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Influence of chloride ions on various corrosion resistance of zinc coating

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Abstract: Corrosion is one of the major causes for global crisis concerning the loss of materials resources and energy. It is also the cause of significant economical loss in many countries. Certain measures can be taken to minimize this problem, which is the first and foremost goal of this research work. The objectives of this study are to investigate respective aspects of chloride ions influence on various galvanic properties of zinc coating. Those included: corrosion resistance properties, the effects different concentrations of chloride solutions thereon, also the properties of galvanically deposited zinc in a variety of coating thicknesses with respect to corrosion resistance of galvanically deposited zinc in chloride solutions and the influence of chloride ions on the zinc coating given by different technologies, as warm and galvanic processes, analysis of their properties on corrosion resistance. All tests were performed with potentiostat/galvanostat Model 263A, guided by potentiodynamic polarization and linear polarization method.

Based on the results presented in this research work, it is concluded that despite the costs the corrosion protection is the most effective way to prevent material loss.

INTRODUCTION

Based on the data of industrially developed countries, corrosion damage can get up 1-3% of national income. In some countries, the corrosion damage is included in the values of national currencies. However, this data is quite unreliable since collateral damage (e.g. accidents, loss of life and loss of production) is not correspondingly measured by money (national currency), and often it cannot be even adequately expressed. Complete protection of metals and alloys from corrosion is almost impossible, but certain measures can be taken to minimize the problem, namely: the choice of material, construction methods, change of the environment, coating. (Dobovišek, 1968; Potter, 1968. Franz *et al.*, 1980. Jelic *et al.*, 2007.)

MATERIALS AND METHODS

The necessary durability of metal structures against corrosion can be determined by studying and defining the basic laws of corrosion processes and also analyising tests of corrosion resistance in a variety of environments. The application of different metals and alloys under unfavorable conditions, which change during exploitation, require testing under different non-destructive and destructive methods in order to evaluate their corrosion resistance. These include: visual inspection, identification of the mechanism and vision and corrosion, determination of the type and composition of the isolated products of corrosion, corrosion rate measurement and penetration depth of damage, loss or gain of mass, examining changes in mechanical properties.

Before each test, it is important to determine the real objectives of the examination, and according to that to make a choice of the most suitable methods for the assessment of damage caused by corrosion.

The purpose of such tests is to solve certain practical problems. (Dobovišek, 1968.; E. Potter C., 1968.; Filipovic, I. *et* Sabioncello, P. 1960; Martinez, S., 2007; Susic, M., V., 1980.)

Performance testing

To test the corrosion resistance of zinc we used five standard solutions of NaCl. Determination of chloride was carried by Mohr procedure and obtained values are presented in Table 1.

Table 1. Concentrations of Cl^- - ions in solutions

MARK SOLUTION	CONCENTRATION of Cl^- ions [g / L]
I	0,02
II	0,03
III	0,05
IV	0,60
V	3,03

All the electrochemical measurements were performed by potentiodynamic and linear polarization method. We used potentiostat/galvanostat Model 263A, connected to the software package Model 270/250 Research Electrochemistry Software 4.30. When performing the tests the temperature was adjusted to a 20°C using RC5 thermostat Lauda. Before each test, the experimental conditions were adjusted accordingly.

All tests were carried out in a standard electrochemical cell, equipped with three electrodes, zinc (electrochemical and chemical process the coating, as well as varying thickness galvanically applied zinc) as the working electrode, silver-silverchloride as the reference electrode and platinum as an auxiliary electrode. Before testing, each electrode had to be adequately prepared.

Auxiliary (platinum) electrode:

Isolated with teflon tape, only the specific surface area had undergone the examination. Electrodes were prepared by sanding the surface with sandpaper of a different fineness (200-600), then polishing it with aluminum oxide powder and finally rinsing it with distilled water.

Working (zinc) electrode:

Isolated with teflon tape, only the specific surface area had undergone the examination, then the surface of electrodes was measured.

The first test was conducted using potentiodynamic polarization method. Measurement has to begin by establishing a stable value of the potential open circuit, i.e.by potential that is 250 mV more negative than the corrosion potential, and ends at a potential that is 250 mV more positive than the corrosion potential.

The testing was then conducted using linear polarization with the same sample. Measurement begins with establishing a stable value of the potential open circuit, the potential that is 30 mV more negative than the corrosion potential, and ends at a potential which is 30 mV more positive than the corrosion potential.

Experimentally obtained values of the current and the potential are shown as semilog E – log *i*, also known as Tafel display.

The obtained values in Tafel diagrams and polarization curves, have helped to determine the corrosion current density, corrosion potential and polarization resistance. Therby the insight on the intensity of the corrosion process is provided as well as the corrosion behavior of a particular material in a particular environment.

After the tests, the preparation is carried out again, and the process is repeated for all samples.

RESULTS AND DISCUSSION

Influence of chloride ions on galvanic zinc coatings

The behavior of galvanic zinc coatings (thickness of about 40 µm (60 min. zinc galvanized)) at different concentrations of chloride-ions in water: 0.02 g / L, 0.03 g / L, 0.05 g / L; 0.60 g / L, 3.03 g / L was analysed

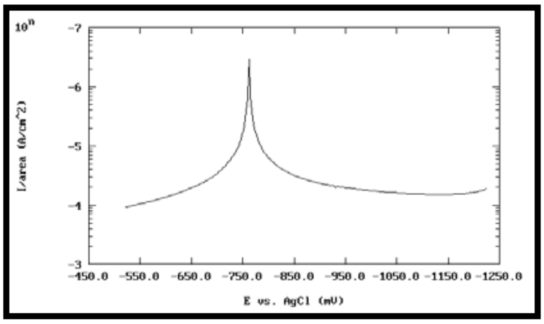

Figure 1. Tafel diagram for galvanic zinc in solution Cl^- - ion concentration. 0.02 g / L

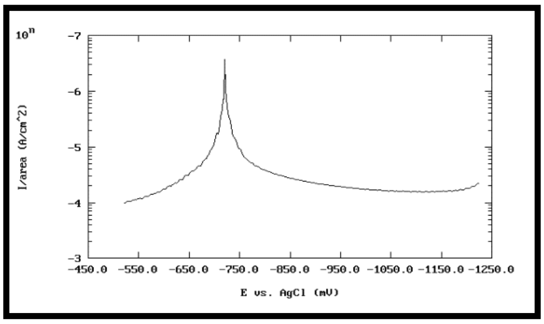

Figure 2. Tafel diagram for galvanic zinc in solution Cl^- - ion concentration. 0.03 g / L

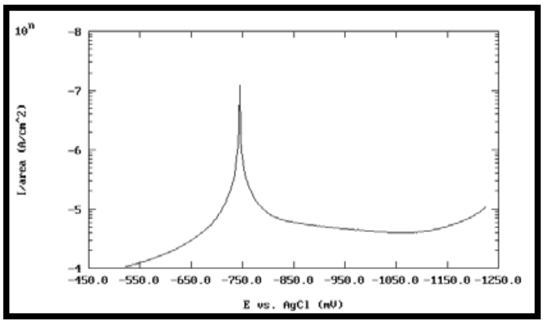

Figure 3. Tafel diagram for galvanic zinc in solution Cl^- - ion concentration. 0.05 g / L

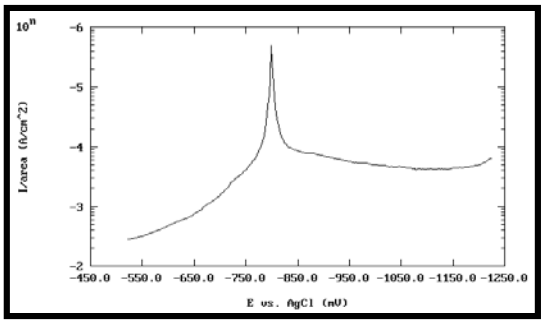

Figure 4. Tafel diagram for galvanic zinc in solution Cl^- - ion concentration. 0.60 g / L

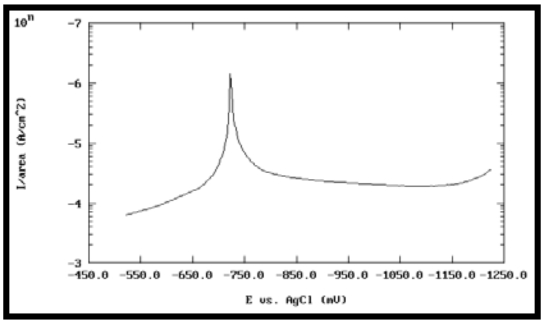

Figure 5. Tafel diagram for galvanic zinc in solution Cl^- - ion concentration. 3.03 g / L

Previously obtained results are presented table 2.

Table 2. Influence of Cl^- - ions on the speed corrosion

CONCENTRATION Cl^- - ions [g / L]	POTENTIAL CORROSION [mV]	POLARIZATION RESISTANCE [mV/A]	DENSITY CORROSION CURRENT [mA/cm^2]	SPEED CORROSION [mm/yr.]
0,02	- 740	9 x 10^7	3,66 x 10^{-4}	0,0055
0,03	- 698	8 x 10^7	4,48 x 10^{-4}	0,0067
0,05	- 722	5 x 10^7	8,85 x 10^{-4}	0,0132
0,60	- 776	8 x 10^6	2,15 x 10^{-3}	0,0321
3,03	- 700	2 x 10^6	2,09 x 10^{-2}	0,3126

Influence of thickness of galvanic zinc on the corrosion resistance

The behavior of galvanic zinc coatings of different thickness such as 40 µm (60 min. zinc galvanized), about 30 µm (45 min zinc galvanized), and about 25 µm (30 min. zinc galvanized), in solution Cl^- - ion concentration 0.60 g/L was analysed and presented in Figures 6,7, and 8.

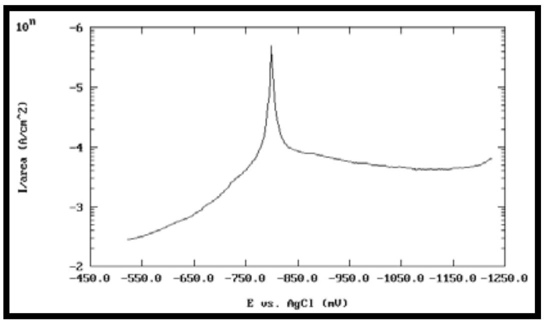

Figure 6. Tafel diagram for galvanic zinc thickness of about 40 µm

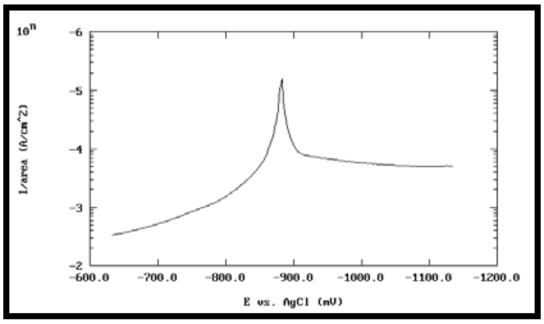

Figure 7. Tafel diagram for galvanic zinc thickness of about 30 µm

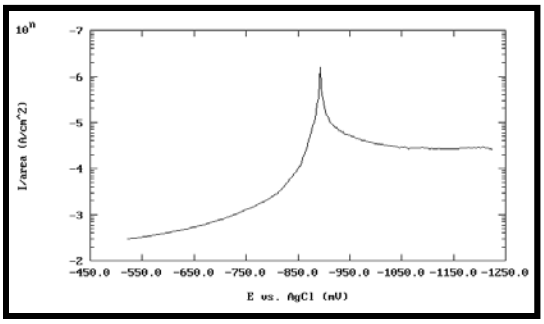

Figure 8. Tafel diagram for galvanic zinc thickness of about 25 µm

Previously obtained results are presented table 3.

Table 3. Influence of coating thickness on the speed corrosion

THICKNESS OF PROTECTION [µm]	**POTENTIAL CORROSION [mV]**	**POLARIZATION RESISTANCE [mV/A]**	**DENSITY CORROSION CURRENT[mA/cm^2]**	**SPEED CORROSION [mm/yr.]**
about 40	- 776	8 x 10^6	2,15 x 10^{-3}	0,0321
about 30	- 860	7 x 10^6	3,64 x 10^{-3}	0,0545
about 25	- 870	2 x 10^6	1,07 x 10^{-2}	0,1600

Influence of various technologies used for applying zinc coating on the corrosion resistance

The behavior of various technologies used for applying zinc coating (chemical process the coating, thickness coating of about 100µm and electrochemical process the coating, thickness coating of about 40µm) in a solution of Cl^- - ion concentration 0.03 g / L was tested and presented here.

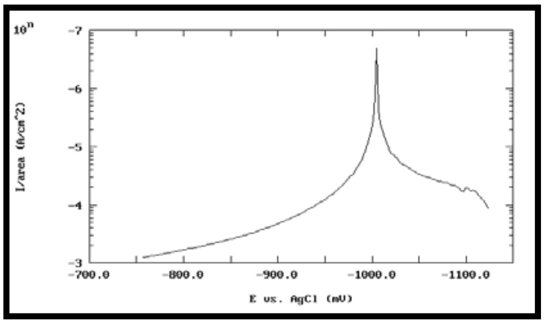

Figure 9. Tafel diagram for chemical process the coating, thickness coating of about 100 µm

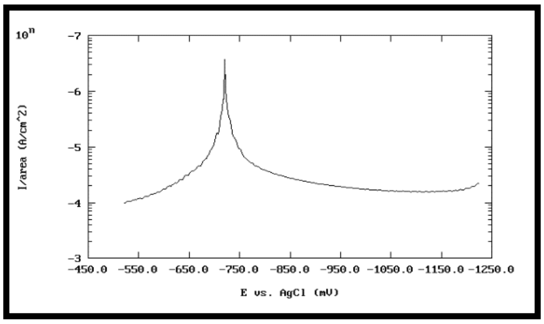

Figure 10. Tafel diagram for electrochemical process the coating, thickness coating of about 40 µm

Previously obtained results are presented in table 4.

Table 4. Influence of technologies coatings on the speed corrosion

APPLICATION OF PROTECTION	**POTENTIAL CORROSION [mV]**	**POLARIZATION RESISTANCE [mV/A]**	**DENSITY CORROSION CURRENT[mA/cm^2]**	**SPEED CORROSION [mm/yr.]**
chemical process	- 982	9 x 10^7	3,96 x 10^{-4}	0,0059
electrochemical process	- 698	8 x 10^7	4,48 x 10^{-4}	0,0067

CONCLUSIONS

The results of the chloride ions effects that was present in concentration range between 0.02 g/L and 3.03 g/L showed that increasing concentration of chloride ions in aqueous solutions caused the increase in the corrosion rate and therefore a decrease of lifetime of the protected structures.

The results showing corrosion resistance of various thicknesses of the galvanic zinc coatings of about 25 µm up to about 40 µm, showed the direct correlation between the increased thickness of the zinc coating and the reduction of corrosion rate. It is also seen that the corrosion potential of thinner zinc layers show trends toward the more negative values, summarizing that the lower the thickness of zinc layers, the higher their corrosion tendency. Therefore, increasing coating thickness leads to a longer lifetime of the protected structure.

The results of the corrosion resistance test, chemical and electrochemical coating process, showed that the rate of galvanic corrosion of zinc deposited to about 40 µm thickness approximately equal to the rate of chemical coating process corrosion of zinc deposited about 100 µm thickness. We showed the positive potential of the galvanic zinc corrosion, reciprocally equals its low galvanic corrosion tendency.

Based on the results presented in this work, we conclude that the zinc coating produced in a galvanic process is much more compact and resistant structure than that achived in the hot-dipped zincing procedure.

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Summary/Sažetak

Korozija je danas jedan od važnih uzročnika svjetske krize materijala i energije i uzrok je znatnih gubitaka u privredi svake zemlje. Izvjesne mjere se mogu preduzeti da se poblem minimizira, što je prvenstveno i cilj ovog rada.

Ciljevi ovog istraživačkog rada bili su da se ispita uticaj hloridnih jona na galvansku pevlaku cinka, praćenjem osobina (korozione otpornosti) galvanske prevlake cinka u rastvorima hlorida različitih koncentracija, uticaj hloridnih jona na različite debljine prevlake, galvanski nanešenog cinka, praćenjem osobina (korozione otpornosti) različitih debljina galvanski nanešenog cinka u rastvoru hlorida i uticaja hloridnih jona na cinkovu prevlaku dobijenu različitim tehnologijama, topli i galvanski postupak nanošenja cinka, praćenjem osobina (korozione otpornosti) tople i galvanske prevlake cinka u rastvoru hlorida.

Sva ispitivanja su vršena na potenciostat-u/galvanostat-u Model 263A, vođena potenciodinamičkom polarizacionom metodom i linearnom polarizacionom metodom.

Na osnovu dobijenih rezultata, prezentiranih ovim istrazivačkim radom, došlo se do zaključka da je efektivna koroziona zaštita skupa, ali nikakva zaštita je neuporedivo skuplja.