Corrosion rate of Al-Si Alloy Reinforced with B_4C Nanoparticle prepared by Powder Metallurgy Method using RSM

Abraham Subaraj. M, Bensam Raj. J, Malkiya Rasalin Prince. R, Glan Devadhas.G, Christopher Ezhil Singh. S

Abstract**: *The current work aims to optimize the Al-Si alloy reinforced with B_4C nanoparticles prepared through powder metallurgy technique. The sample was prepared with different weight percentage 0, 4 and 8; the size of the sample was 20 mm x 20mm and sintered in a furnace upto 500°C with argon gas and their by furnace cooled to room temperature. The samples were brushed to remove the slag present in it, and polished by emery paper. Then the samples were weighed in an electric balancing apparatus to measure the initial weight of the sample before dipping it into acid solution. The weight loss was measured to calibrate the corrosion rate of the samples for 9 days. Response surface methodology was designed for three factors at three levels with a response as corrosion rate. The Analysis of Variance (ANOVA) was used to identify the most influencing factor on corrosion rate. The normal probability plot, residual plot, and desirability plot demonstrates the influence of corrosion rate of the composites.***

Keywords: Al-Si, Boron Carbide, ANOVA, Powder Metallurgy

I. INTRODUCTION

Aluminium Matrix Composites (AMCs) is wangled mixture of the metal alloys and hard ceramic to become tailored properties. Furthermost metals and alloys might be utilized as matrices and they necessitate strengthening materials which requirement to be steady above a variety of temperature and non-reactive too. Light metals form the matrix for temperature application and the strengthening in with the aforementioned causes are considered by maximum moduli. Aluminum and Magnesium are the common matrix metals at present in trend, which are predominantly suitable for aircraft uses. If metal matrix materials have to agree maximum strength, they need maximum modulus strengthening. The strength-to-weight ratios of subsequent composites could be maximum than best alloys. In this general RSM design was utilized for the reason that this kind of design is appropriate for products and process design, process enhancement and industrial investigation. In accumulation, after confident high-order interactions are possibly insignificant, evidence on the key effects and low-order interactions might be achieved by consecutively only a RSM design [5- 7]. Hence, this current work is an effort made to scrutinize the effort of reinforcement, acid and time input factors and arithmetical model to forecast weight loss of Al-12Si-x B4C composites utilizing a Box-Behnken Design (BBD), analysis of variance, the probability and weight loss plot.

II. EXPERIMENTAL PROCEDURE

Aluminum and Silicon were purchased and the perfection of 99% and size minor than 20 and 40 μm from M/S. MEPCO metal powder company, thirumagalam, tamilnadu, india. Boron carbide powder with perfection of 99.9% and size minor than 44 μm used as a secondary fortification material was purchased from Sigma Aldrich, Germany. Nano sized B_4C particles were milled to a size of the elements was ≤100 nm, subsequently 60 h grinding. The SEM microstructures of the composites are shown in the following figures. Fig 1 (a) demonstrates the SEM microstructure of Al elements. It can be observed that aluminum has spherical structure. Fig 1 (b) demonstrates the SEM image of Si element and it is observed to have flattened and large flake like elements. Figure 1 (c) demonstrates that the B_4C particles with rhombohedral shape. Rule of mixtures was used to calibrate the changing weight portions of Al-12Si-xB_4C (x = 0, 4 & 8 wt.%). It was evidently confirmed in the SEM pictures exposed in Fig. 2(a–c). It was perceived that all the elements were disseminated consistently through the compositions. The alloyed powder is compacted in a compression testing machine to achieve 30 mm height and 10 mm diameter with applied pressure of 800 MPa. The compressed specimens are sintered using argon gas purging heating furnace for 120 min at 550°C and furnace cooled to surrounding temperature. The sintered compacted sample was imperiled to wear test by pin-on-disk technique. The alloyed powder mixtures were characterized using SEM. The SEM pictures of Al-Si, Al-12Si-4B_4C and Al-12Si-8B_4C elements are shown in Fig.2 (a –c).

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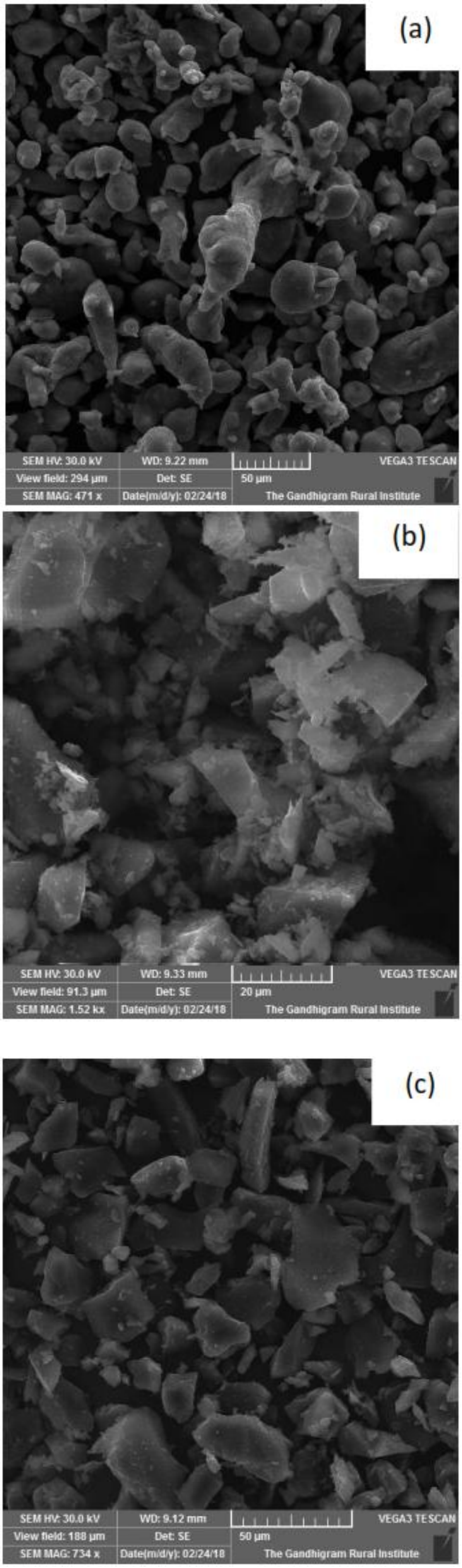

Fig. 1.Demonstrates the SEM pictures of powders a) Al, b) Si, and c) B_4C

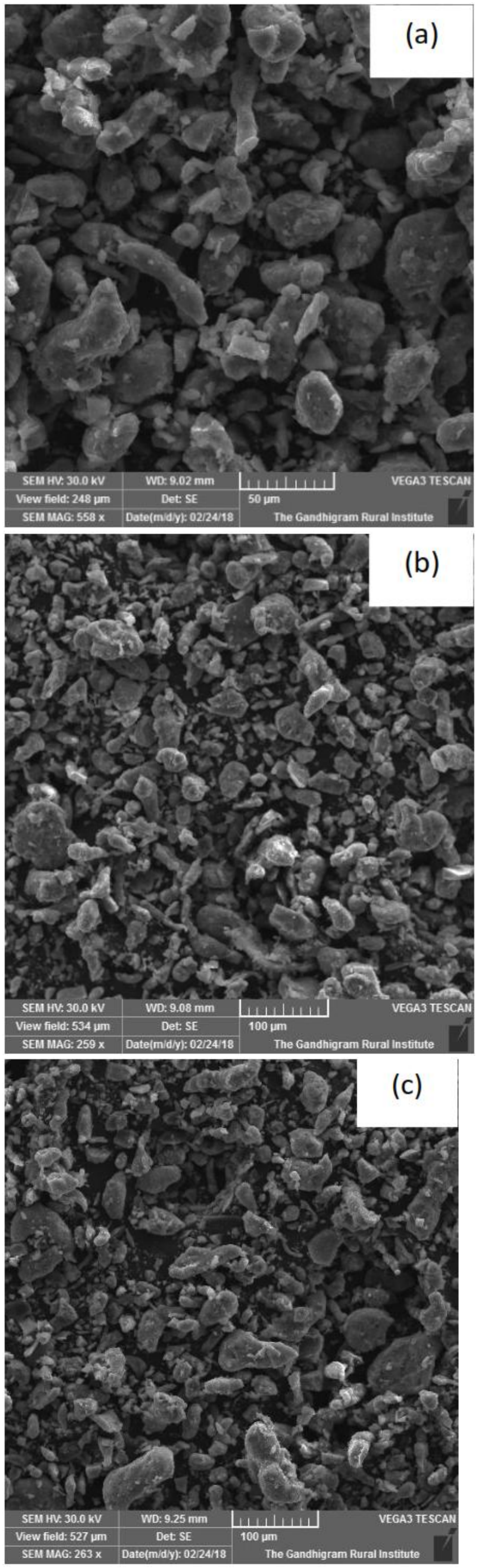

Fig. 2.Demonstrates the SEM pictures of mixed powders a) Al-12Si, b) Al-12Si-4B_4C, and c) Al-12Si-8B_4C

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A. Response Surface Methodology

Response surface methodology is a set of numerical and geometric methods that are helpful for budding, progressing, and best route. This process may be utilized by several investigators for forecasting the wt.% of composites, sliding distance, load, and so forth. The Design Expert Software V11 was utilized to extend the trial design for RSM. In the current work, the wt.% of B_4C, SD and L are measured as self-sufficient parameters and the response variable is the CoF. In RSM, the computable form of the connection among the preferred output and the self-determining input parameters could be characterized as exposed in the subsequent equation.

$$y = f(A, B, C)$$

where, y is the preferred output and f is the output function. The BBD is a first-order design improved by extra points to permit evaluation of the modification factors of a second order model. The testing factors at three levels with their choice are offered in Table 1 and Table 2 exposes the trial runs with the input factors and out response.

Table 1 Experimental factors and number of levels used in design – expert 9.0.5

Testing Parameter	Symbol	Level 1 (-1)	Level 2 (0)	Level 3 (1)
Reinforcement (A)	Wt.% of B_4C	4	6	8
Acid (B)	-	H_2SO_4	HCl	HNO_3
Time (C)	hr	72	144	216

Table 2 shows the experimental run and input factors with its response

Std Run	Run	Input factors			Response
		wt.% of B_4C	Acid	Time	Weight Loss
13	1	0	0	0	0.0348
8	2	1	0	1	0.0391
16	3	0	0	0	0.0295
9	4	0	-1	-1	0.0347
6	5	1	0	-1	0.0419
12	6	0	1	1	0.0347
17	7	0	0	0	0.0316
2	8	1	-1	0	0.0350
1	9	-1	-1	0	0.0502
10	10	0	1	-1	0.0555
11	11	0	-1	1	0.0538
4	12	1	1	0	0.0219
3	13	-1	1	0	0.0339
15	14	0	0	0	0.0347
7	15	-1	0	1	0.0347
14	16	0	0	0	0.0347
5	17	-1	0	-1	0.0220

III. RESULT AND DISCUSSIONS

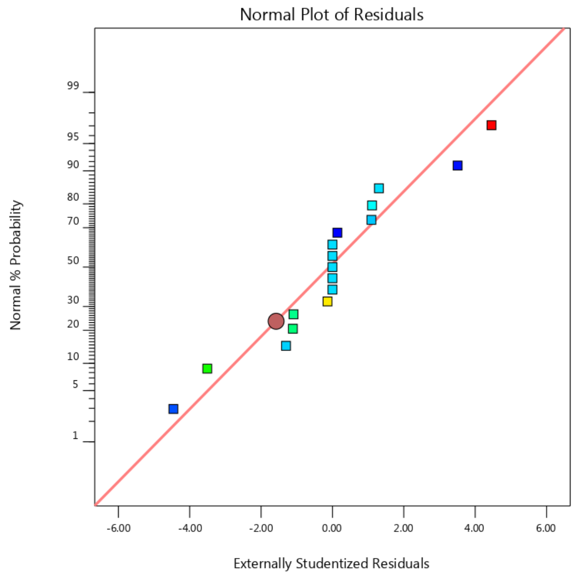
A. *ANOVA for Corrosion Rate*

The influencing parameters can be identified by the ANOVA table given below. ANOVA of corrosion rate for the Al-12Si-xB_4C composite was tabulated by the factors that has considered for designing was of wt. % B_4C, acid and time. The Fisher's F-test could be carried out for testing the influence factor. The ANOVA table mentioned below was having a significance level of α=0.05. The P-value less than 0.05; shows, that the factor has been significant. The ANOVA table indicates that from the p value the time is having more influence than other two factors. This indicates that the corrosion rate depends on the time taken is the influencing factor to corrode as compared to that of acid and reinforcement.

Source	Sum of Squares	df	Mean Square	F-value	p-value	Remarks
Model	$3.34E^{+05}$	9	37080.76	57.72	< 0.0001	significant
A-Reinforcement	50372.11	1	50372.11	78.41	< 0.0001	-do-
B-Acid	65857.97	1	65857.97	102.51	< 0.0001	-do-
C-Time	$1.59E^{+05}$	1	$1.59E^{+05}$	247.17	< 0.0001	-do-
Residual	4497.03	7	642.43	-	-	-
Lack of Fit	4497.03	3	1499.01	-	-	-
Pure Error	0	4	0	-	-	-
Cor Total	$3.38E^{+05}$	16	-	-	-	-

B. Adequacy Check of the Model

C. Normal probability



a

Normal probability plot demonstrates in figure 3(a) that the values near to the red line indicates that it has minimum error, the values which is away from red line indicates that it has maximum error, this plot indicates that the values are near to the red line and the model has least value of error present in it. The residuals shows that the red line which is in coherence with response and the input factors. The RSM designed by BBD provides a better solution by the factor and the response to which it's influenced on residual.

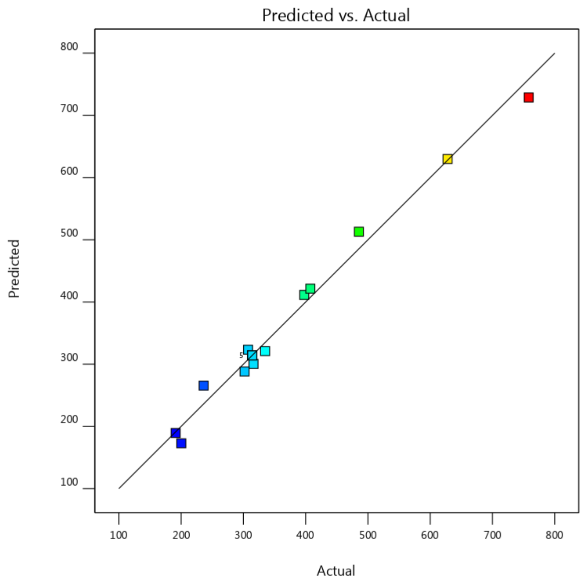


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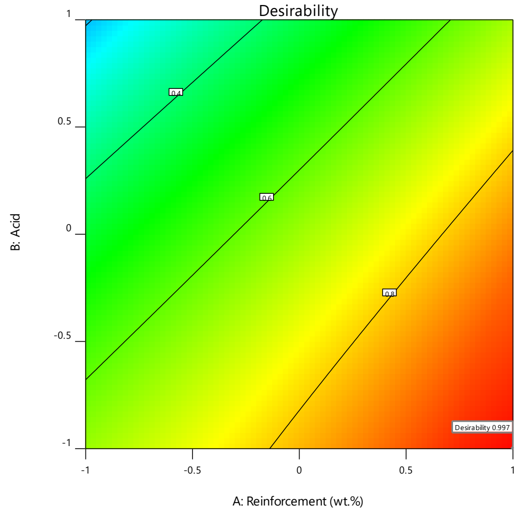
Fig.3. demonstrates the (a) Normal Probability and (b) Predicted vs Actual

D. Predicted versus Actual Value

The Figure 3(b) predicted versus actual value plot demonstrates that almost all the values are near to each other, therefore the residuals makes no change in the actual vs predicted. The differences in values are negligible to make more error on the model.

E. Effect of Corrosion rate on all factors by desirability

Desirability plot demonstrates that the reinforcement against acid medium, where the desirability near to one indicates that the reinforcement is maximum, on the same time the corrosion plot demonstrates that the corrosion rate is less at maximum desirability at the same time the minimum desirability value the corrosion rate will be more represented in the 2D plot. The two plots indicate that the reinforcement reduces the corrosion rate, but the HNO_3 has more corrosion rate than the other two acid mediums. The plot that has shown in figure, the reinforcement against the time, demonstrates that the desirability plot with minimum value has more corrosion rate, and maximum desirability has less corrosion rate. Moreover, when the time with maximum desirability the corrosion rate is less to that of minimum desirability the corrosion is more. The values are differentiated by different colors in the plots. The 2D plot demonstrates that increasing the time the corrosion rate will be more with respect to the reinforcements and the corroded Al-12Si-xB_4C nanocomposites shows the influence of the time on corrosion with reinforcement and acid mediums. Similarly, the acid medium against the time, demonstrates that the desirability plot with minimum value has more corrosion rate, and maximum desirability has less corrosion rate. Moreover, when the time with maximum desirability the corrosion rate is less to that of minimum desirability the corrosion is more. It is differentiated by different colors in the plots. The 2D plot demonstrates that increasing the time the corrosion rate will be more with respect to the acid mediums that corroded on the Al-12Si-xB_4C nanocomposites.



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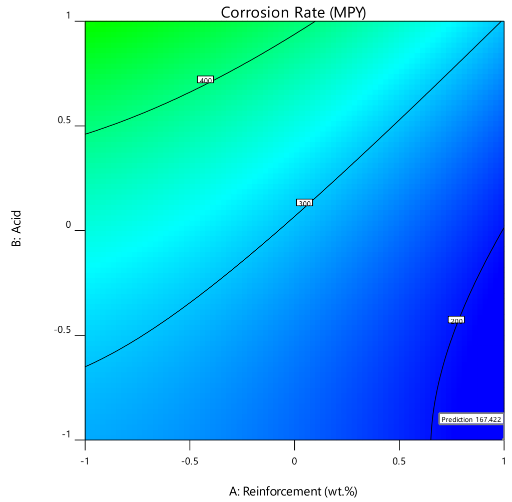

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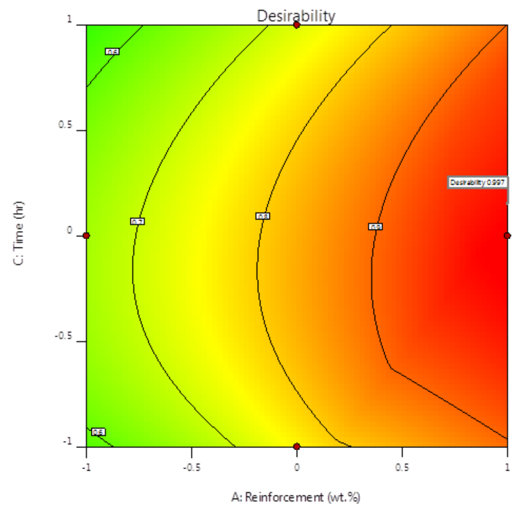

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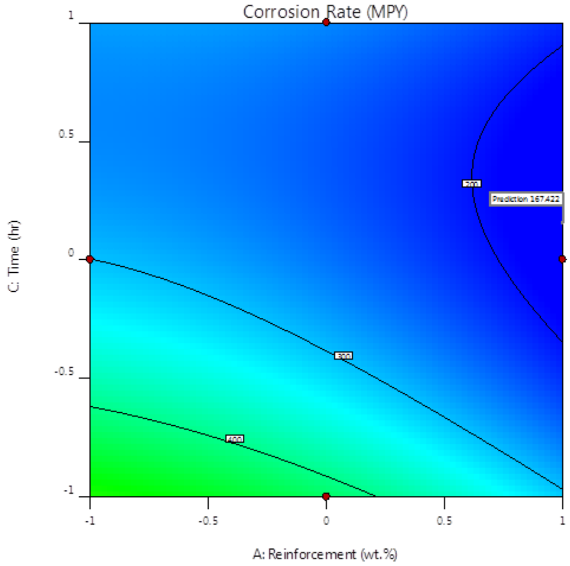

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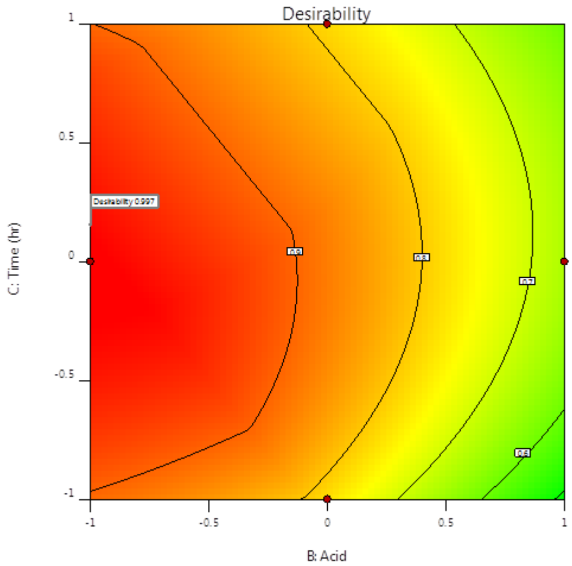

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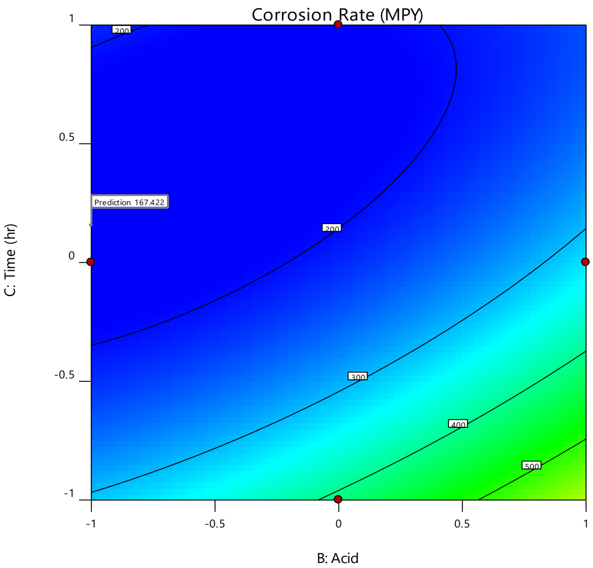

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Fig.4. Demonstrates the Desriability of and Corrosion Rate of Al-Si-B_4C Composites

IV. CONCLUSION

From the present research work, the Al-12Si-xB_4C nanocomposites were investigated for the corrosion rate. The SEM images shows the received powder samples and mixed powder samples used in this investigation. ANOVA table demonstrate the influencing parameter with respect to the reinforcement, acid and time to identify that which factor was influenced more. From the table it was noted that time is the most influence factor compared to that of other two. Normal Probability plots shows that the error was less; since the residuals values lie near to the red line of the model. The desirability plot indicates that the less desirability shows more corrosion rate and maximum desirability shows minimum corrosion rate. The 2D plots of corrosion rate with reinforcement, acid and time shows that the color indicates the maximum and minimum corrosion.

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