EVALUATION OF ELECTROCHEMICAL PROPERTIES OF STEEL SHEETS FOR AUTOMOTIVE APPLICATIONS

J. Koncz, J. Brezinová, D. Draganovská, J. Viňáš

Technical university of Košice, Faculty of Mechanical Engineering, Department of Mechanical Technologies and Materials, Mäsiarska 74, 040 01 Košice, Slovakia

Abstract

Galvanizing as a process of zinc coating of base material is still the most widely used technology applied in surface treatment of materials which are supposed to meet the requirement of high corrosion resistance in various environments. This article presents the results of research aimed at determining the corrosive properties of galvanized sheets in selected environments – distilled water, NaCl and SARS solution, using electrochemical potentiodynamic test.

Introduction

Galvanized sheets are currently used in the construction of vehicle bodies. Even though the vehicle bodies in production undergo through number of processes (cataphoresis bath, painting) which are able to protect their surface from the effects of external influences, it is important that the material itself achieves required anti-corrosion properties. This will ultimately further improve the overall corrosion resistance of the vehicle body. [1-2] This characteristic of the base material applies in mechanical damage of the vehicle body when the layers of covering, filling paint and cataphoresis are not able to fulfil their protective purpose. In such cases the corrosion is partially or fully suppressed by zinc coating which due to its lower electrode potential compared to steel corrodes preferentially. [3]

In zinc coatings the real rate of corrosion is different depending on the current corroding phase. The top most η-phase which is formed by 100% zinc corrodes faster than other phases formed by zinc with a certain content of iron. In steady environmental conditions the rate of zinc corrosion is almost linear. Real environmental conditions, however, are unstable due to the large amount of factors influencing them, such as air temperature, relative humidity, the degree of pollution, etc. Therefore the corrosion aggressiveness of the atmosphere is different at different places. In Slovakia there are C2 categories for rural and urban environments and C3 for industrial environment (categorization according to STN EN ISO 9223). The corrosion resistance of hot-dip galvanized sheets is influenced by other factors such as compliance with technological conditions of the manufacture of zinc coating, structural aspects, etc. [4 - 6]

Materials and methods

For experimental work steel sheet DX54D + Z (EN 10142/2000) was used, producer U.S. Steel Košice (ZINKOHAL 220). This is hot-dip galvanized sheet with zinc coating in which the minimum two-sided coating weight is 140 g.m^{-2}. Chemical and mechanical properties of experimental sheet are shown in Table 1. Surface treatment of the sheet has internal reference MB which means that it is a small texture of zinc and an improved surface according to EN 10 142/2000, without further surface treatment.

Table 1 Chemical composition and mechanical properties of DX54D + Z sheet

	Chemical composition in %							
Material	C_{max}	Mn_{max}	P_{max}	S_{max}	Al	Ti	N_{max}	Fe
ZINKOHAL 220	0.015	0.02	0.015	0.015	min. 0.02	0.06-0.14	0.006	bal.

	Mechanical properties		
Material	$R_{p\,0.2}$ [MPa]	R_m [MPa]	A_{min} [%]
ZINKOHAL 220	max 220	max 350	36

The samples were exposed to three different environments – distilled water with pH=7, 0.1M solution of sodium chloride and SARS solution.

- *0.1 M solution of NaCl* – it is 0.1 M solution which with the molar mass of NaCl of 58.44 g/mol constitutes 5.84 grams of sodium chloride per litre of distilled water. This solution was chosen because NaCl is the most commonly used gritting material for winter maintenance of roads and therefore comes into contact with the vehicle body, especially chassis parts most commonly.
- *SARS solution* – this solution simulates the slightly acidic atmospheric rain with pH=5 which comes into contact with vehicle body in so-called wet acid deposition from atmosphere.

Measurement of potentiodynamic curves was carried out using potentiostat SP 150, of Bio-Logic Science Instruments Company and processed in EC-Lab V10 software. As the reference electrode there was the calomel electrode with constant potential E = 0.242 V connected to the device and as the auxiliary electrode platinum electrode was used. Corrosion cell with an opening of 1.065cm^2 ensured a firm grip of measured sample and its contact with the electrolyte. Circuit diagram for the measurement is shown in Fig.1. The connection of the corrosion cell to the potentiostat is shown in Fig. 2. The outcome of the measurements were potentiodynamic polarization curves rendered in semi-logarithmic coordinates and gradients of anode and cathode dependence were determined using Tafel analysis.

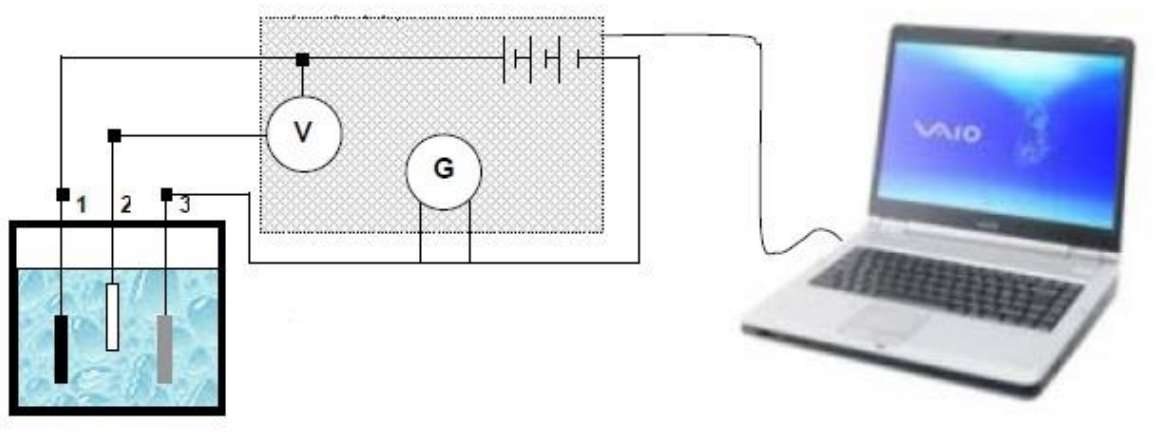

Fig. 1 Circuit diagram for the measurement of potentiodynamic curves
1 – metal sample, 2 – reference electrode, 3 – auxiliary electrode

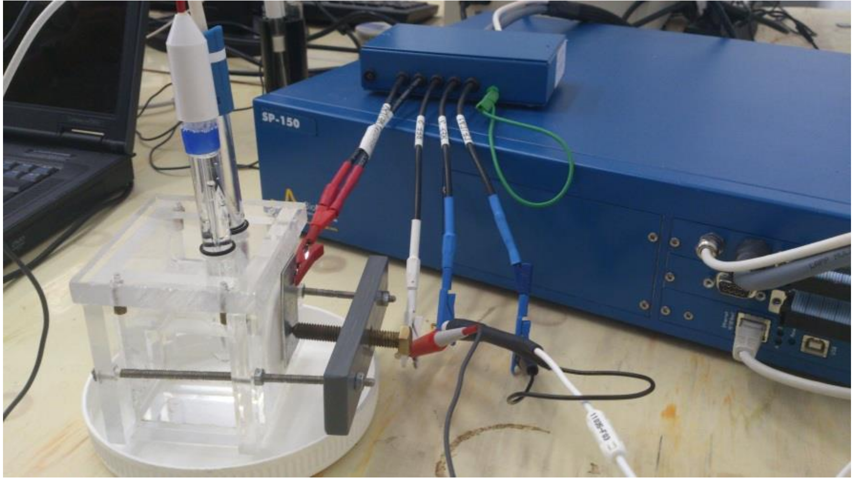

Fig. 2 Connection of corrosion cell to potentiostat

Results

The experimental samples were clamped and sealed in the corrosion cell and after application of the electrolyte checked for the presence of air bubbles. Establishment of the sample ran at the temperature of 20°C. After 10 minute establishment the values of free potentials were as follows:

- distilled water: - 0.7829 V, corrosion potential Ecorr = -782 mV, corrosion current density icorr = 1.470 µA, difference of reduction and oxidation speed was very small.
- 0.1 M NaCl solution: - 1.0137 V, corrosion potential Ecorr = - 1 014 mV, corrosion current density icorr = 25.82 µA.
- SARS solution: - 0.9813 V, corrosion potential Ecorr = -981.27 mV, corrosion current density icorr = 14.31 µA.

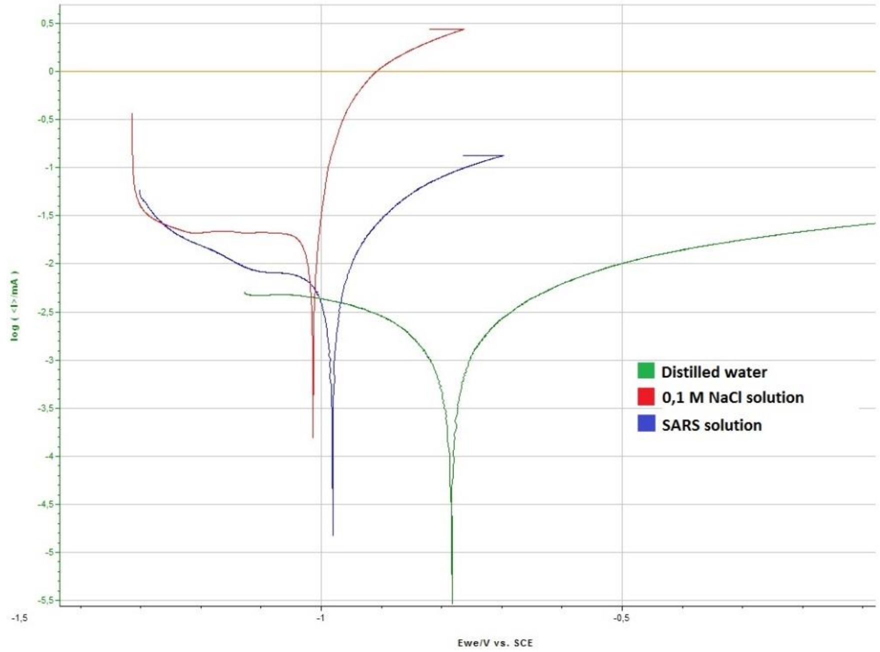

Fig. 2 Potentiodynamic polarization curves of measured samples

Based on entered data such as area of electrolyte effect S (1.056 cm^2), atomic weight M of the material coming into contact with electrolyte (zinc = 65.380 g/mol) and density of the material coming into contact with the electrolyte (zinc = 7.14 g/cm^3) and based on the measured values of corrosion potential and current density we determined the corrosion rate of the material in selected environment. Corrosion rate values obtained by software were as follows:

- in distilled water environment: 0.0417 mm/year,
- in 0.1 M solution of NaCl: 0.7326 mm/year,
- in SARS solution: 0.4059 mm/year.

The graph in Fig. 2 shows potentiodynamic polarization curves of all three measured samples. From these graphs it can be determined with certainty even without using Tafel analysis that the corrosion rate will be highest in the environment of 0.1 M solution of NaCl while the slowest rate of corrosion will be present in the environment of distilled water.

Conclusion

Presented article deals with the analysis of corrosion properties of hot-dip galvanized vehicle body sheets in selected environments. Experimentally obtained results point to the fact that sodium chloride used as most common gritting material for winter maintenance of roads is at concentration of 5.84 g NaCl in one litre of distilled water rather aggressive towards the exposed samples. Oxidation of samples in such electrolyte strongly dominated over the reduction and corrosion rate stabilized at 0.732 mm/year. Although less pronounced but still dominating oxidation reaction was observed in sample exposed to SARS solution, a solution simulating acid rain. In this case the aggressiveness of the environment was supported by nitric acid which is very corrosive, its concentration was however so low that the value of corrosion rate of the exposed sample was 0.4

mm/year. As expected, the lowest corrosion rate was recorded in neutral distilled water where the very small and indistinctive dominance of oxidation resulted into value of only 0.04 mm/year.

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ЛАЗЕРНА УДАРНО-ХВИЛЬОВА ДІЯ НА ВЛАСТИВОСТІ ПРИПОВЕРХНЕВОГО ШАРУ ЗВАРНОГО З’ЄДНАННЯ ІЗ АУСТЕНІТНОЇ СТАЛІ

М.І. Підгурський, Ю.М. Нікіфоров, Б.П. Ковалюк, В.В. Лазарюк, М.Г. Грещук, Х. Лопез[*], Б. Чарч[*]

Тернопільський національний технічний університет імені Івана Пулюя,
Тернопіль, Україна
[*]Університет Вісконсин-Мілуокі, США

The authors have researched the weld joints of austenitic stainless steel 12X18H10T after laser shock wave treatment of the welded joint surface, heat affected area and base metal. The character of the structure and microhardness changes in the weld joint exposed areas in crossing has been established. It has been found that the structural and phase changes in the surface layers occur as a result of laser shock wave treatment at a distance up to 300 mkm from the surface. Increase in corrosion resistance and microhardness of exposed surface layer of weld joint has been observed.

Аустенітні хромонікелеві сталі є поширеним конструкційним матеріалом для виготовлення вузлів енергетичних установок завдяки високій пластичності, корозійній стійкості, добрій зварюваності та технологічності [1, 2]. В результаті термічного циклу зварювання у структурі зварних з’єднань із аустенітних сталей відбуваються зміни фазового та хімічного складу, що суттєво впливають на процеси руйнування зварного з’єднання за механізмами міжкристалітної корозії. Для попередження локальних корозійних пошкоджень проводять термічне оброблення зварних з’єднань при 900 ^{0}C [1, 2]. Високотемпературний вплив сприяє розчиненню карбідів хрому, гомогенізації твердого розчину аустеніту по хрому [2]. З метою запобігань корозійного розтріскування пришовних ділянок з’єднань із нержавіючих хромонікелевих сталей в промисловості проводять термічне індукційне оброблення, механічне зміцнення та зварювання з примусовим тепловідводом [1 - 3].