ECOMET 500 LC: An environment friendly Zinc Aluminum Flake Coatings for Corrosion Protection

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Abstract

Zinc and Aluminum flakes were used in electrically conductive binder system to prepare ECOMET 500 LC paint formulation. The paint was applied non electrolytically (as per ISO10683/ASTM F1136) by dip spinning technique on low carbon steel samples. Corrosion protection performance of the painted low carbon steel samples in 3.5 wt % sodium chloride solution was evaluated using potentiodynamic polarization, electrochemical impedance spectroscopy and salt spray test. The corrosion rate of the paintedsample was foundtobe1.33mpywhichissignificantly lower than un pained steel sample. Higher values of impedance, higher coating resistance and lower coating capacitance even after fifteen days of immersion as compared to the values observed just after immersion revealed the protective nature of the coating in long term. No red rust is observed after 1000 hours. Corrosion protection offered by these coatings can be assigned to the sacrificial cathodic protection mechanism, barrier action and difficult transport of corrosive species. Due to environmental friendly paint formulations and less pollution of the environment makes this coating technology far superior and user friendly compare to the existing metal finishing coating systems.. ECOMET 500 LC paint coating could be an alternative to toxic paints and also environmentally hazardous electro plating processes.

Introduction

Low carbon steels corrode in most of the atmospheric environments when therelativehumidityexceedssixtypercent.Corrosionisthedestructionordeteriorationofam aterialbecauseofreactionwithitsenvironment.Mostcommoncorrosioncontrolmethodsuse coatingsandconversionlayerswhichcontain toxic and environmentally hazardous materials. There is a need to find nontoxic and environmental friendly alternatives compatible with current industria ltechniques. Recently,ECOMET 500 LC paints introduced by EFFCO , Pune (M.S) India offered such an alternative. The aim of this investigation is to study electrochemical behavior of ECOMET 500 LC based painted steel samples in neutral medium.

Experimental

Paint preparation

ECOMET 500 LC paint formulation was prepared using combination of Zinc and Aluminum flakes in electrically conductive binder systemwith integrated lubricants for adjusting co-efficient of friction. Zinc flakes are added to impart cathodic protection where aluminum flakes are added to reduce of white oxidation build-up.

Paint application

ECOMET 500 LC paint, as prepared, were applied non electrolytically (as per ISO10683/ASTM F1136) by dip spinning technique. A combination of organic or inorganic topcoat sealers was used.

Characterization

An optical microscope (Image Z1 M, Zeiss make) was used to study the morphology of the coatin and a digital camera was used to take the photos of the bolted samples before and after salt spray.   .

Corrosion studies

A corrosion cell having three-electrode geometry of painted steel sample as working electrode, platinum as counter electrode and saturated calomel electrode(SCE; pH Products, Hyderabad, India) as a reference electrode was used. The cellwasconnectedwithGamryreferencesystem1000(Wilmington,USA)forelectrochemical measurements. Tafel extrapolation method was used to determine corrosion rate of the painted steel sample. In this technique, the polarization curvesareobtainedbyapplyingpotentialof±250mVwithrespecttoopen-circuitpotential(ASTMG3-74).Longtermperformanceofthepaintedsampleswasassessed by electrochemical impedance spectroscopy over frequency range 100KHz to 0.1 Hz using amplitude signal 10 mV rms(ASTM G106 and ASTM2005b).For all the electrochemical experiments, 3.5 wt % NaCl aqueous solution was used. In addition to these electrochemical tests, salt spray test was carried out on painted bolts(ASTM B117).

All measurements were carried out five times to obtain good reproducibility of the results and reproducible results are reported in this work.

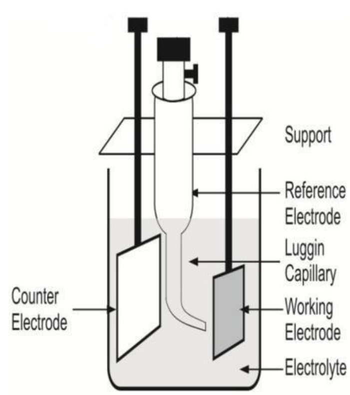

Figure1:Electrochemical cell

Results and discussion: Figure 2 shows photomicrograph of the paint coated surface.

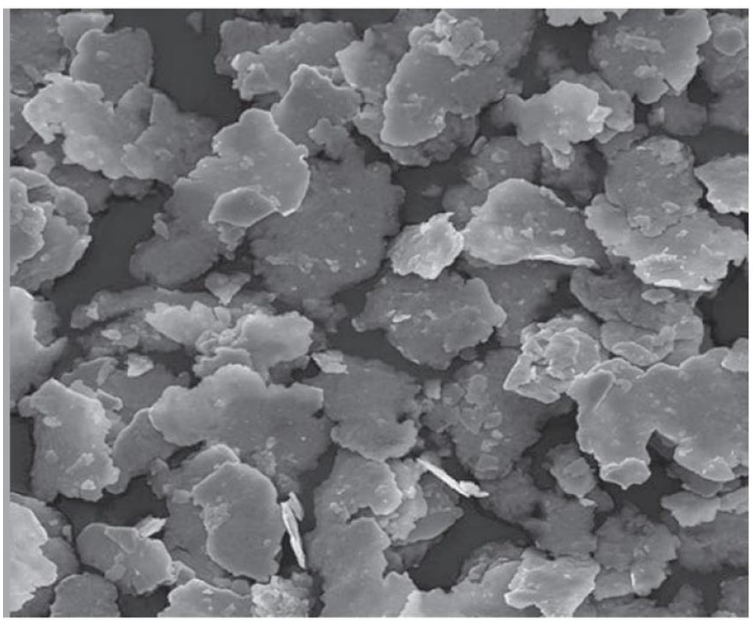

Figure 2 : Zinc Al flakes in ECOMT 500 LC coated steel substrate, 450 X

Optical photomicrograph shown in figure 2 reveals entire coverage of the paint coating on the substrate.

Corrosion rate determination

Figure3 shows potentiodynamic polarization of the painted steels ample in3.5wt%NaCl solution.

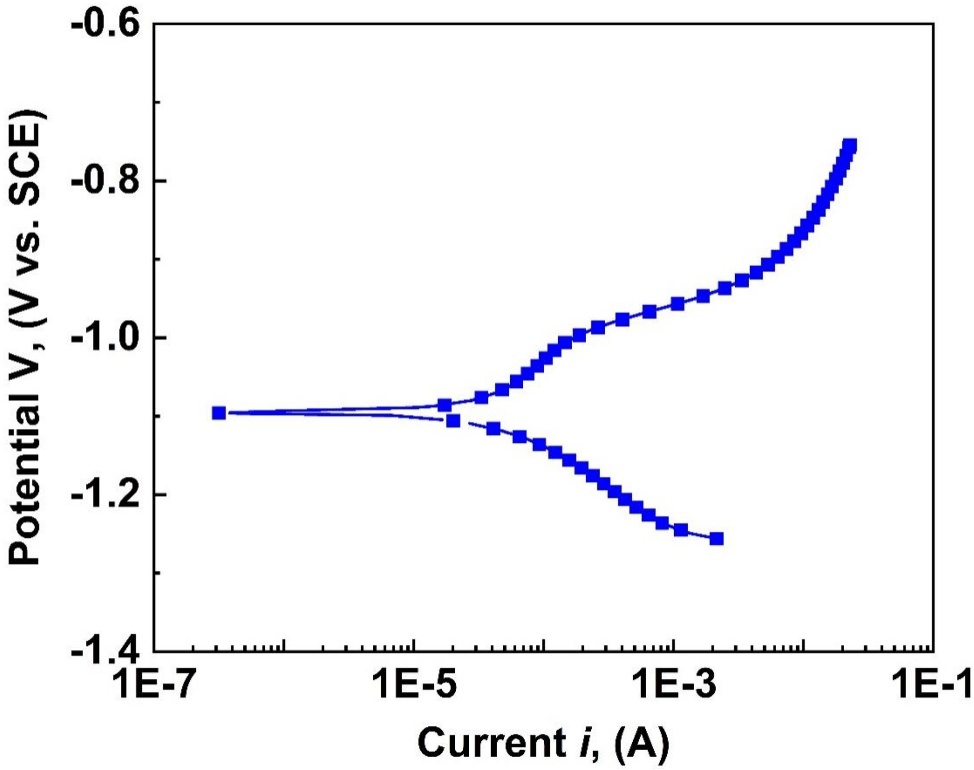

Figure 3: Potentiodynamic polarization ofthe Ecomet 500 LC in3.5 NaCl %solution

Thecorrosionrateofthepaintedsampleisfoundtobe1.33mpywhichissignificantly lower than un pained steel sample (8-12 mpy). Corrosion potentialis observed to be- 1.1 V which implies cathodic protection mechanism.

Impedance spectroscopy

Impedance data obtained in this work is reported in terms of Bode and Nyquist plots. These graphs for painted steel samples just after immersion, after 7 days of immersion and 15 days of immersion in 3.5 %NaCl solution are shown in figures 4 to9 respectively.

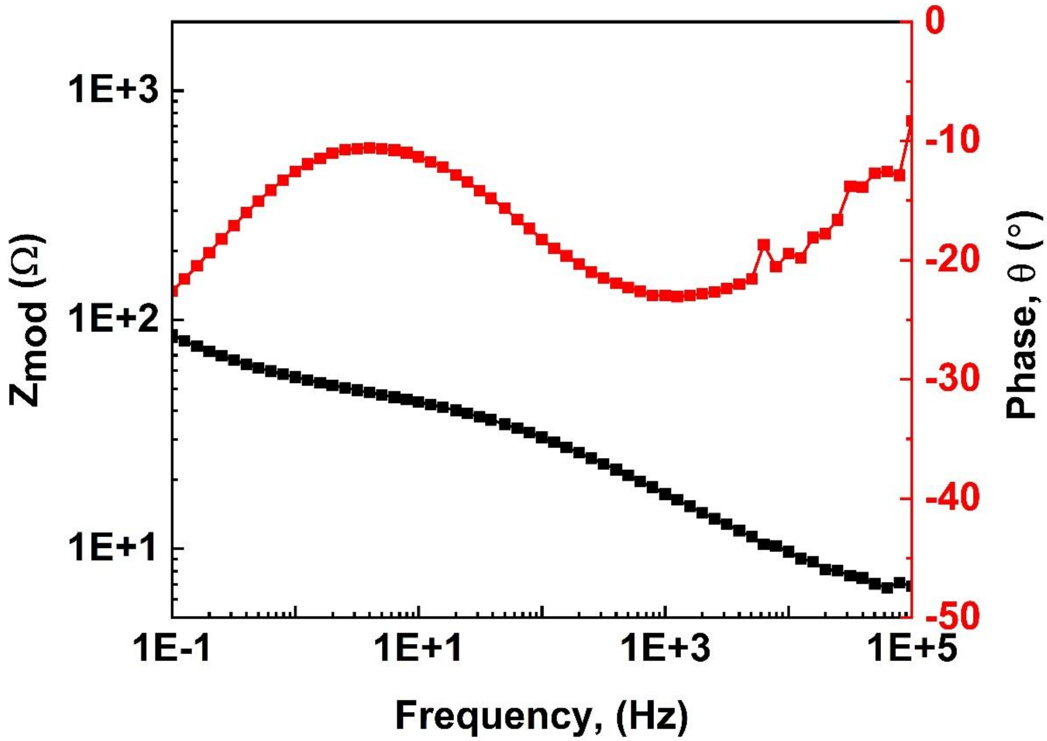

Figure4 : Bode plotof ECOMET 500 LC sample just after immersion

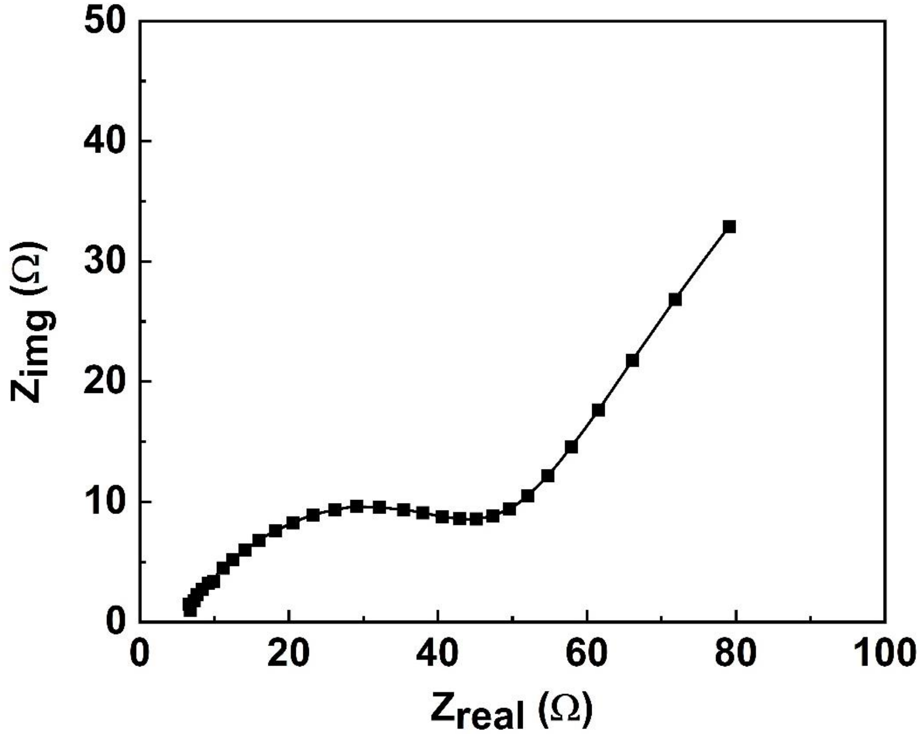

Figure5:Nyquist spectra of ECOMET 500LCsamplejustafterimmersion

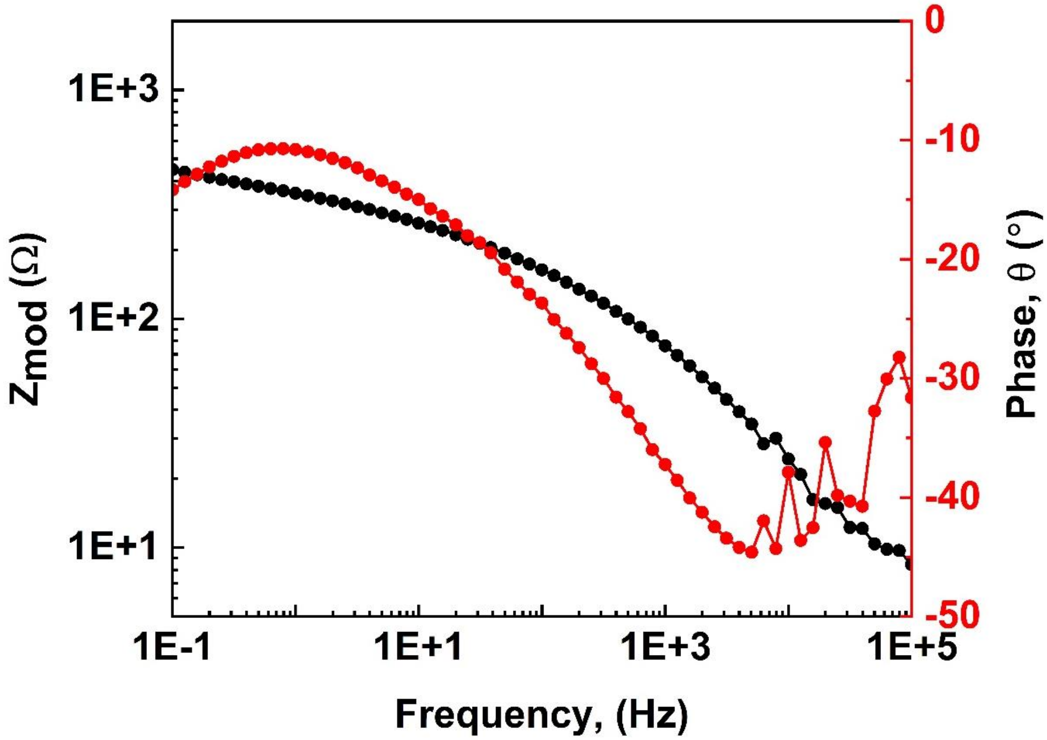

Figure6 : Bode plot of ECO MET 500LC sample after 7 days of immersion

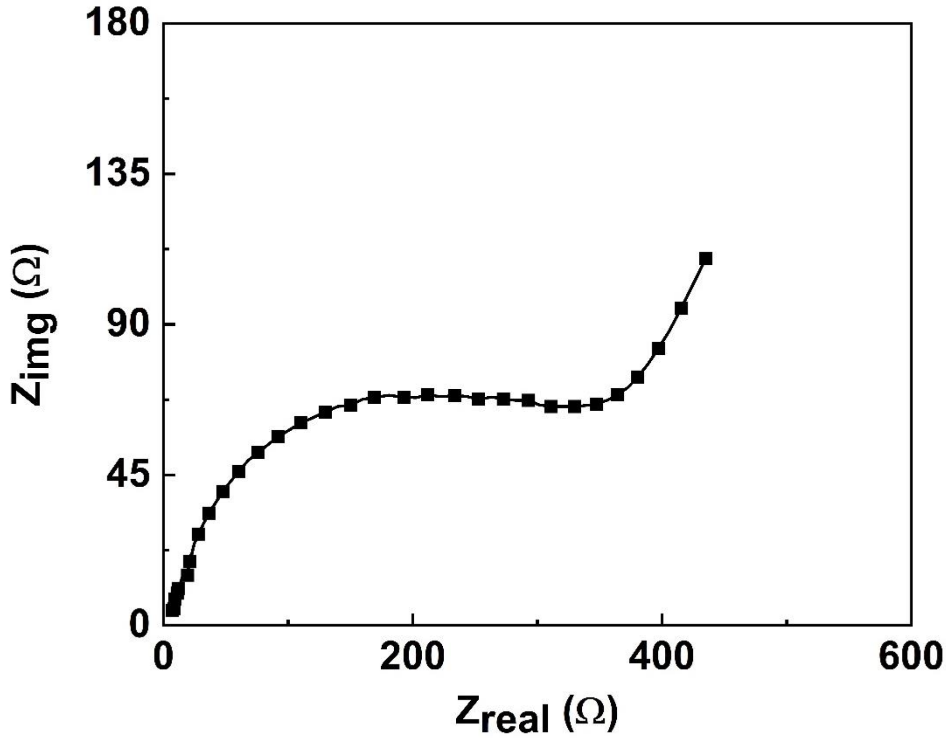

Figure7:Nyquistspectra of ECOMET 500LC sample after7daysofimmersion

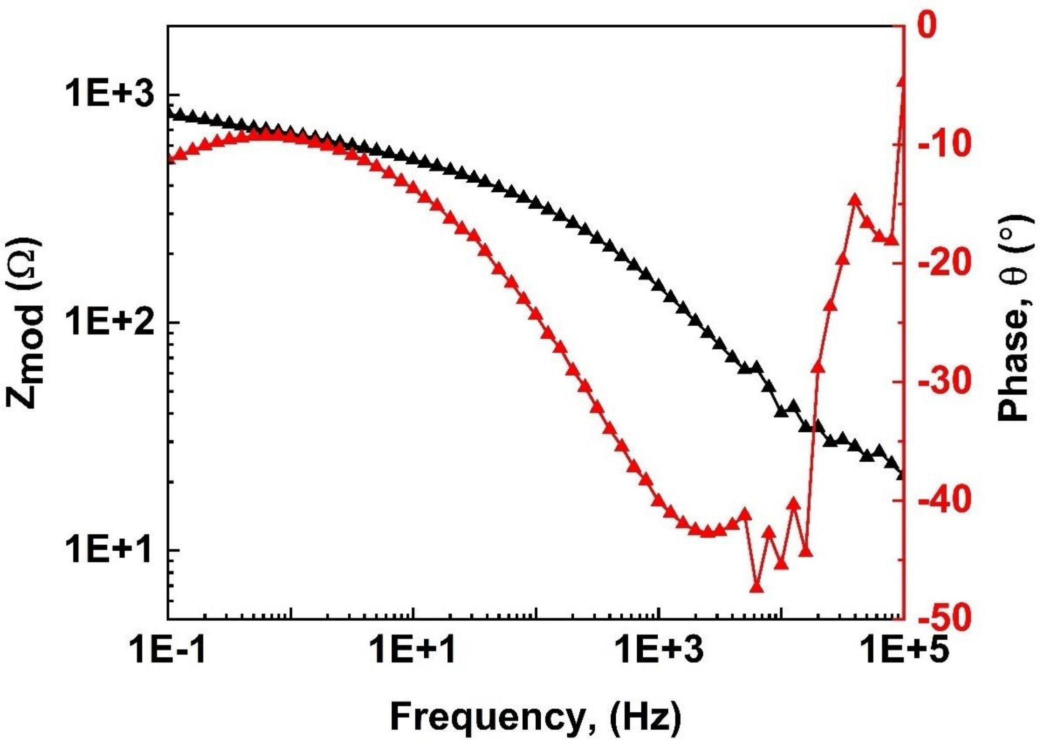

Figure8 : Bode plot of ECO MET500LCsample after15days of immersion.

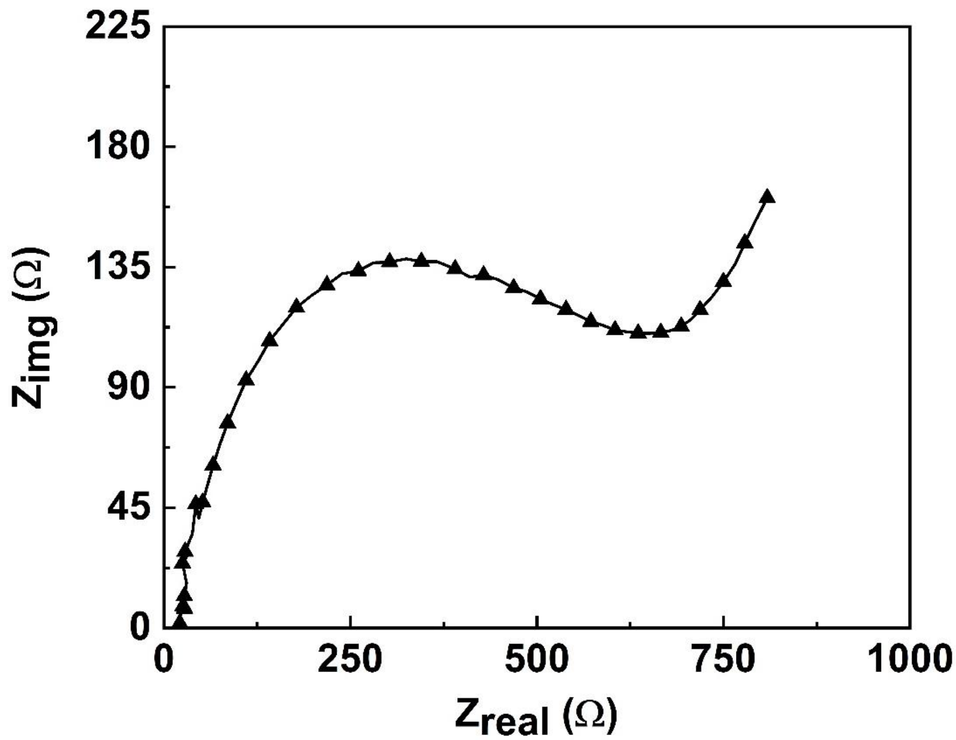

Figure9: Nyquistplot of ECOMET 500 LCsampleafter15 days of immersion.

These plots are analyzed using equivalent circuit shown in figure 10 and the impedance (Zmod), the coating resistance (R_C) and the coating capacitance (C_C)values, except solution resistance (R_U), obtained by modelling these figures arerecordedintable1.

The equivalent circuit shown in figure 10 is Randles circuit. It is a combination of resistor and capacitor can be used to model noncoatedmetalsaswellascoatedmetals.Whenthiscircuitisusedtomodelelectrochemical processes in the case of non coated steel, the resistance of the metal to polarization and capacitance associated with the formation of doublelayerareexpressedintermsofpolarizationresistance(R_p)anddoublelayercapacitance(C_{dl})respectively. In the case of coatedsteel, modeled using thesame circuit, these terms are replaced by coating resistance (R_c) and coatingcapacitance(C_C) respectively.

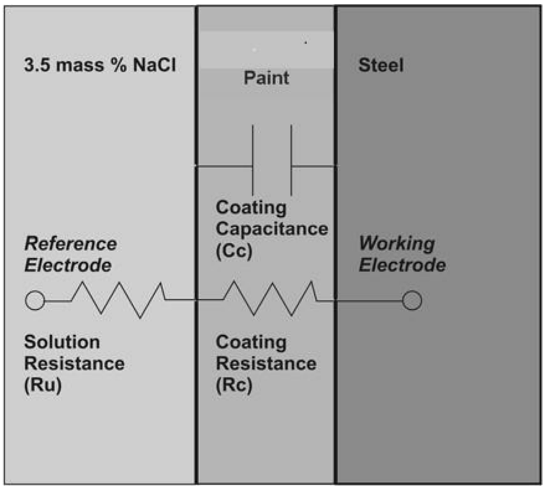

Figure 10 : Equivalent circuit used for modeling

Table 1:Impedancevalues

Sample	Immersion time	Z mod Ωcm^2	Coating resistance, (R_c) Ωcm^2	Coating capacitance(C_c) uF
Ecomet 500 LC	Just after immersion	84.06Ω	33.47	19.14
Ecomet 500 LC	After7daysof immersion	448.8Ω	199.6	1.832
Ecomet 500 LC	After15daysofi mmersion	827.3Ω	426.7	1.2

All the Bode plots reveal two characteristic segments of the straight line. At lower frequencies, the straight line bends so as to become a line parallel to the abscissa: that is, the impedance is independent of frequency at low frequencies, indicating agradualtransitionfromcapacitivetoresistivebehaviour.Theimpedance(z_{mod})is found to be increased as a function of immersion duration. The reason might be that the coating undergoes an electrochemical reaction during immersion which generates an oxidation product on the surface of the steel. This results in the passivation of steel and subsequent reduction in corrosion. A single semi circle is observed for an ideal coating indicating pure capacitive behavior All the Nyquist plots, obtained in this work, however, can be fitted with two semicircles, a smaller one at high frequency range followed by a larger one at lower frequencies. The first semi circle capacitive loop is assigned to the paint / steel interface and the second one to the processes occurring below the paint coating. Water molecules and corrosion species penetrate into the coating as a function ofimmersiontime.Thisisreflectedintheloweringofimpedanceandcoatingresistance. However, higher values of impedance, higher coating resistance and lower coating capacitance evenafter fifteen days of immersion as compared to the values observed just after immersion reveal the protective nature of the coating in long term.

Salt Spray Test

Figure 10 show appearance of the painted bolts before and after salt spray test of 1000 hours.

Figure 10 : Before and after salt spray test

No red rust is observed after 1000 hours. Salt spray results, therefore, support electrochemical tests. As the paint formulation contains zinc aluminum flake coating system, it will protect the underlying substrate by sacrificial mechanism in case of any coating damage.

Environment Friendly Paint Coating System(As per ISO-10683/ASTM-F1136)

ECOMET500 LC Zinc Aluminum flake coating applications do not require hazardous acids or other chemicals. Its use during commercial practice, therefore, do not generate pollutants or gases. Being water based, these coatings exhibit low hazardous air pollution ,low volatile organic contents and therefore meets GADSL, ELV, WEE ,ROHS and various OEM regulations.

Corrosion protection mechanism

ECOMET500 LC Zinc Aluminum paint coating contains zinc as well as aluminum flakes. Zinc works as an anode and sacrifice to protect the metal which becomes a cathode If there is any service damage, the electrochemical activity results in the formation of zinc corrosion products, which in turn, imparts barrier protection. Aluminum flakes extend the permeation path ,thereby, making transport of corrosive ions and water molecules difficult. In addition, these flakesimpart resistance to possible adhesion loss due to other ingredients .

Conclusions

Ecomet500LC based painted low carbon steel exhibits excellent corrosion resistance in the neutral medium and can be used effectively for long term performance. The paint coating could be an alternative to toxic paints and also environmentally hazardous electro plating processes. Corrosion protection can be assigned to the sacrificial cathodic protection mechanism barrier action and difficult transport of corrosive species and water molecules. Due to environmental friendly paint formulations and less pollution of the environment makes this coating technology far superior and user friendly compare to other metal finishing coating systems

Applications

The ECOMET 500 LC zinc flake coating can be applied in Automotive, Wind Turbine Industry, Railways, Energy and infrastructure/Chemical Processing Industry/Marine Industry/ Petroleum & Gas Industry for the components such as :- Fasteners and High tensile Fasteners, Nuts and Bolts, Rivets, Screws and other threaded connecting hardware parts, Springs, Spring Steel Parts, Clips, Clamps, Brackets and other stamping parts, Brake Disc, Brake Drum and Brake Rotors etc.

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