Evaluation of the structural steel corrosion behaviour, covered with epoxy-type paints, by means of electrochemical DC techniques

Y Salas[1], L Guerrero[2], R Martinez[3], T Chicino[3] and C Devia[3]
[1] Universidad Antonio Nariño, Bogotá, Colombia.
[2] Universidad Pedagógica y Tecnológica de Colombia, Tunja, Colombia.
[3] Universidad Antonio Nariño, Tunja, Colombia.

E-mail: yecsalas@uan.edu.co

Abstract. In this work we have studied the behaviour of the electrochemical corrosion of structural steel AISI SAE 1007 with epoxy coatings, using epoxy-type paints, through techniques such as DC resistance Polarization and Potentio-dynamic tests. In order to determine potential and corrosion rates of these coatings, have been correlated this results with different used electrolytes. For this, coatings were characterized by thickness measurement and continuity measurements. The coatings showed a slight degradation in the testing time, due to defects present in their structure, and the attack by the electrolyte; however, epoxy coating system tends to react with the electrolytes based on their chemical composition.

1. Introduction

Epoxy coatings on steel have opened a number of potential uses such as waterproofing, sealing, bonding, damping, reinforcing and protecting load-bearing structures. The slow degradation and low relative cost of these coatings make them ideal for these purposes [1].

The coating system has properties such as: Low permeability, flexibility, heat resistance, abrasion resistance, resistance to acids and alkalis and other properties that make them viable for coating metal surfaces that want protection against corrosion [2]. Given these properties it is very helpful to use the epoxy system which is the most prominent industrial maintenance for their excellent stiffness, adhesion, alkali resistance, and humidity, temporary or permanent immersion to mineral acids, solvents and moderately good resistance at high temperatures (80 to 90ºC) [3].

The purpose of this work is to characterize the corrosion behaviour of epoxy coatings on 1007 steel, using only D.C. electrochemical test (instead of the usual alternating current A.C. method: Electrochemical Impedance Spectroscopy EIS) [4,5], in function of the media (acid, neutral and basic), which give us evidence of coating performance in this different media.

Due to the thickness of the paint the current response was expected it was very small, but the potentiostat used had a very good definition that reached the order of 10^{-12} Amperes (pA), a fact which was verified in preliminary tests that yielded significant and visible data.

2. Methodology

Structural Steel AISI SAE 1007 specimens were used, supplied by the company SIKA Colombia and previously characterized by spectroscopy arc, with dimensions of 20cm long and 10cm wide and 1.035mm thick, with the respective type epoxy coating systems: A Self-priming Grey epoxy FZ HS, A epoxyphenolic S400 Ivory, Sika Epoxy 90HS Series A 200 and A 300 series 100HS Epoxy Sika, whose information was compiled manual metal coatings Sika. Electrolytic solutions NaCl, NaOH and H_2SO_4 with concentrations of 3.5, 3.75 and 5% respectively was used, as suggested by the NACE, Standard-TM0169-2000 [6]. These percentages of concentration are determinate to work the electrochemical tests simulate harsh environments, taking into account two aspects, the first is that the pH of the solution does not exceed the reference electrode (Ag/AgCl) so as to avoid this saturation, and the second is the ohmic overpotential having electrolyte solutions especially NaOH and H_2SO_4.

2.1. Experimental design

An experimental matrix design features two factors: Epoxy system with four levels determined by the paint supplied; and type of electrolyte, with three levels acid (H_2SO_4), neutral (NaCl) and basic (NaOH) (See Table 1).

Table 1. Experimental matrix.

Epoxy System	Electrolyte (Media)	Variables Response
A autoimprimante epóxico gris HS FZ F0898	Acid: H_2SO_4 5% Neutral: NaCl 3.5% Basic: NaOH 3.75%	Thickness (mm)
A epoxifenolico S400 marfil F0909-14	Acid: H_2SO_4 5% Neutral: NaCl 3.5% Basic: NaOH 3.75%	Continuity Ecorr (mV) Icorr (μA)
A sika epoxi 90HS serie 200 F0829	Acid: H_2SO_4 5% Neutral: NaCl 3.5% Basic: NaOH 3.75%	βa (mV/dec) βc (mV/dec) CR (mm/yr)
A sika epoxi 100HS serie 300 F0994	Acid: H_2SO_4 5% Neutral: NaCl 3.5% Basic: NaOH 3.75%	LPR (Ω*cm^2)

2.2. Materials and methods

For the electrochemical test was used the electrolytes mentioned in the experimental matrix, a scan rate of 2mV/s, an exposed area of 9,62cm^2 with a sweep from -250mV to +250mV with respect to Ecorr [7]. The SAE 1007 steel was previously characterized by means of arc spectroscopy and painted in the sika's plant in Tocancipa, Colombia. The reference electrode used was Ag/AgCl.

2.2.1 Electrochemical methods. Potentio-dynamic curves performed were analysed by means of Tafel approximation and in the LPR test values of linear polarization resistance were deducted.

2.2.2. Continuity tester. For continuous measurements epoxy coatings systems of all samples the same procedure was performed considering the suggestions described ASTM D 5162-A [8], both for the preparation of the specimens, as for the measurement and use Meter Compact equipment continuity PCWI™.

2.2.3. Electrochemical equipment. The Gamry G-750 Potentiostan-Galvanostats, an electrode Ag/AgCl and a flat electrochemical cell was used for generate the potentio-dynamics and LPR curves and is located in the Materials Lab of the Universidad Antonio Nariño, Tunja, Colombia.

2.2.4. Magnetic thickness gauge. Epoxy coating thickness can be measured on magnetic 1020 steel surfaces using a digital Elcometer™ coating thickness gauge. The principle of electromagnetic induction is used for non-magnetic coatings, on magnetic substrates such as SAE 1007 steel.

3. Results

The obtained results are reported in the Figure 1 and in the Table 2. In the potentio-dynamics graphics (Figure 1), the x axis is the base 10 logarithm of current (Amperes) and the y axis is the potential E in volts respect to E reference.

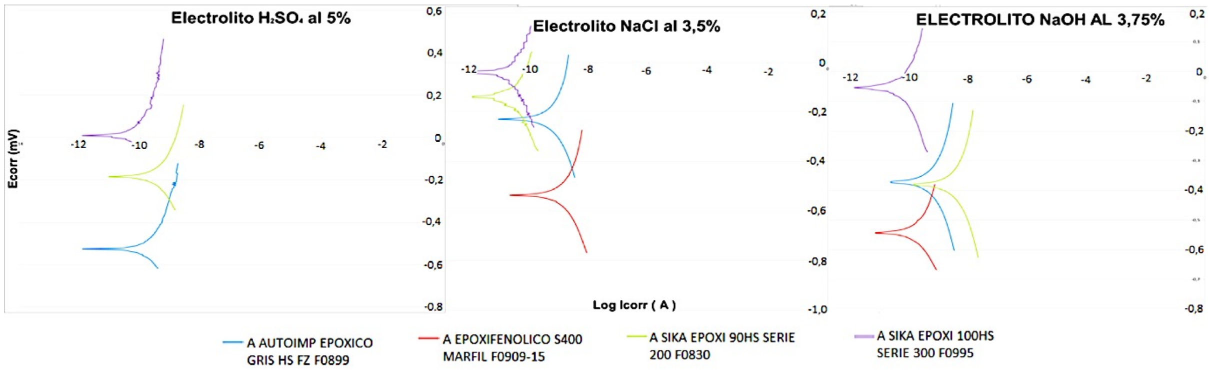

Figure 1. Curves for the three types of electrolyte with the four coating systems.

Table 2. Resume for experimental data obtained.

Epoxic system	NaCl 3,5% electrolyte			NaOH 3,75% electrolyte			H_2SO_4 5% electrolyte		
	CR mm/y	LPR Ω*cm^2	Thick mm	CR mm/y	LPR Ω*cm^2	Thick mm	CR mm/y	LPR Ω*cm^2	Thick mm
A autoimprim epoxic gris HS FZ	8,41E-07	1.92E+09	0.34	8,86E-07	9.62E+08	0.45	1,22E-07	1.92E+09	0.31
A epoxifenolico S400 marfil	2,05E-06	5.77E+08	0.61	1,62E-07	1.92E+09	0.37	-	-	-
A sika epoxi 90HS serie 200	3,26E-08	9.62E+09	0,3	5,53E-06	2.89E+08	0,3	3,84E-07	9.62E+08	0,3
A sika epoxi 100HS serie 300	3,25E-08	9.62E+09	0,95	7,61E-08	4.81E+09	0,57	1,78E-07	3.85E+09	0,43

4. Discussion

In the Figure 2 it is compared the corrosion rate for the four types of paint systems. It is noteworthy that the system epoxyphenolic saturate the equipment when subjected to H_2SO_4 electrolyte. The epoxy 90HS system present a notable corrosion rate for a basic media, the same way that the epoxyphenolic with neutral medium. The epoxy 100HS system had the best performance to maintain their corrosion rates around 10^{-7}mm/y for all electrolytes.

For all the systems the polarization resistance is practically the same values remaining at around tenths of Giga Ohms per square centimeter.

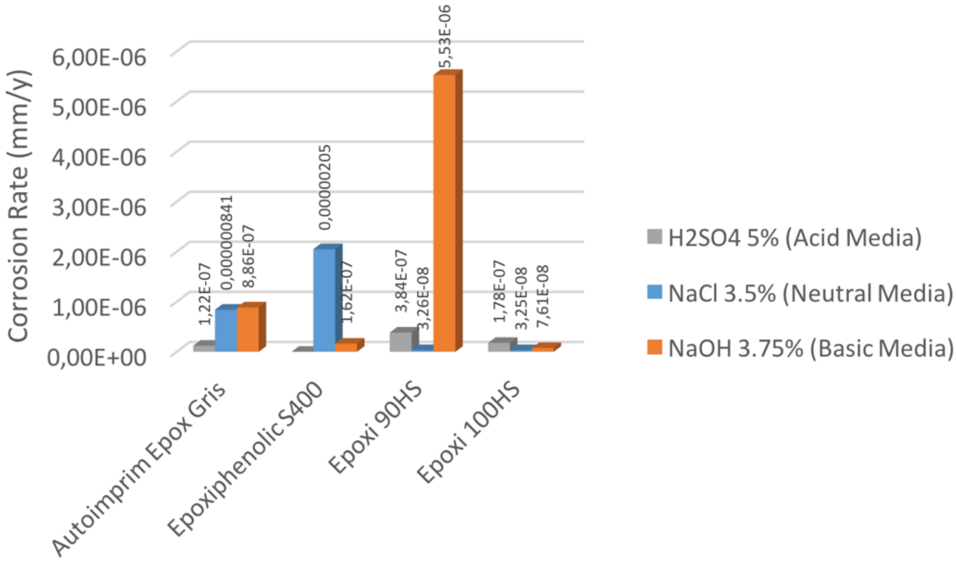

Figure 2. Corrosion Rate comparison for the four paint systems.

5. Conclusions

The Electrochemical Techniques D.C. are a very good method to determine the quality of epoxy coatings systems and application media, based on their respective corrosion and graphical analysis.

The coating system A epoxyphenolic S400 Ivory did not react to the acid environment by having polyamide in their chemical composition.

Based on the results obtained in the study and evaluation of epoxy systems with respect to pH range, i.e. the means in which we evaluated, we can say that more stable system and better performance in the three media both rich chlorides such as alkali and acid was sika epoxy system A 100HS Series 300, which does not mean that the other systems are not as efficient as this, since the lineal polarization resistance as was observed were in the order of G Ω*cm^2.

Coating systems possessing polyaminoamides have better performance than polifenilamida systems present in their chemical structures.

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