge[6] provided the conductive connection between the electrolyte and specimens. The inner resistance of the apparatus used to measure the potential[7] was 10^4 Ohms. The level of electrolyte was kept at 100 mm above the surface of the samples because the depth of plunge has significant influence on the course of the corrosion process, in which oxygen depolarisation is involved. Distillation water was used as electrolyte.

One-coat of S 2000 paint was applied on the surface peened with zinc-coated peening device. The average thickness of the coating was 52,5 μm. Applying the coating on the samples was performed immediately after peening, then after 2, 6, 24 and 48 hours according to the measurement of the activity of the peened surfaces.

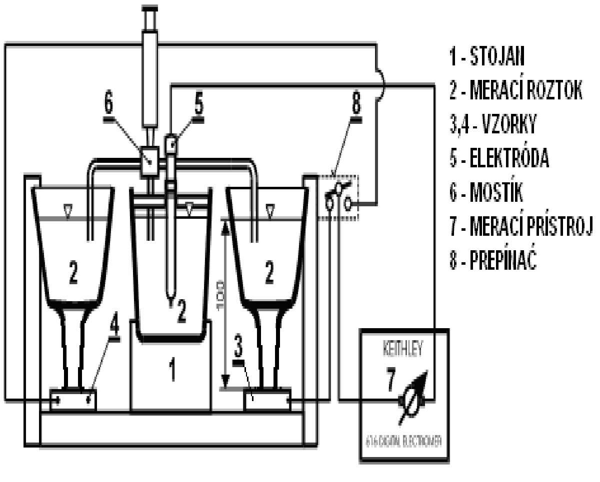


Figure1. Scheme of equipment for electrode potential measurement[5]

To determine the influence of the applied zinc interlayer, the coating adhesion to the base was evaluated by means of the destructive test according to STN EN 24624 standard. ChS EPOXY 1200 glue was used as an adhesive between the test roll and paint. Adhesion was expressed by strength acting in the direction vertically to the surface of the base material, which is necessary to be overcome in order to tear the coating off the base.

The samples with the applied coating were exposed to accelerated corrosion test in the presence of SO_2 and water vapour condensation according to STN ISO 6988. Exposure time was 28 days. Evaluation of the coating appearance was carried out according to STN 03 8103. The coating surface was observed by free eye with description of the occurrence of corrosion manifestations. Microscope observation was carried out by means of the light microscope OLYMPUS BXFM and photographic documentation was performed by the digital camera OLYMPUS C-40 40 ZOOM.

Experiment Results

Creation Mechanism of Zn Coatings

Observation of the surface of peened samples by SEM has shown the occurrence of a non-contiguous zinc coating on the steel base, Figure 2 Energy-dispersive records of surfaces, Figure 3 also confirmed the presence of zinc on the surface of the samples.

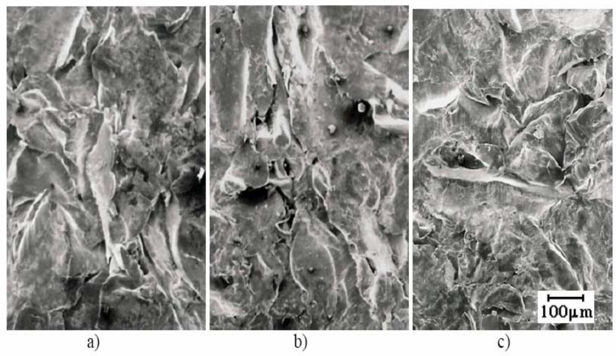


Figure 2. The surfaces after peening with galvanized PD at various impact angles

Uneven distribution of zinc coating can be ascribed to adhesion of randomly oriented grains of the galvanized cut wire after falling onto the steel surface because zinc coating was formerly only around the perimeter of the cut wire. Repeated falling of PD grains may destroy the already created coating or push it back into the material and thus cause total non-contiguity of the coating.

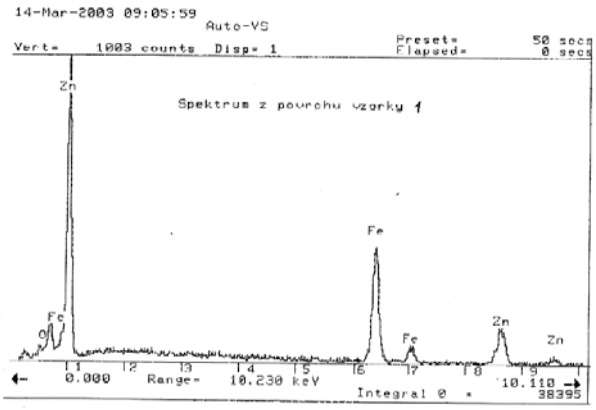


Figure.3 Energy-dispersive record of surface after peening with galvanized PD

It is possible that the transposition of the material surface layer causes different cracks and hacks depending on the used angle. The maximum average thickness of zinc coating was determined at the impact angle of 75°. Coating thickness increased with the mass of necessary quantity of PD.

Evaluation of Surface Activity

Results of measuring the electrode potentials by means of the calomel electrode, which can be considered as the so-called reference electrode, are graphically displayed in Figure 4 By comparing the measured values in dependence on exposure time of the samples in the atmosphere we can say that the highest values of the potential were found out immediately after peening. Increase in exposure time causes decrease in surface activity.

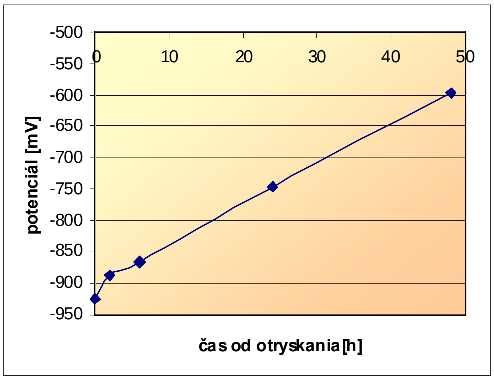


Figure 4. Course of electrode potential changes in dependence on exposure time of specimens

Evaluation of Paint Adhesion

Adhesion of paint was evaluated in dependence on the period from peening with zinc-coated PD until the next paint application. The measured values of adhesion, Figure5, do not at all correspond with the established values of the surface activity. The reason of this anomaly may be the presence of ZnO under the applied coating, which has not been confirmed yet.

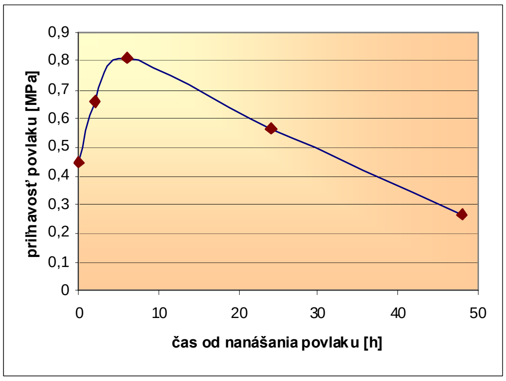
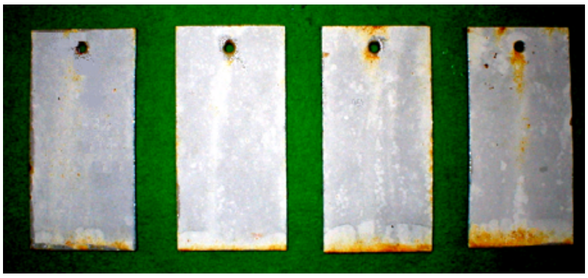


Figure 5. Adhesion changes in dependence on time from painting application

Corrosion Resistance of Coating

Corrosion test in condensation chamber was carried out in accordance with the standard STN ISO 6988. The tested specimens were exposed to the influence of water vapour in the presence of SO_2. The influence of the zinc coating applied by peening on corrosion resistance of the upper paint layer was evaluated. The symptoms of corrosion attack after the first day of exposure in the condensation chamber were observed in those specimens, which were covered with paint after 48 hours. In this series of specimens mild pitting corrosion occurred. On the third day of the exposure, corrosion of zinc was found on the sample surfaces along with the occurrence of ZnO, Figure 6. The longer was the time passed from the surface peening until applying the coating the greater was the extent of the so-called white rust, which manifested itself.



(a) (b) (c) (d)

Figure 6. Appearance of samples after exposure to corrosive environment – application of paint a) immediately after peening , b) after 2 h, c) after 6 h, d) after 24 h

Conclusions

The results of the experiments show that by applying the technology of cold zinc coating by peening with galvanized PD it is possible to create a zinc coating on the surface of a steel substrate. Applying zinc coatings by peening takes place simultaneously with the process of scale removing, as well as the processes of surface roughening and surface hardening. The destructive gravimetric method used to determine zinc-coating thickness appears to be as suitable. The angle of the PD impact also influences the thickness of coatings created by peening technology. The maximum thickness of zinc coatings was reached at an impact angle of 75°.

The submitted paper presents the first experimental results of the evaluation of the activity of the surface created by peening with galvanized PD. The increase in exposure time brings about the decrease in surface activity as a result of chemical reactions between the surface and the surrounding atmosphere. The method of electrode potential measurement against saturated calomel electrode appears to be suitable, however, it is necessary to consider oxygen depolarisation.

On the basis of the experimental results we can say that adhesion of paint depends on the time between surface peening and the following application of coating. Zinc interlayer influenced the properties of the whole paint system, both adhesion and its anticorrosion protection.

The aim of the experiment was to determine the function of zinc interlayer on adhesion of the subsequently applied paint and anticorrosion protection of the created paint system. The obtained results confirmed that zinc coating applied by peening could be used as temporary protection of the surface and simultaneously as the surface pre-treatment with possibility of the subsequent surface treatment of the material. With respect to the price of peened media the economic consideration of suitability of the given technology for temporary surface treatment of metal surfaces will be the subject of the further work.

Acknowledgements

This research was supported by grants VEGA No. 1/2203/05.

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