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Surface Protection of Carbon Steel with ZrO_2 Composite Induced Zinc Based Electrolytic cell via Electrodeposition Technique

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Abstract-

The effect of Zirconium dioxide (ZrO_2) as additive to Zn-MgO electrolytic chemical bath coating by co-deposition on carbon steel was investigated. Weight loss was conducted on the electrodeposited mild steel and it was inspected. The anti corrosion properties were assessed by linear polarization procedure in 1 mole of HCl medium. From the results gotten, all deposited coatings displayed significant improvement. An amazing improvement was accomplished in every one of the coatings as against the as-received sample. Zn-MgO-ZrO_2 (0.8V) with the best performing coating showing an upgrade indicates enhanced anti-wear and friction qualities displaying wear resistance improvement.

Key Words: Coating; Zirconium dioxide; Carbon steel; Electrodeposition

1. Introduction

Corrosion threats causes plant shutdowns, misuse of significant assets, lessening in effectiveness and exorbitant upkeep of machinery [1]. It likewise imperils wellbeing and represses mechanical advance [2]. All the more, the interest in fossil powers has developed rapidly which add to rising corrosion challenges with potential catastrophes that can bring about significant issues including negative social effects, water assets and natural contamination. Corrosion issues in the oil fields division additionally happen at all phases from down hole to surface hardware and processing facilities prompting repetitive fractional and possible process shutdown, bringing about serious financial misfortunes. The other vast issue in working channel corrosion for the most part is because of stress corrosion cracking [3]. [4] established that the advantages of electro-deposition particularly zinc coating over other coatings are consistently of multifaceted shapes, decline of waste in deposition techniques, low tainting levels, constant and high production rates, sensible startup capital venture required among others. Electrodeposition of zinc with different composites produced, are materials that persevere through the demonstration of corrosive chloride particles, natural solvents and other high temperature stress. Electrodeposition of zinc on steel are broadly utilized for corrosion prevention because of their monetary significance and cost proficiency [5-10]

2. Experiment Procedures

2.1 Materials

Sectioned rectangle mild steel plate used for this experiment was of dimension 40mm x 30 mm x2 mm. Steel composition are presented in Table 1. The anode is 99.9 % pure zinc. The MgO and ZrO_2 powder were also certified pure. The mild steel was polished with emery papers, pickled with 10 % HCl and then rinsed in distilled water.

Table 1. Wt. % of mild steel

Element	Mn	C	S	Si	P	Ni	Al	Fe
Composition	0.43	0.16	0.033	0.16	0.02	0.008	0.007	Bal.

2.2 Electrodeposition Process

The summaries of bath formulation are presented in Table 2. The electrodeposition was carried out at a pH of 5.6, voltage of 0.6/ 0.8V and deposition time of 15 minutes. The anodes (zinc) and cathode (mild steel) were connected to the positive and negative terminal of the rectifier (power supply) respectively. The cathode was positioned equidistance from the anodes and the deposition was achieved at the current density of 2 A/cm^2. A stirring rate of 250 rpm was applied throughout the deposition process so as ensure homogeneous dispersion of the particles on the surface of the steel. The stirring also assists the fast movement of the ions to the deposition sites and consequently resulting in fast deposition of the particles and quick exchange of ions. The electrodeposition parameters and weight gain by the samples were obtained after the coating and these are presented in Table 3.

Table 2: Bath Formulation

Composition	Mass concentration (g/L)
ZnCl	70
KCl	5
Boric Acid	10
MgO	15
$MgCl_2.6H_2O$	15
Thiourea	5
NaCl	5
pH	5.6
Voltage	0.6/ 0.8V
Time	15 min.

Table 3: Coating Parameters for Zn-MgO/-ZrO_2 Deposition

Sample	Time (min)	Weight Gain (g)	Voltage (V)
Zn-MgO	15	0.0342	0.6
Zn-MgO	15	0.0483	0.8
Zn-MgO-ZrO_2	15	0.3091	0.6
Zn-MgO-ZrO_2	15	0.1833	0.8

2.3 Electrochemical property testing

The coatings tendency to corrode was studied employing linear polarization experiment and weight loss. The linear polarization experiment was carried out employing Autolab potentiostat (PGSTAT30 computer controlled) in a simulated 0.5 M HCl solution. The coated samples were made the working electrodes while the graphite rod and a silver/silver chloride 3 M KCl were the counter and reference electrode respectively. The working electrodes mounted on resin were immersed in the test medium and the corrosion parameters were obtained from –1.5 V to 1.5 V. Weight loss experiment runs for the duration of 6 days (approximately 144 hours).

3. Results and Discussion

3.1 Corrosion resistance of deposit film

The electrochemical parameters are shown in Table 4. It is significant to note that the Zn-MgO-ZrO_2 (0.6V) coating possesses the lowest current density of 1.0052E-7 A/cm^2 and corrosion rate of 0.0010482 (mm/yr). The low values of the current density and corrosion rate recorded are indication that Zn-MgO-ZrO_2 film minimized the penetration of chloride ion into the steel's active sites . The Tafel plot in figure 1 also unveiled that Zn-MgO-ZrO_2 coating exhibits substantially good corrosion resistance.

Table 4: Polarization data of the deposit film

Sample	I_{corr} (A/cm^2)	R_P (Ω)	E_{corr} (V)	C_R (mm/yr)
As-received	7.04E-02	2.7600	-1.53900	4.1
Zn-MgO (0.6V)	4.0728E-7	23515	-1.0652	0.0042209
Zn-MgO (0.8V)	8.0849E-7	50881	-0.64345	0.0083613
Zn-MgO-ZrO_2 (0.6V)	1.0052E-7	34017	-0.70456	0.0010482
Zn-MgO-ZrO_2 (0.8V)	2.1701E-7	12213	-0.46751	0.0022446

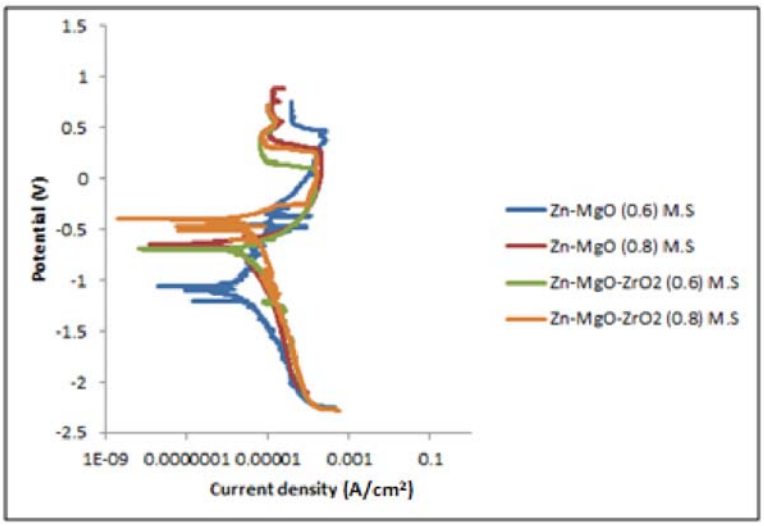

Figure 1: Potentiodynamic Polarization Curves for Zn-MgO/-ZrO_2 Deposition

3.2 Corrosion Rate and Weight loss

The weight loss of the coatings immersed in HCl for a period of 6 days are shown in figure 2. From the graph, it can noticed that there is heavy weight loss in the first 2 days in all specimen. It was also noticed that the specimen with Zirconium (ZrO_2) and 0.8V potential was least affected followed by the other specimen with Zirconium (ZrO_2) and 0.6V potential. The specimens without Zirconium exhibit higher weight loss

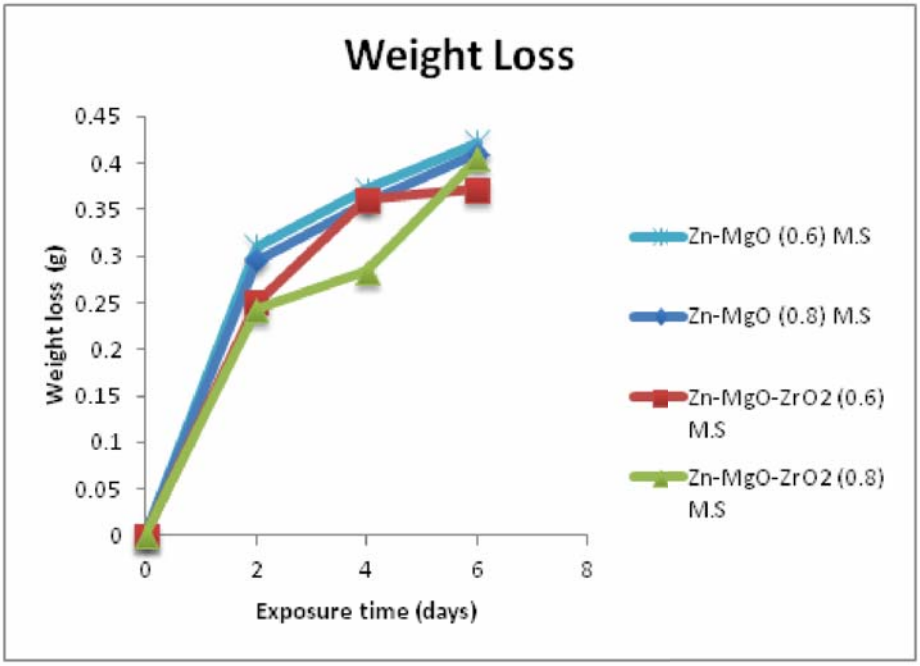

Figure 2: Weight loss Vs. exposure time in HCl

$$\text{Corrosion Rate } (C_r) = \frac{87.6 \times W}{D \times A \times T} \quad (1)$$

Where: W, D, T, A are Weight Loss (g), Density of Alloy (g/cm), Time (Hours) and Area (cm^2) respectively.

$$\text{Inhibitor Efficiency \% (IE)} = \frac{Wb - Wi}{Wb} \times 100 \quad (2)$$

Where: W_b, W_i are Weight loss without and with inhibitor respectively

The corrosion rate vs. exposure time results in Figure 3 is interrelated with the results in figure 2 as corrosion rate is inversely proportional to the weight loss. The rate of corrosion of the steel was calculated using equation 1 [10]. Zn-MgO-ZrO_2 (0.8V) coating displays the least corrosion rate.

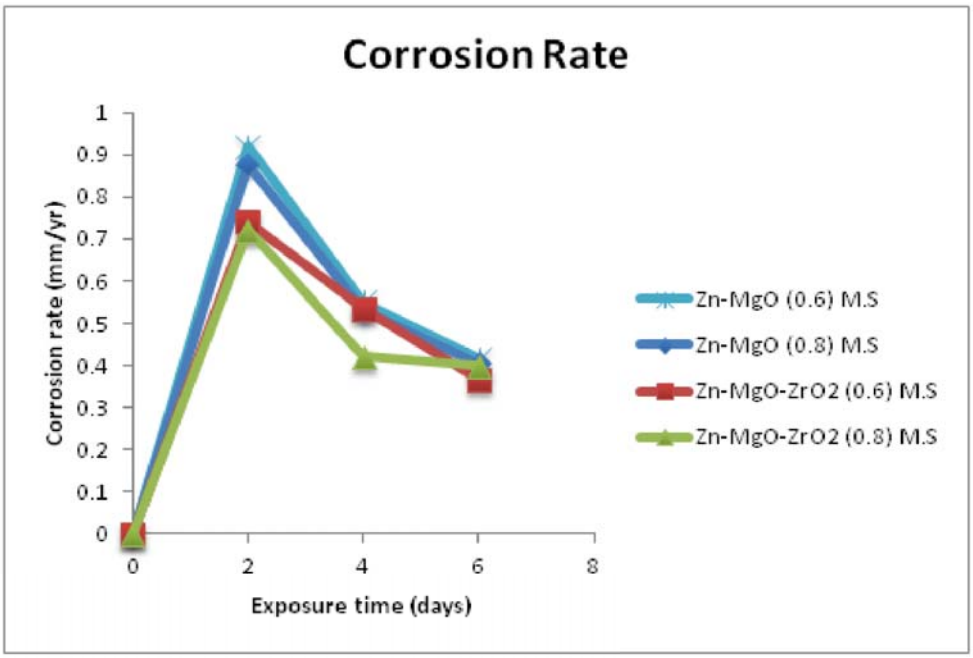

Figure 3: Corrosion rate Vs. exposure time in HCl

The corresponding coating efficiency vs. the exposure time results are presented in figure 4. The coating efficiency was computed using equation 2 [11]. The plot indicates that Zn-MgO-ZrO_2 (0.8V) coating possesses higher coating efficiency compared to other samples.

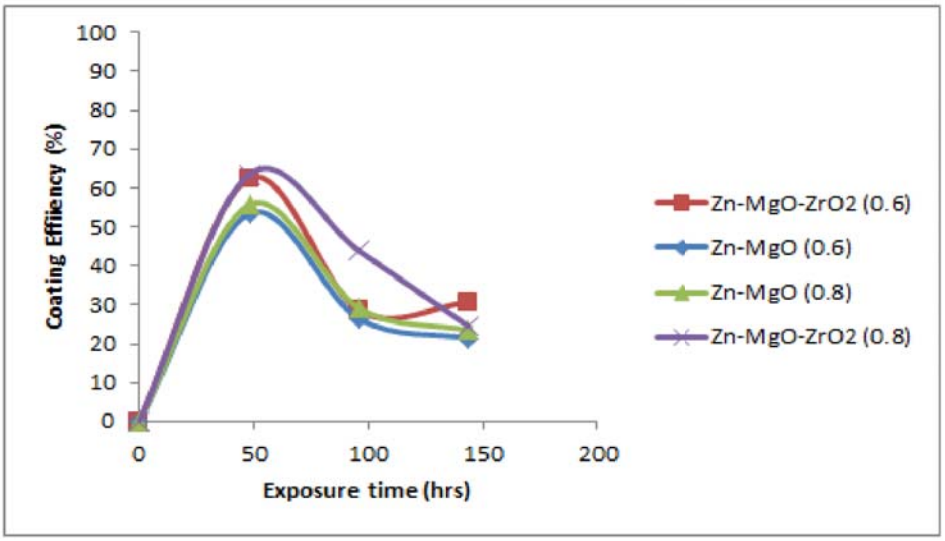

Figure 4: Coating efficiency Vs. exposure time in HCl

4. Conclusion

- The Zn-MgO-ZrO_2 (0.6V) coating exhibits the highest degree of passivity during the linear potentiodynamic experiment but the Zn-MgO-ZrO_2 (0.6V) coating was slightly better during the weight loss experiment
- The coating efficiency improved based on the characteristics of the addition of Zirconium and voltage potential those having Zirconium additives having better coating efficiency with relation to its voltage potential.
- The weight loss resistance improved based on the characteristics of the addition of Zirconium and voltage potential those having Zirconium additives having better weight loss resistance with relation to its voltage potential.

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