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New Trends in Corrosion Analysis of Al-Sn Alloy Duplex System

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ABSTRACT

The corrosion characterization of binary Al-Sn alloy systems has been statistically analyzed in the light of developed model equations. It was observed that the modeled corrosion penetration rate values generated using the developed model equations are in tandem with the experimental values.

Keywords: *Al-Sn, Statistical Analysis, Corrosion, Model Equations, Correlation*

1. Introduction

It has since been a worldwide problem for man to combat the menace of material degradation. Many structural failures and general loss of valuable engineering materials have been traced to be caused basically by analysis and not synthesis [1] as over 313 failure cases studied [2] have shown that well over 56.90% are due to corrosion. The causes of materials degradation with the associated environmental variables have been well explained in many literatures [3-14].

A critical look at all forms of corrosion show that they are merely a statistical phenomenon hence, the yardstick behind the adoption of statistics techniques in this present study. However, even with the somewhat semi-empirical nature of corrosion (as it show the relations between available data and measurements that do not necessarily reveal any relation between cause and effect), statistical models attempt to determine the fundamental relationship between sets of input data (predictors) and targets (predictands) [15,16].

The adoption of statistical analysis in corrosion analysis in metals has been predicted for years but, its usage has been hampered primarily by the specialty skill needed in applying this principle which, its impediment lies basically on the lack of reference frame for its application [16].

In this present study, we will apply the non-linear regression analysis technique to obtain model equations that will be used to determine the corrosion parameter of interest and other statistical parameters adequate for discussing and understanding the phenomenon of corrosion (in this case, Al-Sn alloys of compositions 2.5% and 4.5% by weight respectively of Sn) in selected media environments: HCl and NaCl of concentrations 0.5 M and 1.0 M respectively, using the statistical software SPSS™.

The data of Idenyi *et al.* [17] has been used for this analysis.

2. Results

The results of the corrosion penetration rate values for the experimental and modeled values are as shown in **Tables 1 to 8**, while **Table 9** is the model equation of the corrosion parameters of the various Al-Sn alloy systems in the various concentrations of hydrochloric acid and brine environments.

3. Discussion of Results

A cursory look at **Tables 1-8** clearly reveals that the modeled corrosion penetration values of the various binary alloy samples subjected to the varying concentrations (0.5 M and 1.0 M) of hydrochloric acid and brine environments respectively, are in tandem with the observed experimental values. This is further confirmed by the nearly perfect coefficient of correlations of all the composites which is in the range $0.94 \le R \le 1.00$ (see **Table 9**). The implication of this high positive coefficient of correlation is that the modeled values are in good agreement with the experimental data. Thus, our model can be of good usage in studying effect of the studied environments on Al-Sn binary alloy system on expanded time scale. In order to further confirm the dependence of the corrosion penetration rate mainly on the exposure

Table 1. CPR Data for Al – 2.5% Sn in 0.5 M HCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	2.08	1.763
24	1.25	1.334
36	0.90	1.083
48	0.73	0.905
60	0.62	0.767
72	0.55	0.654
84	0.51	0.559
96	0.47	0.477
108	0.44	0.404
120	0.43	0.338
132	0.42	0.28
144	0.39	0.226

Table 2. CPR Data for Al – 2.5% Sn in 1.0 M HCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	3.12	2.815
24	2.08	2.201
36	1.66	1.843
48	1.46	1.588
60	1.25	1.391
72	1.14	1.229
84	1.07	1.093
96	1.01	0.975
108	0.92	0.870
120	0.85	0.777
132	0.79	0.693
144	0.74	0.616

Table 3. CPR Data for Al – 2.5% Sn in 0.5 M NaCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	3.74	3.201
24	2.29	2.488
36	1.66	2.071
48	1.46	1.775
60	1.37	1.545
72	1.35	1.358
84	1.22	1.199
96	1.12	1.062
108	1.02	0.941
120	0.94	0.832
132	0.87	0.734
144	0.81	0.645

time (though alloy composition and other physical factors play a vital role in corrosion experiments), the coefficient of determination of the various samples in their different environments were also determined. It can be verified (see **Table 9**) that the range of the coefficients of determination is $0.88 \le R^2 \le 0.99$. This shows that approximately 92.64% of the total variation in the corrosion penetration rate in the whole environments is accounted for by the corresponding variation in the exposure time.

The remaining 7.36% may be due to alloy composition and other factors not incorporated in the model equations. This is overwhelmingly significant and it further confirms that the developed model equations will be a good

Table 4. CPR Data for Al – 2.5% Sn in 1.0 M NaCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	2.50	2.140
24	1.46	1.646
36	1.18	1.357
48	0.99	1.152
60	0.87	0.993
72	0.80	0.863
84	0.71	0.753
96	0.65	0.657
108	0.62	0.573
120	0.58	0.498
132	0.55	0.430
144	0.52	0.368

Table 5. CPR Data for Al – 4.5% Sn in 0.5 M HCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	3.12	2.549
24	1.66	1.890
36	1.18	1.505
48	0.94	1.231
60	0.79	1.019
72	0.73	0.846
84	0.64	0.699
96	0.60	0.573
108	0.54	0.461
120	0.5	0.360
132	0.46	0.270
144	0.43	0.187

Table 6. CPR Data for Al – 4.5% Sn in 1.0 M HCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	3.33	2.724
24	1.77	2.012
36	1.25	1.596
48	0.99	1.30
60	0.85	1.071
72	0.75	0.884
84	0.65	0.725
96	0.6	0.588
108	0.55	0.467
120	0.51	0.359
132	0.47	0.261
144	0.44	0.172

Table 7. CPR Data for Al – 4.5% Sn in 0.5 M NaCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	3.95	3.941
24	3.02	3.074
36	2.77	2.568
48	2.18	2.208
60	1.87	1.929
72	1.63	1.702
84	1.43	1.509
96	1.27	1.342
108	1.16	1.195
120	1.08	1.063
132	1.00	0.944
144	0.95	0.835

Table 8. CPR Data for Al – 4.5% Sn in 0.5 M NaCl Environment.

Time (Hrs)	Experimental CPR (mm/yr)	Modeled CPR (mm/yr)
12	3.53	3.483
24	2.91	2.656
36	2.15	2.173
48	1.66	1.83
60	1.37	1.564
72	1.18	1.346
84	1.04	1.162
96	0.94	1.003
108	0.86	0.863
120	0.79	0.737
132	0.78	0.623
144	0.75	0.520

Table 9. The Modeled Corrosion Parameters for the Various Al-Sn Alloys in Different Media Concentration.

MEDIA CONCENTRATION	COEFFICIENT OF CORRELATION (R - VALUES)	COEFFICIENT OF DETERMINATION (R^2 - VALUES)	MODEL EQUATIONS
Al – 2.5% Sn IN VARIOUS CONCENTRATIONS OF HCl			
0.5 M	0.94935	0.90126	$CPR = 3.299919 - 0.618580 In\tau$
1.0 M	0.97840	0.95726	$CPR = 5.014043 - 0.885003 In\tau$
Al – 4.5% Sn IN VARIOUS CONCENTRATIONS OF HCl			
0.5 M	0.93906	0.88183	$CPR = 4.910416 - 0.950385 In\tau$
1.0 M	0.94087	0.88524	$CPR = 5.275761 - 1.026965 In\tau$
Al – 2.5% Sn IN VARIOUS CONCENTRATIONS OF NaCl			
0.5 M	0.95146	0.90527	$CPR = 5.757208 - 1.028719 In\tau$
1.0 M	0.95772	0.91722	$CPR = 3.912334 - 0.713126 In\tau$
Al – 4.5% Sn IN VARIOUS CONCENTRATIONS OF NaCl			
0.5 M	0.99582	0.99165	$CPR = 7.045895 - 1.249661 In\tau$
1.0 M	0.98574	0.97168	$CPR = 6.445930 - 1.192448 In\tau$

predictor of the corrosion trend in the various duplex Al-Sn alloy systems being investigated.

3. Conclusion

The statistical analysis of the corrosion behaviour of Al-Sn duplex alloy system has been investigated. It can be observed that the modeled values of CPR obtained from our model equations correlates well with the experimental data. This is attributed to the nearly perfect positive coefficient of correlation that obtained in the analysis which is consistent for all the alloy compositions.

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