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Optimization of Corrosion Performance on nano ZrC particles reinforced with Al-12Si alloy Using RSM Design

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Abstract

This paper investigates the corrosion rate of ZrC nano particle reinforced with Al-12Si metal matrix composites produced by powder metallurgy. The acidic solutions used for corrosion is 1 N HCl, 1 N H_2SO_4 and 1 N HNO_3. The reinforcement percentage was 0 wt. %, 5 wt. % and 10 wt. %. The result indicates that with the enhancement of nano ZrC particles into the matrix decrease the corrosion rate respectively. The corrosion behavior of composites was studied by SEM and corrosion rate. As input parameters such as reinforcement, acid and time were designed by RSM design and the response parameter was corrosion rate was obtained experimentally by corrosion rate. RSM design was investigated for the evaluation of interactions between response parameter and input parameters. The corrosion rate specifies varying results depending on the input values of the response parameters. The outcomes revealed that all the parameters had significant effects on the corrosion rate at 95 % confidence level.

Keywords: Al-Si, corrosion rate, ZrC, RSM design, SEM, powder metallurgy.

INTRODUCTION

Today the lightweight materials are having a significant role to rule the world and most of the researchers are trying to investigate light weight components to the society. In this Aluminium composite plays an excellent roll and having excellent mechanical properties combined with good corrosion resistance. To enhance the above said properties, researchers have effectively disseminated various hard and soft reinforcements such as ZrC, B_4C, SiC, Al_2O_3, TiC and WC in aluminium alloys by different processing routes [1]. The processing methods adopted for Zirconium carbide reinforced Al-12Si metal matrix composites were prepared by powder metallurgy (P/M) [2]. Use of ZrC as reinforcement in aluminium alloys has received little attention although it possesses high hardness and modulus with larger wear and corrosion resistances [3]. In current years, aluminium alloy based metal matrix composites are being investigated as candidate materials in some applications such as automobile parts and aerospace etc., [4]. In this general RSM design was used because this type of design is suitable for products and process design, process improvement and industrial experimentation. In accumulation, when confident high-order interactions are possibly negligible, evidence on the main effects and low-order interactions may be achieved by running only a RSM design [5- 7]. Hence, this paper report an attempt made to examine the interdependence of reinforcement, acid and time input parameters and mathematical model to predict corrosion rate of Al-12Si-xZrC composites using a general RSM designs, analysis of variance, the probability and corrosion rate plot.

EXPERIMENTAL PROCEDURE

The pure electrolytic Aluminium and Silicon were purchased from M/S. MEPCO metal powder company, thirumagalam, tamilnadu, india. Zirconium carbide powders were purchased from US Research Nanomaterials, Inc. The powders were compacted and pressed in a die and punch set assembly. The attained green compact was subjected to corrosion test by corrosion rate. The as alloyed powder mixtures were characterized using SEM. The SEM micrograph of Al – Si, Al-12Si-5ZrC and Al-12Si-10ZrC particles are shown in Fig. 1 (a –c).

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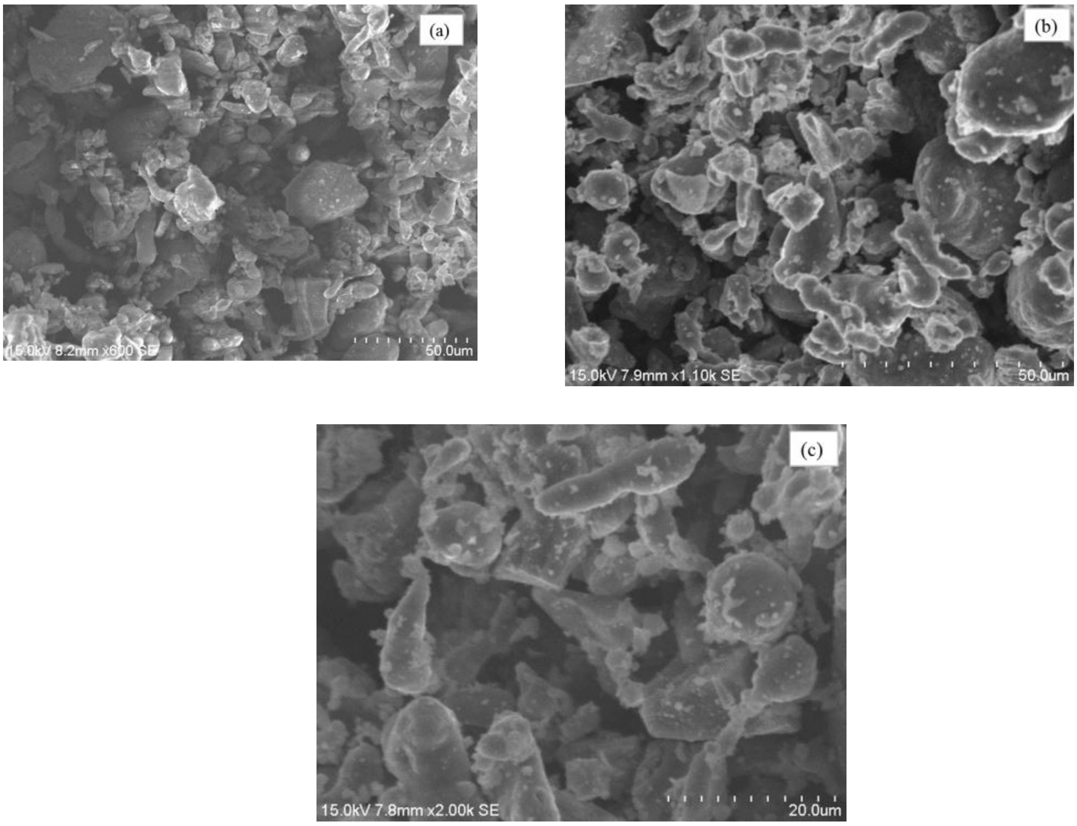

Figure 1. SEM Micrographs of Composites after Mixing (a) Al-12Si, (b) Al-12Si-5ZrC (c) Al-12Si-10ZrC,

RSM Design

General RSM designs were executed to corrosion rate (WL) with three levels and three variables. In this effort, we designated three factors to be analyzed (Table 1). Therefore the experiments were designed to three levels for each factor. The experimental domain of each factor (A, B, C) is expressed with the maximum and minimum values taken during the experiment. An implicit notation of -1 for the lowest level and +1 for the highest level (- and + to simplify) was then assigned. Table 2 shows all the runs of the experiments resulting from the factor level arrangement according to the RSM design methodology. The factor levels are stated in the matrix of experiments with implicit units such as - and +, and the numerical values of these codes are thorough in the experimentation plan. The structure of runs was executed randomly to reject any influence of systematic errors, which are difficult to stabilize and control. The response corrosion rate is shown in the last column (Table 2).

Table 1 RSM Design Experimental Plan using Design – Expert 10

Factors	**Designation**	**Levels**		
		-1	**0**	**1**
Reinforcement (A)	wt.%	0	5	10
Acid (B)	N	H_2SO_4	HCL	HNO_3
Time (C)	hr	72	144	216

Table 2. Experiments for a RSM Design and Responses

Std Order	Run Order	Input Parameters			Corrosion rate (MPY)	
		A	B	C	Actual	Predicted
1	1	-1	-1	0	0.00134	0.0013
6	2	1	0	-1	0.00176	0.0017
10	3	0	1	-1	0.00224	0.0023
14	4	0	0	0	0.00136	0.0014
15	5	0	0	0	0.00136	0.0014
16	6	0	0	0	0.00136	0.0014
5	7	-1	0	-1	0.00266	0.0025
9	8	0	-1	-1	0.00151	0.0017
13	9	0	0	0	0.00136	0.0014
11	10	0	-1	1	0.00082	0.0008
17	11	0	0	0	0.00136	0.0014
3	12	-1	1	0	0.00155	0.0017
12	13	0	1	1	0.00121	0.0011
8	14	1	0	1	0.00072	0.0009
2	15	1	-1	0	0.00073	0.0006
7	16	-1	0	1	0.00128	0.0013
4	17	1	1	0	0.00116	0.0012

Interaction Effect on Corrosion rate

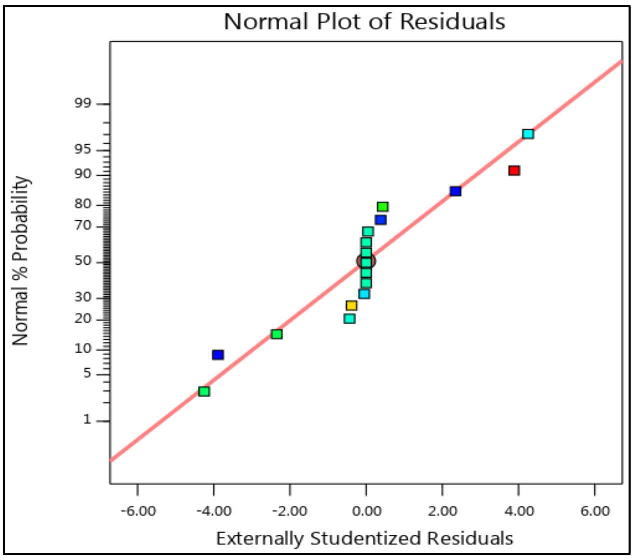

Figure 2. Shows the probability plot

Fig. 3 (a-c) shows the interaction of two dimensional (2D) contour effects of the input parameters on the corrosion rate. Fig. 3 a shows the interaction effect of reinforcement of ZrC and acid on corrosion rate. It can be determined from the reducing the corrosion rate with increasing the ZrC % up to 10% and acid due to the oxides development between the specimen surface. This influence can be evidently identified with the effect of 2D contour plot in three different colors namely, blue for lowest value, green for average value and red for greater value. Fig. 3 b represents the interaction influence of response surface plot of ZrC % and time on corrosion rate. The contour plots which confirms that the corrosion rate is decreased with increasing the ZrC % and time up to 10%. During this period the oxide layers acts as a shielding coating and decrease the corrosion rate. Fig. 3b shows the three different colors namely, blue for lowest value, green for average value and red for greater value. Minimum corrosion rate is attained at a greater time with 10% of ZrC and high at lower time and lesser ZrC %. In the other region the corrosion rate is small. Fig. 3 c represents the interaction contour plot response of acid and time on corrosion rate. The corrosion rate is reasonably decreased with increasing the acid and time. It shows that the lowest corrosion rate is obtained at a greater acid and greater time and in the remaining region it is small. Fig. 3 d shows the predicted versus actual value and it shows that there is minimum error in the corrosion rate.

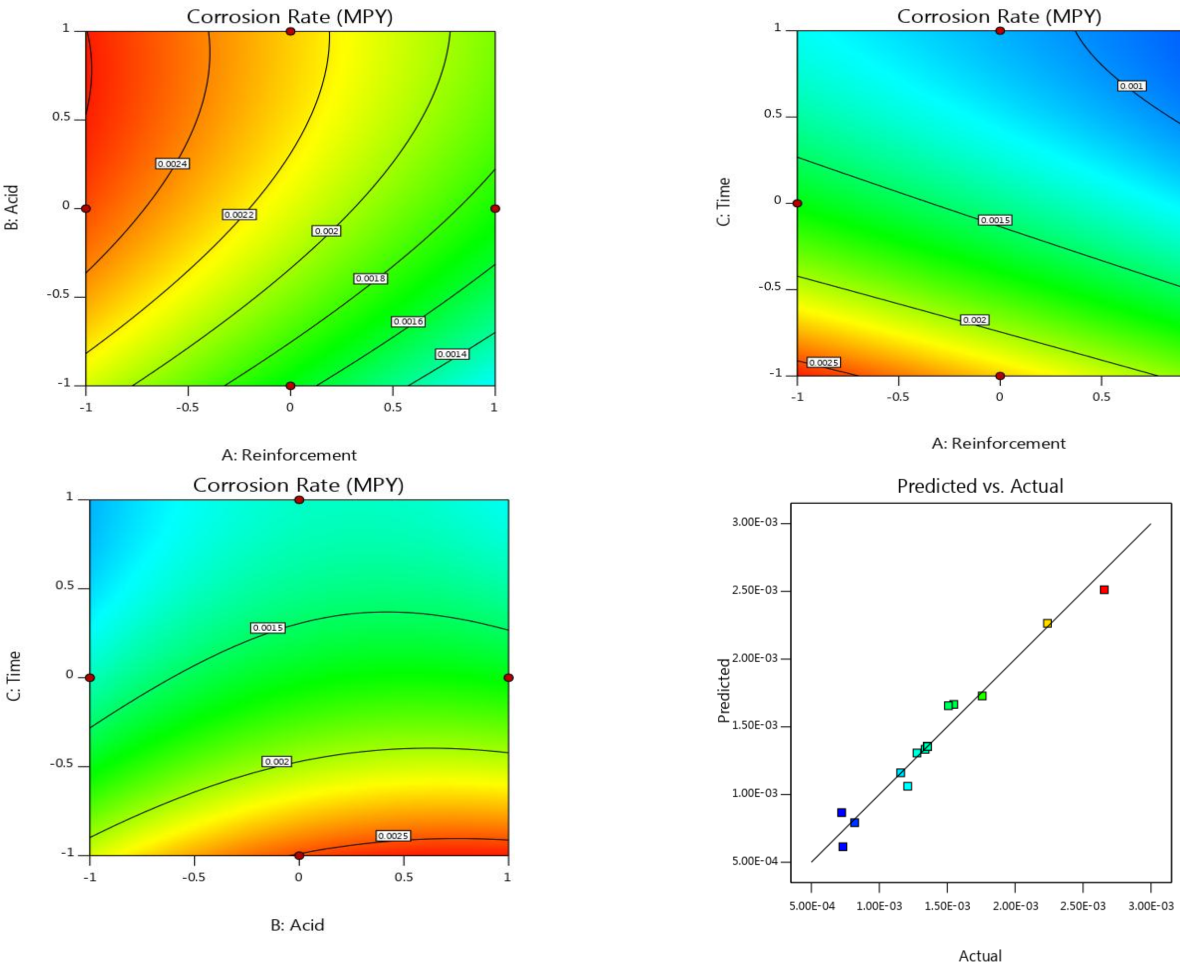

Figure 3 (a-c) Shows the contour plot for corrosion rate on reinforcement, acid and time, (d) shows the actual Vs predicted plot for corrosion rate.

Analysis of Variance

Using design expert software, the ANOVA is performed to determine which parameter significantly disturbs the corrosion rate. The results of ANOVA for response values with A, B, and C are shown in Table 3. Results show that the time is the most significant parameter compared to reinforcement and acid of corrosion rate.

Table 3. ANOVA for Corrosion rate

Source	Sum of Squares	df	Mean Square	F-value	p-value	Remarks
Model	3.69E-06	9	4.10E-07	24.83	0.0002	significant
A-Reinforcement	7.49E-07	1	7.49E-07	45.35	0.0003	significant
B-Acid	3.85E-07	1	3.85E-07	23.32	0.0019	significant
C-Time	2.14E-06	1	2.14E-06	129.24	< 0.0001	significant
AB	1.15E-08	1	1.15E-08	0.6935	0.4325	insignificant
AC	2.96E-08	1	2.96E-08	1.79	0.2227	insignificant
BC	2.87E-08	1	2.87E-08	1.74	0.2287	insignificant
A^2	2.03E-12	1	2.03E-12	0.0001	0.9915	insignificant
B^2	1.09E-07	1	1.09E-07	6.57	0.0373	significant
C^2	2.61E-07	1	2.61E-07	15.79	0.0054	significant
Residual	1.16E-07	7	1.65E-08	-	-	-
Lack of Fit	1.16E-07	3	3.86E-08	-	-	-
Pure Error	0	4	0	-	-	-
Cor Total	3.81E-06	16	-	-	-	-

Regression equation for corrosion rate with coded factor,

Corrosion rate= 0.0014 - 0.0003 A + 0.0002 B - 0.0005 C + 0.0001 AB + 0.0001 AC - 0.0001 BC - 6.94E-07 A^2 - 0.0002 B^2 + 0.0002 C^2

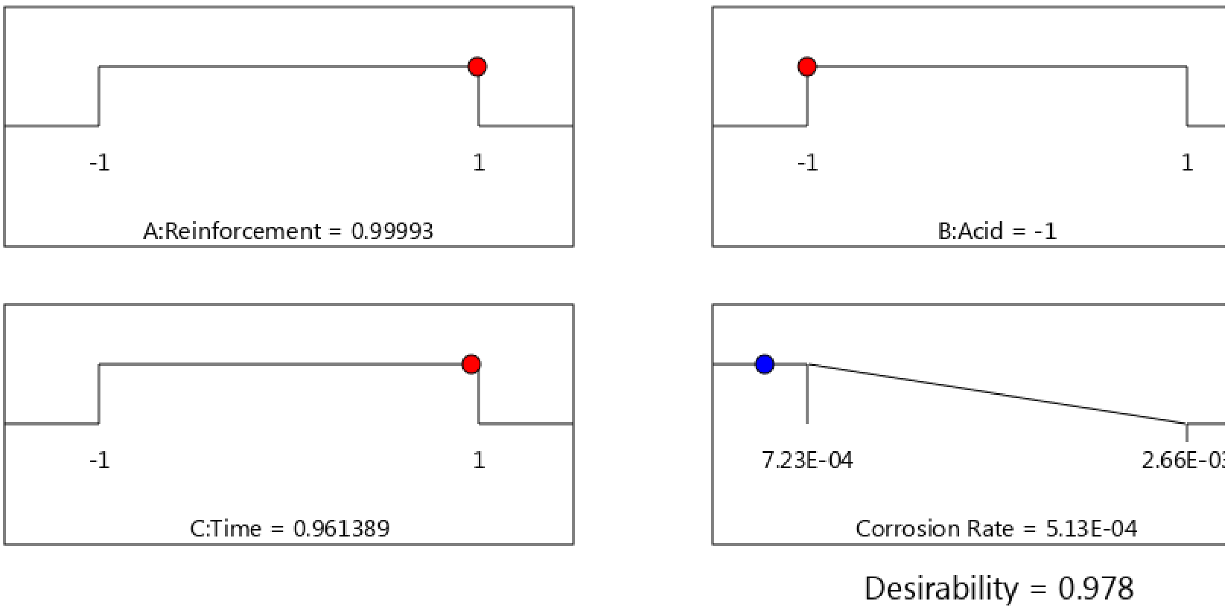

Figure 4. shows the numerical optimization of corrosion rate

Numerical optimization

Figure 4 shows the numerical optimization shows that the reinforcement at 10 wt. %, the H_2SO_4 and the time 216 hrs has the corrosion rate at minimum of $5.13e^{-04}$ when the desirability is 0.978.

CONCLUSIONS

- The corrosion behavior of Al-12Si-xZrC composites was considered at room temperature with reinforcement, acid and time, by means of RSM designs to confirm the significance and effect of testing parameters on the corrosion rate.
- ANOVA specifies the significance of the input parameters and the % contribution of input parameters influencing on corrosion rate. It shows that time is the most influencing factor compared to that of reinforcement and acid.
- The experimental corrosion rate depends on acid, reinforcement and time and the second-order model indicated that the time had a major influence on the corrosion rate of the Al-12Si-xZrC composites.
- The corrosion rate increases with an increase in the time and acid and decreases with an increase in the reinforcement.
- The predicted and the measured values are adequately close to each other which specify that the developed quadratic model can be successfully used for predicting the corrosion rate of Al-12Si-xZrC composites with 95% confidential level.

REFERENCES

[1] R. Ganesh, D.K.S. Neshan, K. Rajendra Prasad, Chandrasekaran Kesavan, "Modeling and Optimization of the Wear Performance of Aluminium Metal Matrix Composite Using

Response Surface Methodology", Applied Mechanics and Materials, Vols. 592-594, pp. 1336-1340, 2014

[2] N. Radhika, R. Raghu, Dry Sliding Wear Behaviour of Aluminium Al–Si12Cu/TiB2 Metal Matrix Composite Using Response Surface Methodology, Tribology Letters (2015) vol. 59(2), pp.1-9.

[3] C. Fradaric John, R. Christu Paul, S. Christopher Ezhil Singh and T.Ramkumar, “Tribological behavior, mechanical properties and microstructure of Al-12Si-ZrC composite prepared by powder metallurgy”, Bulletin of the Polish Academy of Sciences: Technical Sciences, 65(2), 149-154 (2017).

[4] Muna K. Abbass, Khairia S.Hassan, and Abbas S. Alwan, Study of Corrosion Resistance of Aluminum Alloy 6061/SiC Composites in 3.5% NaCl Solution, International Journal of Materials, Mechanics and Manufacturing, Vol. 3, No. 1, 2015, pp. 31-35.

[5] H C Ananda Murthy, V Bheema Raju and C Shivakumara, Effect of TiN particulate reinforcement on corrosive behavior of aluminium 6061 composites in chloride medium, Bull. Mater. Sci., Vol. 36, No. 6, 2013, pp. 1057–1066.

[6] M. Sambathkumar, P. Navaneethakrishnan, K. Ponappa, K.S.K. Sasikumar, Mechanical and corrosion Behavior of Al7075 (Hybrid) Metal Matrix Composites by Two Step Stir Casting Process, Latin American Journal of Solids and Structures vol. 14, (2017), pp.243-255.

[7] El-Sayed M.Sherif , A. A. Almajid , Fahamsyah Hamdan Latif , Harri Junaedi, Effects of Graphite on the Corrosion Behavior of Aluminum-Graphite Composite in Sodium Chloride Solutions, Int. J. Electrochem. Sci., vol. 6, (2011) pp. 1085-1099.