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PRODUCTION OF ZINC COATINGS BY ELECTRO-SPARK DEPOSITION

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Abstract: The paper describes the method of producing a zinc coating on steel by electro-spark deposition technology. The technology of applying electro-spark zinc to the surface was presented. Microscopic observations and corrosion resistance tests were made. The possibilities of practical application of this type of coatings in the process of repairing zinc coatings, either damaged or with manufacturing defects, were analyzed.
Keywords: electro-spark deposition, coating, microstructure, corrosion resistance

1. INTRODUCTION

Zinc is most current metal for anticorrosion protection in steel constructions. It was first used in 18th century and now we know many methods zinc coatings covering, for example (Maass et al., 2011; Depczyński, 2001; Depczyński, 2004):

- hot-dip,
- galvanizing,
- diffusion,
- spraying.

The electro-spark deposition method is one of surfacing engineering tools (Radek et al., 2009) on steel (Radek et al., 2014) or titanium (Chang-bin et al., 2011) core material. Many investigations were focused on WC-Co coatings (Burkov and Pyachin, 2014; Salmaliyan et al., 2017). It does not mean leaving traditional methods in cases, when using of them is rational under economical and technical considerations. Advantages of this method decided on its using in wide range of surfaces treatments, in particular:

- local interaction possibility,
- deposition of thin tight coatings (from 1 μm) and thick coatings (up to 100 μm) from any metallic materials,
- simple and cheap system for coatings deposition.

Now, electro-spark treatment has established position in coatings techniques. Wide practical applications are confirmed from enhancing of typical tools to bio-resistive implants and hi-tech construction tools. Electro-spark coatings also have some disadvantages, which cause deterioration of the obtained coating properties (porosity, roughness).
The operational scheme of the zinc layer formation on the surface of metal is shown in Fig. 1.

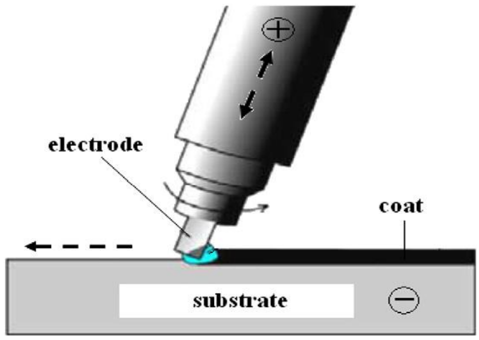


Fig. 1. Scheme of the zinc layer formation on the surface of metal

Hot-dip zinc coating has to conform technical specifications of standard DIN 50976. This does not include local damage that precludes the use of this coating in practice (Mass et al., 2011). Usually, before selling, the manufacturer makes corrections to areas where there is no zinc coating (Depczynski, 2011; Depczynski, 2004).
The choice of surface conditioning method depends on the operating conditions and these are::

- zinc thermal spraying,
- coat, based on zinc dust (at least 92%), made from epoxy resins or polyurethane resins, or ethyl silicate with zinc dust,
- for small defects, coating by soldering methods from a special soft alloy;
- zinc or aluminum foil coating.

In most cases, surface preparation is required before recoating. For soldering coating, the efficiency is the lowest while the highest quality is obtained by spraying coating.
It seems that above arguments are logical when using the test of electro-spark depositions method. In this case the preparations surface and special materials are unnecessary. The coating is from the same materials as in galvanizing bath.

2. METHODOLOGY

In experiment, MHD alloy (Zn with Al, Ni) was used for coating deposition. An electrode, matched to the installation in terms of form and size, was made from this alloy. A device made in Ukraine (model EIL-8A) was used for electro-spark deposition. The following operating parameters were used in experiment:

- capacity C = 150 μF,
- current intensity I = 0.7 A,
- voltage U = 230 V,
- deposition time τ = 2 min/cm^2.

Base material was C45 steel prepared in mechanical mode. The working area has been sanded with sandpaper (gradation 220) and then blown with compressed air.

Experiment was made in two variant: 1 – without shielding gas, 2 – with argon blow-in. The coating was applied manually under the operator's visual control. The process was terminated when the operator decided that the repair was complete.

3. RESULTS AND DISCUSSION

Microstructures observations was made in the JEOL 5400 scanning electron microscope (magnification 350x - 5000x). Adhesive coatings were observed in the range of 15 to 35 μm (Fig. 2). At higher magnifications, porosity is observed, but the pores are closed. The surface of this coating has a strongly developed shape (Fig. 3).

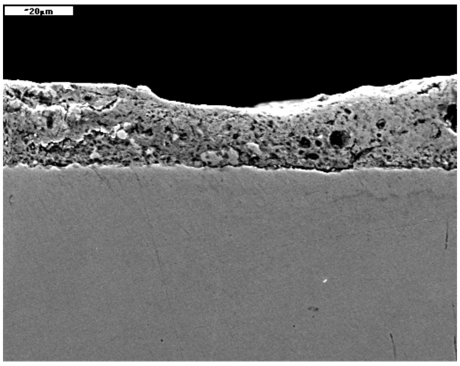
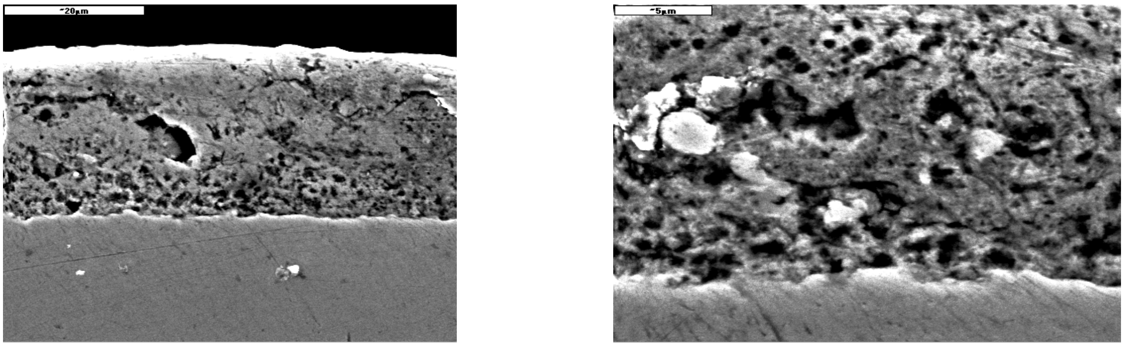


Fig. 2. Microstructure of electro-spark deposited Zn coating



x2000 x5000

Fig. 3. Microstructure of electro-spark deposited Zn coating

An analysis of the line scan, performed normally to the surface, showed the distribution of Fe and Zn elements important for coating (Fig. 4). The diagram shows a small diffusion zone. This fact is advantageous because the coating has better adhesion. Presumably, the size of this zone can be controlled by process parameters.

The corrosion resistance of the samples was analyzed using the Atlas'99 computer electrochemical testing system (manufacturer Atlas-Sollich). The potentiodynamic method was used because it is considered one of the most effective methods of electrochemical testing. Samples with a zinc coating applied by electro-spark deposition under ambient conditions and argon shielding were tested, as well as a sample cut from hot-dip galvanized sheet.

The cathode polarization curve and the anode polarization curve were determined by polarizing the samples with a potential shift rate of 0.2 mV/s in the range of ±200 mV of the corrosive potential, and with 0.4 mV/s in the range of higher potentials. Samples with a marked area of 10 mm in diameter were polarized up to a potential of 500 mV. The polarization curves were drawn for samples exposed for 24 hours to a 3.5% NaCl solution so that the corrosive potential could be established. The tests were performed at 21±1°C.

The corrosion resistance results are shown in Fig. 5.

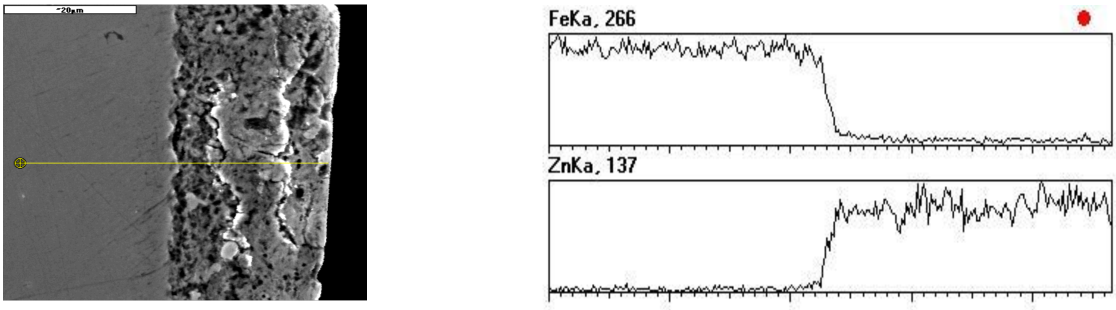


Fig. 4. Microstructure and linear distribution of elements
in the electro-spark deposited Zn coating

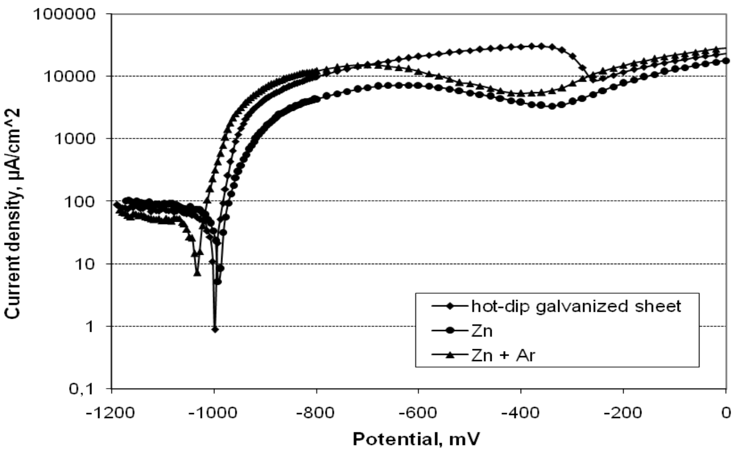


Fig. 5. Polarization curves of the zinc coatings

Table 1
The values of current density and corrosion potential of the tested samples

Material	Corrosion potential [mV]	Corrosion current density [μA/cm^2]
hot-dip galvanized sheet	-1000	76
C45+Zn	-990	98
C45+Zn(Ar)	-1040	64

The highest corrosion resistance was demonstrated by a zinc coating made in argon shield, with a corrosion current density of 64 μA/cm^2. The zinc coating applied in the ambient atmosphere had I_{kor} = 98 μA/cm^2, while samples made of hot-dip galvanized steel sheet had a corrosive density of 76 μA/cm^2. The roughness of the electro-spark coatings had an effect on the corrosion resistance results. Zinc coatings applied in an argon shield had a roughness Ra = 4.51÷6.86 μm, while zinc coatings applied in an ambient atmosphere had a roughness of 8.50÷11.90 μm. The characteristic electrochemical values of the tested materials are presented in Table 1.

3. CONCLUSION

Three main conclusions can be made:

1. Coatings with a thickness of 15÷35 μm applied by the electro-spark treatment give the possibility of using this technology to repair hot-dip galvanized products.
2. The use of protective gas in the form of argon in the application of electro-spark coatings reduces the roughness and increases the corrosion resistance of the layers produced.
3. Obtaining layers with a thickness of 100 μm will allow the application of the electro-spark deposition as an independent method of zinc coating. In conjunction with robotic machining, this will be a method of securing elements, e.g. of a complicated shape and at the same time made of materials that cause significant difficulties in hot dip galvanizing (e.g. Sandelin effect).

The obtained results may be very useful for many branches of industry, where damaged anti-corrosion coatings may be found e.g. fuel cells (Wlodarczyk et al., 2011), medical supplementary tools and equipment (Pawlowska et al., 2017), power plant infrastructure (Osocha, 2018) or steelworks (Ulewicz et al., 2013; Maszke et al., 2018). Aggressive corrosive environments are also a premise for applying this repair method in biotechnology (Skrzypczak-Pietraszek et al., 2018a; Skrzypczak-Pietraszek et al., 2018b; Skrzypczak-Pietraszek et al., 2019). Similar corrosive media are found in hydraulic actuators so this repair method should be considered in design (Domagala, 2013; Domagala and Momeni, 2017), production (Filo, 2013; Filo, 2015), maintenance (Domagala et al., 2018a; Domagala et al., 2018b) and repairing (Fabis-Domagala, 2013; Fabis-Domagala and Domagala, 2017) of heavy-duty machines.

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