

Correlation between Neutral Salt Spray (NSS) Test and Potentiostat Dynamic Test for Corrosion on Zinc Plated Steel

Prithiviraj D ^[1], Rajendran R ^[2], Venugopal ^[3]

Department of Mechanical Engineering, B.S.Abdur Rahman University, Chennai, Tamilnadu, India ¹

Professor, Department of Mechanical Engineering, B.S.Abdur Rahman University, Chennai, Tamilnadu, India ²

R&D member, WABCO India Ltd, Chennai, Tamilnadu, India ³

ABSTRACT: Zinc plating is the basic process of protective coating to protect the substrate from coating. Zinc plated steel plates are prepared for neutral salt spray test (NSS) and potentiostat dynamic test (PDT). The correlation was developed for prediction of corrosion occurrence time of zinc plated steel using accelerated corrosion factors of NSS and PDT. Salt spray test is an accelerated corrosion test which is used to predict the suitability of the protective finish. Potentiostat dynamic test is a three electrode cell test to run most electro analytical experiments. The comparison between corrosion occurrence time showed an average error of 18%. The lead time of the potentiostat test is reduced to 98% compared to neutral salt spray test.

KEYWORDS: Salt spray test, Potentiostat test, Zinc plated steel, Corrosion occurrence time

I. INTRODUCTION

Corrosion is defined basically as the destruction or deterioration of the material because of the reaction with the environment. Rusting, the formation of iron oxides is a known example of an electrochemical corrosion. Corrosion has the tendency to degrade the properties of materials including strength, appearance and permeability of materials. Zinc plating is the basic process of protective coating to protect the substrate from coating. Neutral salt spray test is the commonly used practice to determine the corrosion occurrence time. The Tafel Plot of the potentiostat dynamic test is another method to predict corrosion occurrence time by corrosion rate using the three electrode cell type electro analytical experiment. The main objective of the study is to correlate the corrosion occurrence time by NSS test and PDT to reduce the lead time.

II. MATERIALS & METHOD

1.1 Materials Used

CR4 grade steel is the material used in this study and was obtained from WABCO INDIA LTD., Chennai. The chemical composition of the CR4 grade steel is listed in the Table.1.

Table 1: chemical composition of base material

ELEMENT	COMPOSITION (Wt. %)
Carbon	0.05 - 0.26
Manganese	0.4
Phosphorus	0.02
Sulphur	0.03
Iron	balance

2.1 SURFACE PREPARATION

CR4 grade steel samples of size 150 x 70 x 1.5 mm have been used for this study. The sample is machined to a surface finish of about $Ra\ 0.8\mu m \pm 0.3\mu m$. The sample is polished by emery cloth to get the surface ready for electroplating. The Zn plating has been done on the samples with an average thickness of 12 μm (approx.)

2.2 NEUTRAL SALT SPRAY TEST

The salt spray test is the common practice used to produce a corrosive attack to the coated samples to predict the suitability as a protective finish. The corrosion product appearance is evaluated after some period of time. Test duration depends on the thickness of the coating; the longer the period without showing red rust shows more the corrosion resistant. Testing procedure and parameters are standardized under standard of ISO 9227.

Parameters used in NSS test is given in Table 2.

Table 2: Parameters of salt spray test

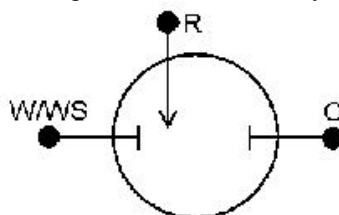
PARAMETER	SPECIFICATION
Temperature	35 \pm 2°C
Solution	5% NaCl
pH	6.5 – 7.2
Fog collection	1.1 – 1.3ml/hr
Air pressure	18 psi

2.3 POTENTIOSTAT DYNAMIC TEST

A potentiostat is a three electrode cell electronic hardware device used to run electro analytical experiments. The instrument control the voltage difference between working and the reference electrode, these electrodes with an auxiliary electrode which is implemented to control the voltage by injecting current is contained in the electrochemical cell. The principle behind the potentiostat dynamic test is Faraday’s electrolysis law. The faraday’s law states that the mass of the substance altered at an electrode during electrolysis is directly proportional to the quantity of electricity transferred at that electrode.

The electrode setup of the Potentiostat test equipment is shown in Fig. 1

Fig. 1 Electrode assembly



Quantity of electricity refers to the quantity of electrical charge, typically measured in coulomb. The systems functions by maintaining potential of working electrode at constant level with respect to reference electrode by adjusting the current at auxiliary electrode.

The electrode specification is shown in Table 3.

Table 3: Electrode Specification

ELECTRODE TYPE	MATERIAL	PROBE COLOR
Working Electrode (Anode)	Specimen	Green
Reference Electrode (Cathode)	Ag/AgCl ₂ , Saturated Calomel Electrode	White
Counter Electrode (Cathode)	Pt wire	Red

The corrosion rate calculation in potentiostat dynamic test is determined by Electro chemical technique. In Electrochemical technique, by means of Tafel Plot corrosion current is obtained. This Tafel plot is discovered by Professor Julius Tafel, around 1905.

The formula for calculating Corrosion Rate from Potentiostat test is

$$\text{Corrosion Rate, CR} = \frac{I_{\text{corr}} * K * \text{Eq.Wt}}{D * A}$$

I_{corr} : Corrosion Current (A/cm)

K : Faraday's Constant (Coulomb) = $1.288 * 10^5$

Eq.Wt : Equivalent Weight (g/mole)

D : Density ($\frac{\text{g}}{\text{cm}^3}$)

A : Area (cm)

III. RESULTS AND DISCUSSION

a. Neutral Salt Spray

The corrosion occurrence time is the red rust occurring time on the material which can be obtained by regular inspection of the material in the salt spray chamber. The sample is pre-processed and cleaned to eliminate dirt, oil or other foreign matter with appropriate organic solvent (Hydrocarbon with boiling point between 60°C and 120°C) using clean soft brush or an ultrasonic cleaning device then the specimens are rinsed with fresh solvent and dried it. After the material is tested in salt spray chamber it is post processed to remove the corroded particle with 100ml HCl, 1.45g Hexa-methylene-tetra-amine and 200ml distilled water. The Zinc plated steel in various stages during testing is shown in Fig. 2-4

Figure 2: As received condition

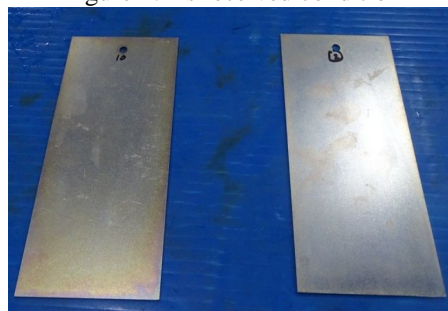


Figure 3: After 96 hrs (no red rust observed)

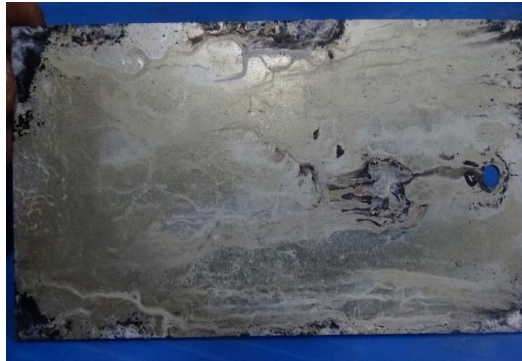


Figure 4: After 305 hrs

(Red rust started on zinc panel)

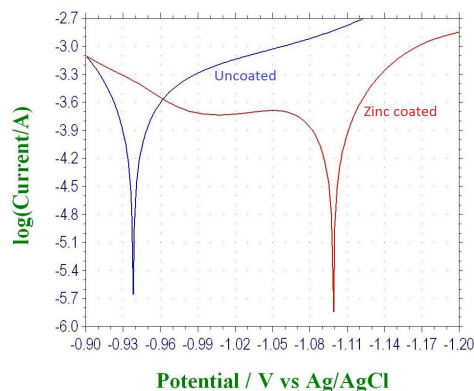


The various conditions shows the red rust occurring time in the material in salt spray chamber. The red rust starting on the Zinc coated panel shows the failure occurred in the Zinc coated material in 305 hrs.

b. Potentiostat Dynamic Test

The TAFEL PLOT of Zinc coated and uncoated samples are shown in the graph.1

Graph 1: Zinc coated Vs. Uncoated Sample



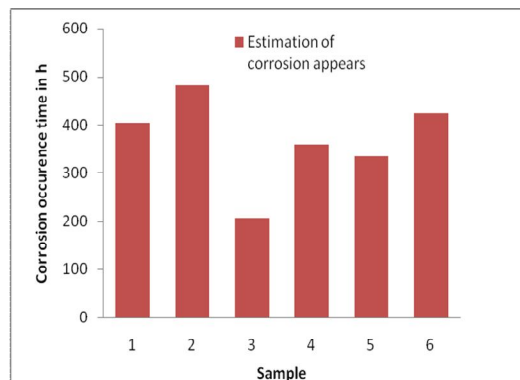
The corrosion rate for the zinc plated samples are shown in Table 4

Table 4: Corrosion rate

SAMPLE	CORROSION RATE (g/h)
1	0.001945
2	0.001767
3	0.003809
4	0.002183
5	0.002350
6	0.001854

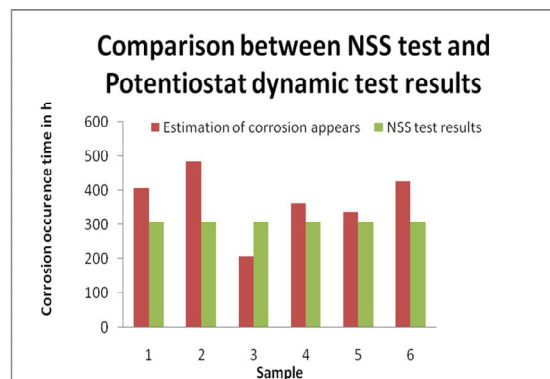
The estimation of the corrosion occurrence time for the samples are shown in Graph 2

Graph 2: Corrosion occurrence time



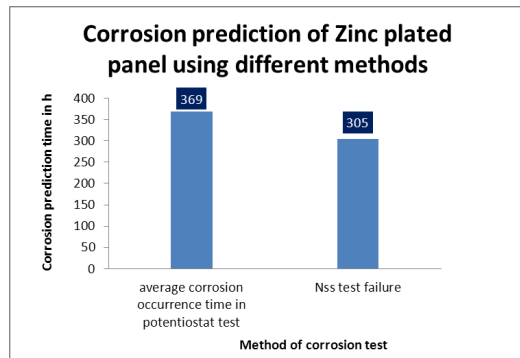
The comparison between NSS test and Potentiostat Dynamic test results are shown in Graph 3

Graph 3: Comparison of results



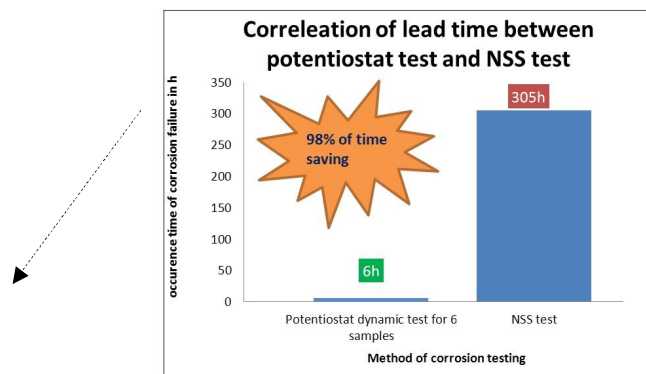
The corrosion prediction of Zinc plated samples using different methods are shown in Graph 4

Graph 4: corrosion prediction



The correlation of lead time between NSS test and potentiostat dynamic test is shown in Graph 5

Graph 5: Correlation of test data



c. Scanning Electron Microscope (SEM)

The scanning electron microscope is used to determine the chemical composition of the zinc plating. The SEM observations are shown in figure 5. The microstructure of the Zinc plate is retrieved from scanning electron microscope. The microstructure of zinc plated sample is shown in figure 6.

Figure 5: SEM of Zinc

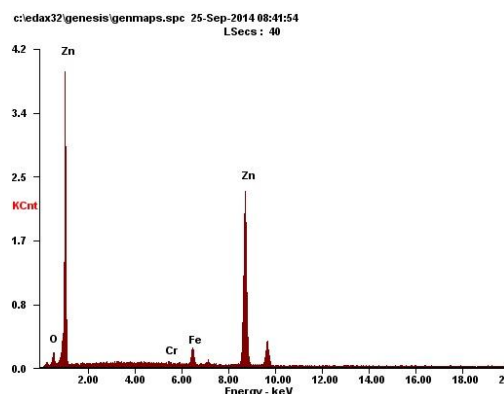
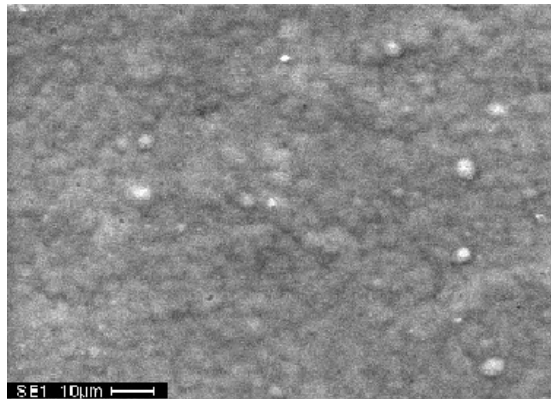


Figure 6: Microstructure of Zinc plated sample



The chemical composition identification is more important for prediction of the corrosion rate in PDT.

IV. CONCLUSION

The correlation of the neutral salt spray test and the potentiostat dynamic test of zinc plated sample is studied and the experimental result shows that the corrosion occurrence time has an average error of 18%. Time taken to predict the failure using potentiostat dynamic test is 6 hour for six samples (including the calculations), whereas the time taken to predict the failure using NSS took 305 hours to find failure of Zinc coated samples. Drastic save of time of about 98% is achieved using PDT over NSS test.

REFERENCES

1. Mars G. Fontana, Corrosion Engineering, TATA McGraw Hill, 3rd Edition, 2005.
2. Chuen-Chang Lin and Chi-Xiang Wang, Correlation between accelerated corrosion tests and atmospheric tests on steel, Springer 2005.
3. B.M. Durodola, J.A.O. Olugbuyiro, S.A. Moshood, O.S. Fayomi, A.P.I. Popoola, Study of influence of Zinc plated mild steel deterioration in seawater environment, International Journal of Electrochemical Science 6 (2011) 5605 – 5616.
4. Experimental procedure from PrF-labsystruktan CH-Instruments 600C manual.
5. N.LeBozec, N.Blandin, D.Thierry, Accelerated corrosion tests in automotive industry: A comparison of the performance towards cosmetic corrosion, Materials and Corrosion 2008.
6. S. Fujita, D. Mizuno, Corrosion Science, 2007.
7. B.M. Durodola, J.A.O. Olugbuyiro, S.A. Moshood, O.S. Fayomi, A.P.I. Popoola, Study of Influence of Zinc Plated Mild Steel Deterioration in Seawater Environment, International Journal of Electrochemical Science, 2011.
8. W. Brain James, Leander F. Pease, Salt spray and immersion corrosion testing of PM stainless steel materials, report. Hoeganaes Corporation.
9. George E. Dieter, Mechanical Metallurgy, McGraw Hill Book Company.
10. M.H.Roberts, A potentiostat for corrosion study, IOP science.