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Weight Loss Method for corrosion behaviour of Al-12si-ZrC Composites Using Response Surface Methodology

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Abstract

This paper investigates the weight loss 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 weight loss respectively. The corrosion behavior of composites was studied by SEM and weight loss method. As input parameters such as reinforcement, acid and time were designed by RSM design and the response parameter was weight loss was obtained experimentally by weight loss method. RSM design was investigated for the evaluation of interactions between response parameter and input parameters. The weight loss specifies varying results depending on the input values of the response parameters. The outcomes revealed that all the parameters had significant effects on the weight loss at 95 % confidence level.

Keywords: Al-Si, weight loss, 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 weight loss of Al-12Si-xZrC composites using a general RSM designs, analysis of variance, the probability and weight loss 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 weight loss method. 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).

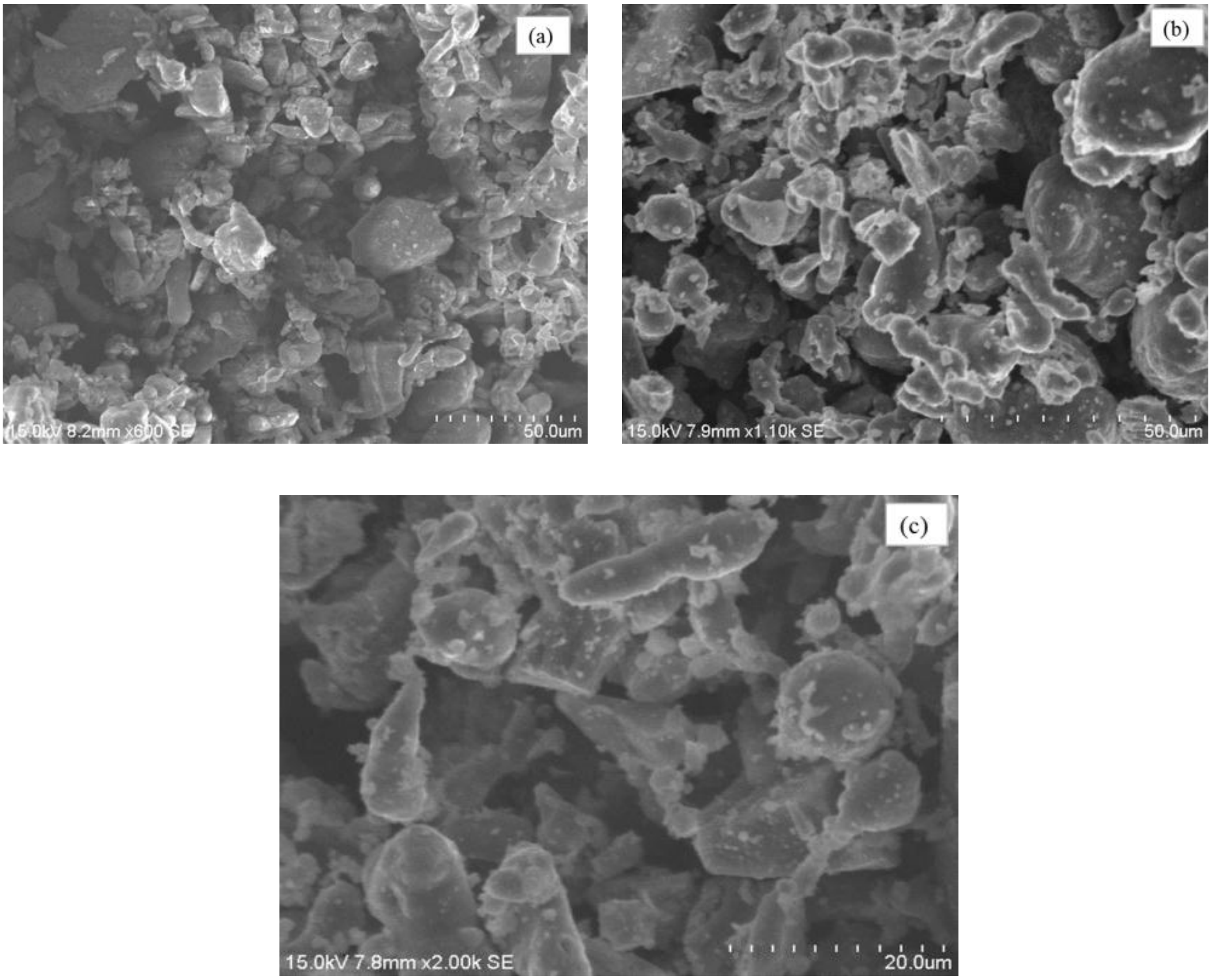

Figure 1. SEM Micrographs of Composites after Mixing (a) Al-12Si, (b) Al-12Si-5ZrC (c) Al-12Si-10ZrC,

RSM Design

General RSM designs were executed to weight loss (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 weight loss 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			Weight loss (MPY)	
		A	B	C	Actual	Predicted
1	1	-1	-1	0	0.0350	0.035
6	2	1	0	-1	0.0265	0.0257
10	3	0	1	-1	0.0316	0.0324
14	4	0	0	0	0.0383	0.0383
15	5	0	0	0	0.0383	0.0383
16	6	0	0	0	0.0383	0.0383
5	7	-1	0	-1	0.0348	0.033
9	8	0	-1	-1	0.0218	0.0237
13	9	0	0	0	0.0383	0.0383
11	10	0	-1	1	0.0347	0.0339
17	11	0	0	0	0.0383	0.0383
3	12	-1	1	0	0.0437	0.0448
12	13	0	1	1	0.0510	0.0491
8	14	1	0	1	0.0327	0.0345
2	15	1	-1	0	0.0221	0.021
7	16	-1	0	1	0.0502	0.051
4	17	1	1	0	0.0349	0.035

RESULT AND DISCUSSION

Normal Probability Plot

To confirm the effects of variables is the normal probability plot for variables. The benefit of the probability plot is in the procedure of effects from variables on the "noise" line (red line in the Fig. 2). The additional distant parameter is from the "noise" line, the better effect on the weight loss with greater accuracy can be obtained. Fig. 2 confirms the significant factors present in the model. The reinforcement, acid and time interfaces between the variables have been revealed statistically by the -normal probability plot analysis. The results revealed that interaction between the reinforcement and other parameters is below the 5 % significance level.

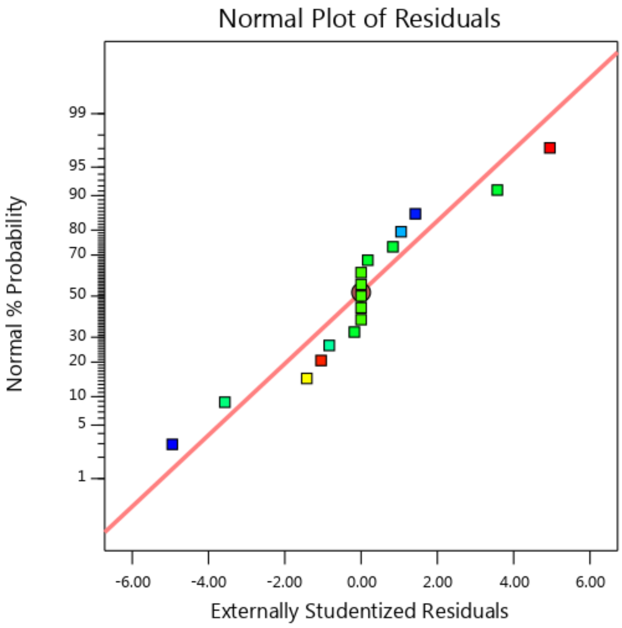

Figure 2. Shows the probability plot

Interaction Effect on Weight Loss

Fig. 3 (a-c) shows the interaction of two dimensional (2D) contour effects of the input parameters on the weight loss. Fig. 3 a shows the interaction effect of reinforcement of ZrC and acid on weight loss. It can be determined from the reducing the weight loss 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 weight loss. The contour plots which confirms that the weight loss 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 weight loss. Fig. 3b shows the three different colors namely, blue for lowest value, green for average value and red for greater value. Minimum weight loss is attained at a greater time with 10% of ZrC and high at lower time and lesser ZrC %. In the other region the weight loss is small. Fig. 3 c represents the interaction contour plot response of acid and time on weight loss. The weight loss is reasonably decreased with increasing the acid and time. It shows that the lowest weight loss 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 weight loss.

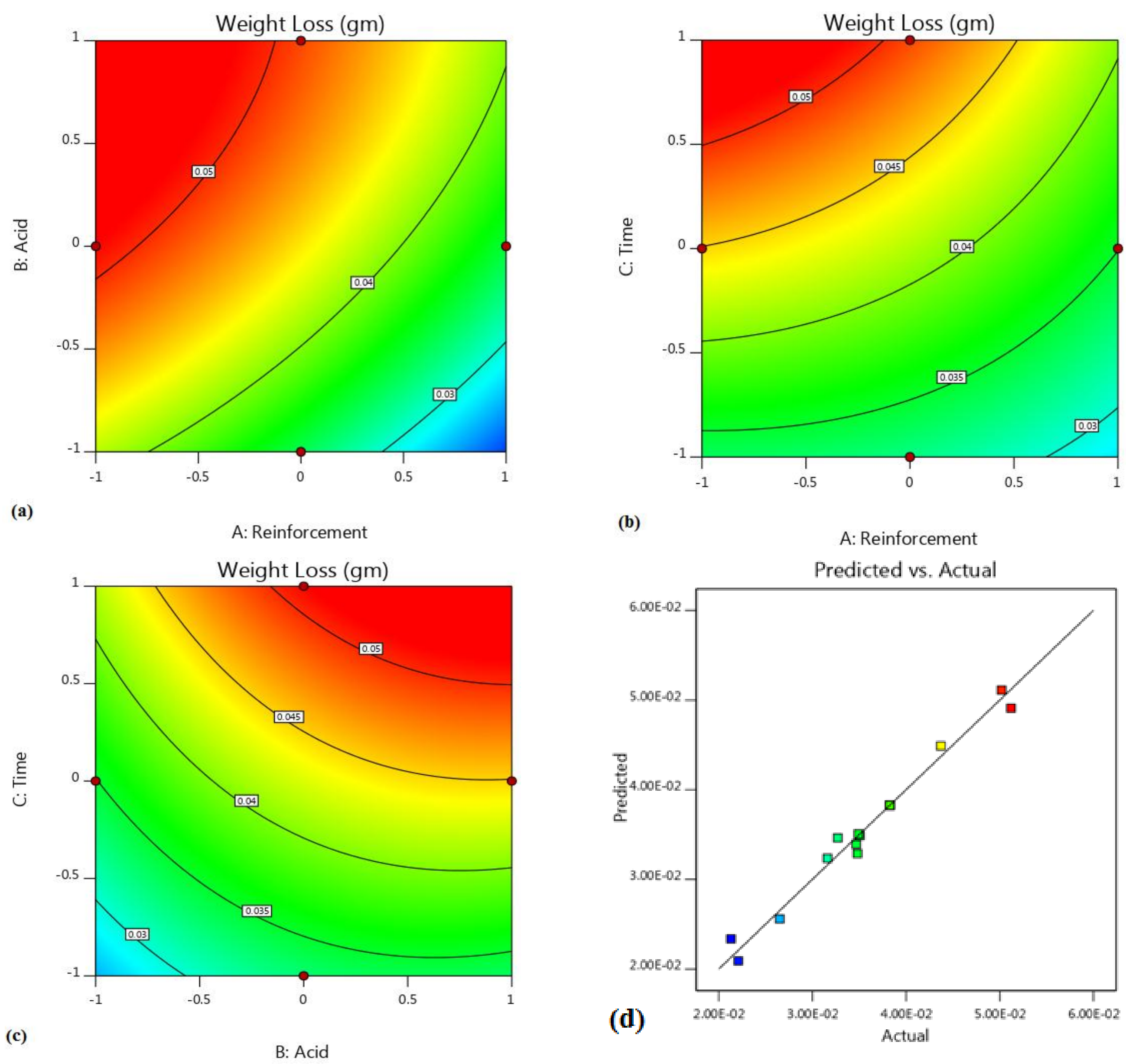

Figure 3 (a-c) Shows the contour plot for weight loss on reinforcement, acid and time, (d) shows the actual Vs predicted plot for weight loss.

Analysis of Variance

Using design expert software, the ANOVA is performed to determine which parameter significantly disturbs the weight loss. 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 weight loss.

Table 3. ANOVA for Weight Loss

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	Remarks
Model	0.001	9	0.0001	36.84	< 0.0001	significant
A-Reinforcement	0.0003	1	0.0003	90.95	< 0.0001	significant
B-Acid	0.0003	1	0.0003	93.78	< 0.0001	significant
C-Time	0.0004	1	0.0004	119.67	< 0.0001	significant
AB	$4.29E^{-06}$	1	$4.29E^{-06}$	1.38	0.279	insignificant
AC	0	1	0	6.81	0.035	significant
BC	$9.73E^{-06}$	1	$9.73E^{-06}$	3.13	0.1203	insignificant
A^2	$9.31E^{-06}$	1	$9.31E^{-06}$	2.99	0.1274	insignificant
B^2	0	1	0	10.94	0.013	significant
C^2	$2.26E^{-06}$	1	$2.26E^{-06}$	0.7257	0.4225	insignificant
Residual	0	7	$3.11E^{-06}$	-	-	-
Lack of Fit	0	3	$7.26E^{-06}$	-	-	-
Pure Error	0	4	0	-	-	-
Cor Total	0.0011	16	-	-	-	-

Regression equation for weight loss with coded factor,

$$\text{Weight loss} = 0.0383 - 0.0059\,A + 6.00E^{-03}\,B + 0.0068\,C + 1.00E^{-03}\,AB - 2.30E^{-03}\,AC + 0.0016\,BC - 1.50E^{-03}\,A^2 - 0.0028\,B^2 - 0.0007\,C^2$$

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 weight loss at minimum of 0.0231gm when the desirability is 0.978.

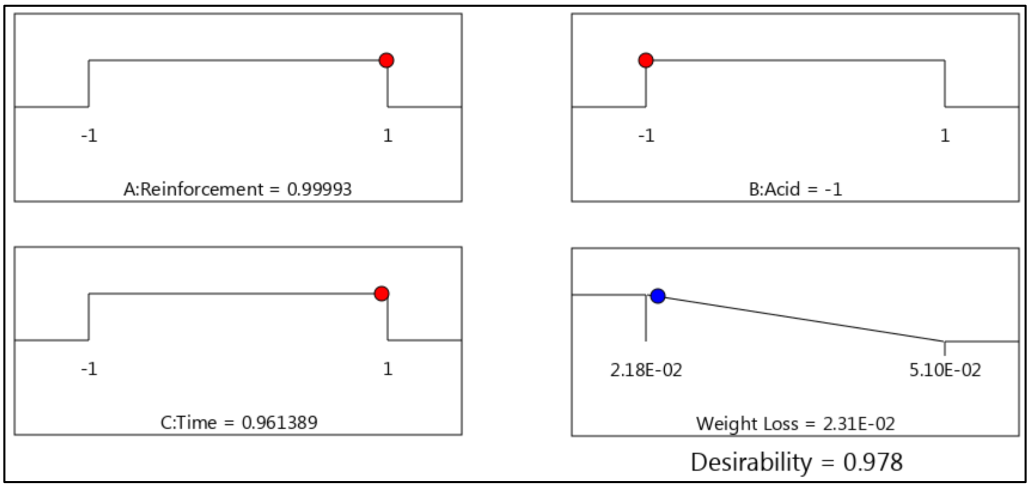

Figure 4. shows the numerical optimization of weight loss

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 weight loss.
- ANOVA specifies the significance of the input parameters and the % contribution of input parameters influencing on weight loss. It shows that time is the most influencing factor compared to that of reinforcement and acid.
- The experimental weight loss depends on acid, reinforcement and time and the second-order model indicated that the time had a major influence on the weight loss of the Al-12Si-xZrC composites.
- The weight loss 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 weight loss of Al-12Si-xZrC composites with 95% confidential level.

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