JJMIE

Volume 12, Number 4, December. 2018
ISSN 1995-6665
Pages 313 - 321

Jordan Journal of Mechanical and Industrial Engineering

Effects of SiC Particles Parameters on the Corrosion Protection of Aluminum-based Metal Matrix Composites using Response Surface Methodology

Shashi Prakash Dwivedi*, Rohit Sahu

G. L. Bajaj Institute of Technology & Management, Greater Noida, Gautam Buddha Nagar, U.P. 201310, India

Received 3 August. 2018

Abstract

In the automobile industries materials, durability with respect to time (corrosion behavior) of materials is one of the most important factors observed since many past years. In the present investigation, aluminum (AA6061) based metal matrix composite successfully developed using SiC as reinforcement material through electromagnetic stir casting route. Three parameters (preheat temperature, size, weight percent) of SiC were selected to reduce the corrosion rate of metal matrix composite. From the result, it was observed that by increasing the preheat temperature of SiC, corrosion rate decrease. Increasing the particle size and weight percent of SiC, corrosion rate also increases. Regarding optimal values of SiC preheat temperature, SiC particle size and wt. % of SiC were found to be 370.120C, 38.7 µm and 2.94 wt. % respectively for minimum corrosion rate 1.16444 mm/year with desirability one of metal matrix composite using Response Surface Methodology. Microstructure at optimum reinforcement parameters was carried out. Uniform distribution of composite was observed at optimum SiC particles parameters.

© 2018 Jordan Journal of Mechanical and Industrial Engineering. All rights reserved

Keywords: Preheat temperature, size, weight percent, corrosion rate, RSM;

1. Introduction

Aluminum alloys reinforced with ceramic particulates have considerable potential due to their high specific strength and stiffness as well as low density. The higher specific strength is, the higher strength and lighter weight the material is. It is important to select materials with high specific strength or improve the specific strength to lift buildings' height, reduce structural weight and lower project costs. Stiffness is proportional to the cube of the thickness. To neutralize aluminum being one-third the stiffness of steel, an aluminum part must be made 44 percent thicker than the steel part [1-2]. These properties have made particles reinforced metal matrix composites (MMCs) an attractive material for the use in aerospace, transportation and industrial sectors [3-5]. Aluminum based metal matrix composite is used in various industrial applications where good mechanical properties are required. Its demand in aircraft industries and automobile industries is mainly due to its low cost of processing and a broad range of properties [6-9]. Aluminum based metal matrix composite (AMC) is used in the design of specific aerospace and automotive components such as ventral fins, fuel excess door covers, rotating blades sleeves, gear parts, crankshafts, and suspension arms [10-13]. In the electronics industry, it is used in the processing of integrated heat sinks, microprocessor, microwave, aircraft wings, fuselages frames and landing gears [14-15]. Though, mechanical properties of materials such as hardness and tensile strength are much important factor in the application of materials in various manufacturing sector [16-18]. But from some past years, other factors are also considered by the automobile industries as well as manufacturing industries; this factor is materials' durability with respect to time [19-20].

Pen Jin et al. [21] found the effect of SiC particle size on the structures and properties of Ni–SiC nanocomposites deposited by magnetic pulse electrodeposition technology. Results showed S-30 nanocomposites with fine, compact and uniform structures consisting of fine nickel grains (average size: 381.7 nm) and SiC nanoparticles (average size: 34.2 nm). For SiC particle size of 30 nm, diffraction peaks of Ni and SiC appeared wide with low intensity, indicating S-30 nanocomposites with small-sized Ni grains and SiC nanoparticles. Reza Zare et al. [22] investigated the effect of SiC particles on the physical and thermal properties of Al6061/SiCp composite. It was seen that with increasing the amount of the reinforcement, the density of the samples decreased, while the porosity increased. D. Ahmadkhaniha et al. [23] observed the effect of SiC particle size and heat-treatment on microhardness and corrosion resistance of NiP electrodeposited coatings. It was found that the heat-treatment doubled the

* Corresponding author e-mail: spdglb@gmail.com.

microhardness and changed the anodic polarization behaviour of the coatings from passive to active with respect to the as-plated conditions. S. Vijayabhaskar et al. [24] showed the effect of nano SiC particles on properties and characterization of Magnesium matrix nanocomposites. The results showed that the increase in weight % of nano SiC improves the mechanical properties. Pham Van Trinh et al. [25] investigated the effect of oxidation of SiC particles on mechanical properties and wear behaviour of SiCp/Al6061 composites. The results revealed an improvement in interfacial bond strength between Al6061 and oxidized SiC_p due to the formation of a $MgAl_2O_4$ continuous phase and suppression of brittle Al_4C_3 formation at the interfacial layer. Łukasz Rogal et al. [26] designed novel metal matrix nanocomposites exploring the CoCrFeMnNi high entropy alloy as a matrix and SiC spherical nanoparticles with a diameter of 20–50 nm as a reinforcement phase and manufactured by mechanical alloying followed by hot isostatic sintering. Li Zhang et al. [27] identified the effect of SiC particles and the particulate size on the hot deformation and processing map of AZ91 magnesium matrix composites. Results show that compared with the monolithic AZ91 alloy, the incorporated nano-SiC particles effectively increase the flow stress of the composites by blocking the strain-induced dislocations, while the effect of the micro-SiC particles varies due to the competition between pinning effect and particle stimulating nucleation (PSN) mechanism.

From the literature review, it was observed that very few researchers find out the reinforcement parameters effect on the corrosion rate of aluminum-based MMC. No researchers have given the optimum value of the combination of reinforcement parameters to reduce the corrosion rate using response surface methodology. Keeping these facts in mind, optimum condition of reinforcement parameters was obtained using Response Surface Methodology followed by confirmation experiment which was carried out to identify reduced corrosion rate as compared to the base material.

2. Materials and Methods

2.1. Matrix Material

In this study, aluminum alloy 6061 is chosen as the matrix material. Alloy 6061 is one of the most widely used alloys in the 6000 series. AA6061 is used in the fabrication of various rotating and reciprocating parts such as brake-rotors, driveshafts, piston and in other structural parts which require lightweight and high strength materials [19]. Typical chemical composition of Al 6061 is presented below:

Table 1. Chemical Composition of Aluminum 6061 alloy

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
0.4-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.25	0.15	0.35	Balance

2.2. Reinforcement Material

Silicon Carbide is used as a reinforcement material. Silicon carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC. Usually, SiC particles in composite improve the tensile strength and hardness of the composite. In this investigation, the effect of SiC addition on corrosion behavior of the composite was investigated [21-23].

2.3. Development of Al/SiC Metal Matrix Composite

In this study, the composite material was developed by using stir casting technique. AA6061/SiC composite was developed with different compositions as shown in Table 2. Argon gas was used at the surface of composite material during the stirring process to avoid porosity and blow holes. The vacuum pump was also used to create the vacuum environment at the time of development of composite. SiC reinforcement particles were preheated before adding into the melt matrix material to obtain proper wettability between the matrix material and reinforcement particles after the solidification process. Matrix material was melted in the muffle furnace. The liquid aluminium alloy at 700^0C temperature was poured into a graphite crucible packed with glass wool between magnetic coils. Current is supplied to provide the magnetic force in the motor. Due to the magnetic force, the melted composite material was begun to rotate as shown in Figure 1. The prepared composite was removed from the graphite crucible after the solidification to observe different properties. Electromagnetic parameters are shown in Table 2.

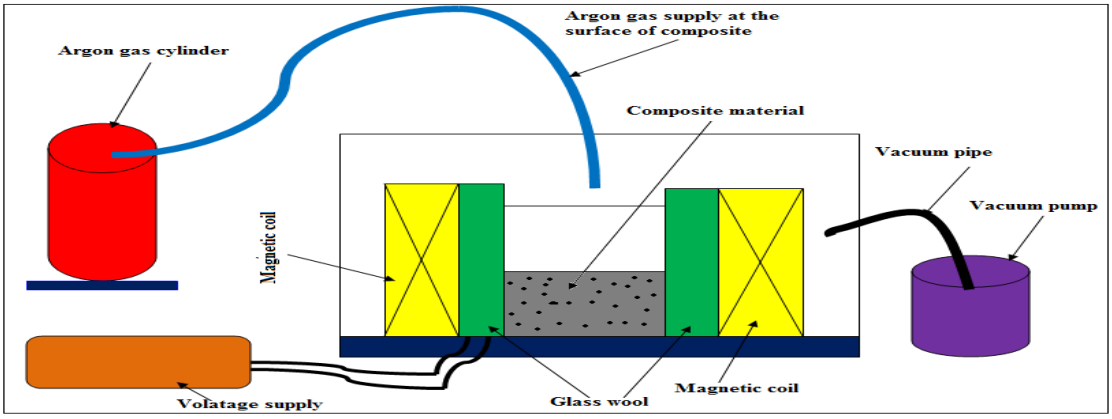

Figure 1.: Electromagnetic Stir Casting Set-Up

Table 2. Electromagnetic stir casting process parameters

S.No	Parameters	Values set as
1	Voltage supply	200 V
2	Current	20 Ampere
3	Stirring speed	200 RPM
4	Stirring time	3 minutes
5	Stirring temperature	700^0C
4	Percentage of SiC	2.5 %- 12.5 %

2.4. Corrosion Test

Corrosion test of all developed metal matrix composite was carried out in high alkalinity bath tub. Corrosion test of each sample were carried out for 120 hours with 3.5 wt. % NaCl in the bath tub. Weight of each sample was kept constant (9 gm). All seventeen samples were kept in the bath tub for 120 hours. After 120 hours, the final weight of each sample was measured. Weight loss of each sample was calculated by subtracting the weight of each sample after corrosion test to the initial weight of samples (9 gm). Corrosion rate was calculated from the given equation [28].

$$\text{Corrosion Rate (CR)} = \frac{\text{Weight loss (g)} * K}{\text{Alloy Density (g/cm}^3\text{)} * \text{Exposed Area (A)} * \text{Exposure Time (hr)}}$$

Where, K = 8.75 x 10^4, Exposed area A = 9 cm^2, Exposure time = 120 hour

2.5. Design Matrix Table for Corrosion Test

Design matrix table was obtained by using design expert software [29]. The corrosion test specimens were randomly tested for corrosion rate using response surface methodology to avoid any possible bias. For the selection of SiC parameters as reinforcement (SiC Preheat Temperature in degree centigrade, particle size of SiC in µm and SiC wt. %), numerous experiments were conducted. In the pilot run, arbitrarily the SiC preheat temperature was chosen as 100^0C for the development of AA6061/SiC composite material and others reinforcement parameters (particle size of SiC in µm and SiC wt. %) were kept constant. Some porosity was observed. In addition to porosity problem, wettability between the SiC and aluminium was not formed properly. When SiC was preheated to 200^0C, some porosity was disappeared and wettability between the matrix material and SiC was enhanced. Further, SiC preheat temperature was increased to 500^0C, it was observed that some porosity was obtained. After the pilot run investigation, SiC preheat temperature was chosen in the range of 200^0C to 300^0C. The same course of action was conducted to decide the ranges for other reinforcement parameters. Design matrix table with corresponding corrosion rate for each run was shown in Table 3.

Table 3. Design matrix and experimental results for corrosion rate

Standard order	Run	A: SiC Preheat Temperature (Degree centigrade)	B: Particle size of SiC (µm)	C: SiC wt. %	Corrosion rate (mm/year)	Composition of Composites
12	1	300.00	105	12.5	3.4	AA6061+ 12.5% SiC
14	2	300.00	70.00	7.5	2.2	AA6061+ 7.5 % SiC
10	3	300.00	105.00	2.5	1.52	AA6061+ 2.5 % SiC
6	4	400.00	70.00	2.5	1.3	AA6061+ 2.5 % SiC
16	5	300.00	70.00	7.5	2.2	AA6061+ 7.5 % SiC
13	6	300.00	70.00	7.5	2.29	AA6061+ 7.5 % SiC
5	7	200.00	70.00	2.5	2	AA6061+ 2.5 % SiC
15	8	300.00	70.00	7.5	2.25	AA6061+ 7.5 % SiC
9	9	300.00	35.00	2.5	1.2	AA6061+ 2.5 % SiC
4	10	400.00	105.00	7.5	2.8	AA6061+ 7.5 % SiC
3	11	200.00	105.00	7.5	3.4	AA6061+ 7.5 % SiC
17	12	300.00	70.00	7.5	2.27	AA6061+ 7.5 % SiC
7	13	200.00	70.00	12.5	3.4	AA6061+ 12.5% SiC
8	14	400.00	70.00	12.5	2.3	AA6061+ 12.5% SiC
1	15	200.00	35.00	7.5	2.7	AA6061+ 7.5 % SiC
11	16	300.00	35.00	12.5	2.05	AA6061+ 12.5 % SiC
2	17	400.00	35.00	7.5	1.7	AA6061+ 7.5 % SiC

3. Results and Discussion

3.1. Mathematical modelling

From the ANOVA Table 4, it can be seen that the Model F-value of 209.06 implies the model is significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case, A, B, C, A^2, B^2, C^2, AB, AC, BC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

The "Lack of Fit F-value" of 4.14 implies the Lack of Fit is not significant relative to the pure error. There is a 10.19% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good -- we want the model to fit.

The "Pred R-Squared" of 0.9537 is in reasonable agreement with the "Adj R-Squared" of 0.9915. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 45.662 indicates an adequate signal. This model can be used to navigate the design space.

Equation (1) shows the mathematical model for corrosion rate with respect to SiC particles parameters.

$$\text{Corrosion Rate (mm/year)} = +5.10644 - 0.023215 \times \text{SiC Preheat Temperature} - 0.01867 \times \text{Size of SiC} + 0.26510 \times \text{Weight of SiC} + 3.07750E\text{-}005 \times \text{SiC Preheat Temperature}^2 + 8.18367E\text{-}005 \times \text{Size of SiC}^2 - 0.011990 \times \text{Weight of SiC}^2 + 2.85714E\text{-}005 \times \text{SiC Preheat Temperature} \times \text{Size of SiC} - 2.00000E\text{-}004 \times \text{SiC Preheat Temperature} \times \text{Weight of SiC} + 1.47143E\text{-}003 \times \text{Size of SiC} \times \text{Weight of SiC} \quad (1)$$

The diagnostics graph of predicted v/s actual and residual plots are shown in Figure 2 and Figure 3 respectively. The predicted v/s actual graph as well as residual plots show accurate straight line. Both graphs are not showing any definite trend.

Table 4. ANOVA Table for corrosion rate

Source	Sum of square	DF	Mean square	F value	Prob. > F	
Model	7.37	9	0.82	209.06	< 0.0001	Significant
A	1.44	1	1.44	369.09	< 0.0001	
B	1.51	1	1.51	384.45	< 0.0001	
C	3.29	1	3.29	840.26	< 0.0001	
A^2	0.40	1	0.40	101.86	< 0.0001	
B^2	0.042	1	0.042	10.81	0.0133	
C^2	0.38	1	0.38	96.63	< 0.0001	
AB	0.040	1	0.040	10.22	0.0151	
AC	0.040	1	0.040	10.22	0.0151	
BC	0.27	1	0.27	67.75	< 0.0001	
Residual	0.027	7	3.915E-003			
Lack of Fit	0.021	3	6.908E-003	4.14	0.1019	Not significant
Pure Error	6.680E-003	4	1.670E-003	Pure Error		
Cor Total 16	7.39	16				
Std. dev.	0.063		R-Square	0.9963		
Mean	2.29		Adj-R squared	0.9915		
C.V.	2.73		Pred R-squared	0.9537		
Press	0.34		Adeq precision	45.662		

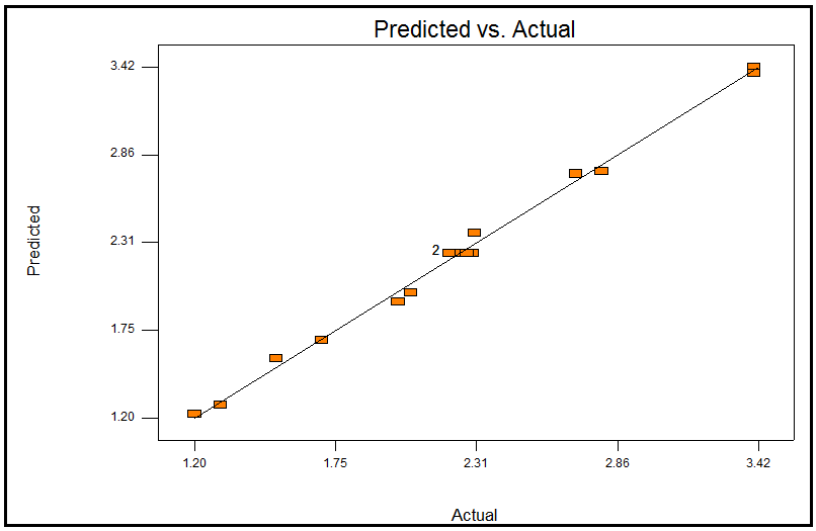

Figure 2. Diagnostics graph of predicted v/s actual

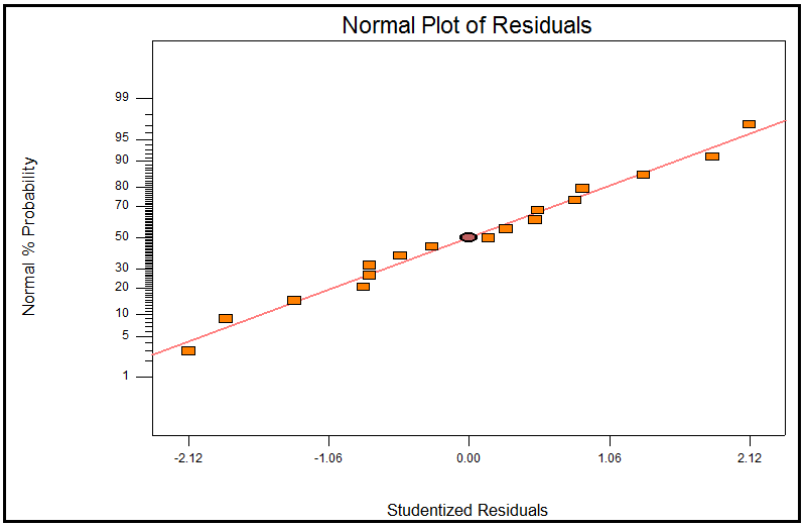

Figure 3. Diagnostics graph of residual plots

3.2. Optimum SiC Particles Parameters for Minimum Corrosion Rate

3.2.1. Effect of SiC preheat temperature on corrosion rate

Effect of SiC preheat temperature on corrosion rate is described with the help of Figure 4. Within the range of SiC preheat temperature; it was observed that the corrosion rate of metal matrix composite decreases by increasing the SiC preheat temperature. Basically, by increasing the preheat temperature of SiC, wettability of SiC particles with aluminium is improved while porosity is reduced. Minimum porosity and good wettability reduce corrosion rate and improve the mechanical properties of composite.

3.2.2. Effect of SiC particle size on corrosion rate

Figure 5 shows the relation between SiC particle size and the corrosion rate of metal matrix composite. From Figure 5, it can be observed that by increasing the SiC particle size, corrosion rate continuously increases. When particle size increases then more porosity is obtained. Porosity is a type of defects due to which more corrosion weight loss occurs. Figure 6 (a) shows the microstructure image of AA6061/3 wt. % SiC composite with particle size 105 µm. Cracks and porosity were observed in the composite material after solidification process. Figure 6 (b) shows the microstructure image of AA6061/3 wt. % SiC composite with particle size 35 µm. Porosity free composite was obtained.

3.2.3. Effect of SiC weight percent on corrosion rate

Figure 7 shows the effect of SiC weight percent on the corrosion rate. It can be observed that by increasing the weight percent of SiC particles corrosion rate continuously increases. When, weight percent of SiC particles increases, electrochemical reactions of the aluminum-based material composite reinforced with SiC may increase. The electrochemical reaction occurs when most or all the atoms on the same metal surface are oxidized, damaging the entire surface. Most metals are easily oxidized: they tend to lose electrons to oxygen in the air or in water. Usually, by increasing the weight percent of SiC particles (more than 12.5 wt. %), blow holes and porosity is formed. This porosity increases the corrosion rate rapidly. Figure 8 (a) shows the microstructure image of AA6061/12.5 wt. % SiC composite material. Microstructure results showed uniform distribution of AA6061/12.5 wt. % SiC composite material. However, the microstructure image of AA6061/15 wt. % SiC composite material showed the agglomeration of SiC particles. These agglomeration produced porosity and cracks inside the composite.

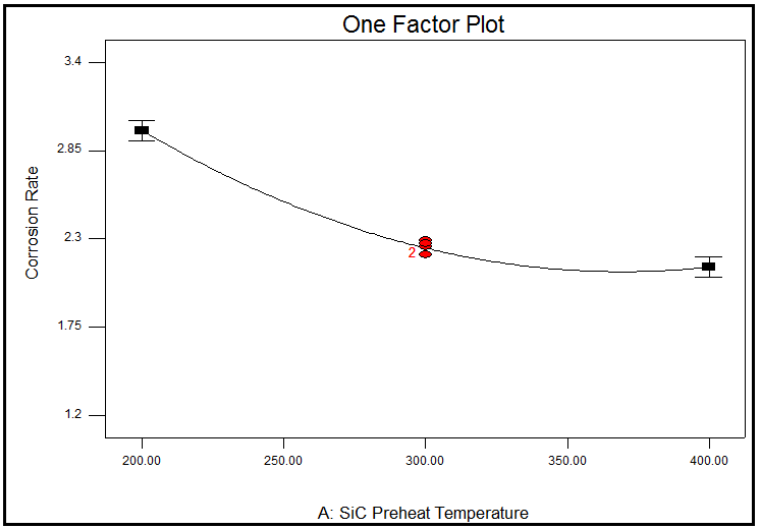

Figure 4. Effect of SiC preheat temperature on corrosion rate

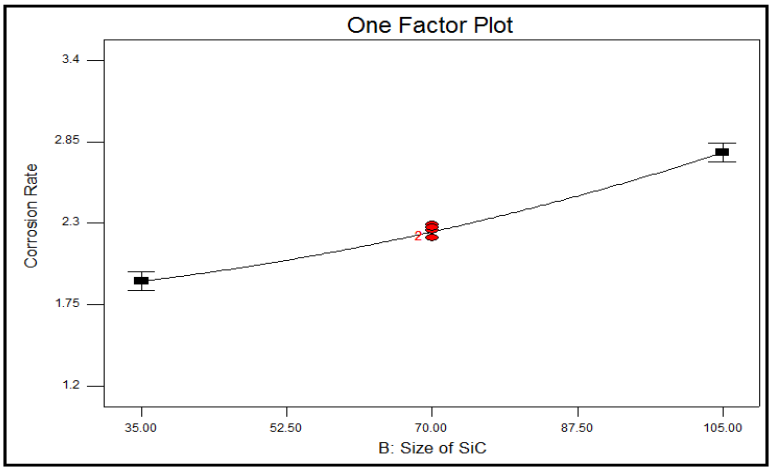

Figure 5. Effect of SiC particle size on corrosion rate

 © 2018 Jordan Journal of Mechanical and Industrial Engineering. All rights reserved - Volume 12, Number 4 (ISSN 1995-6665)

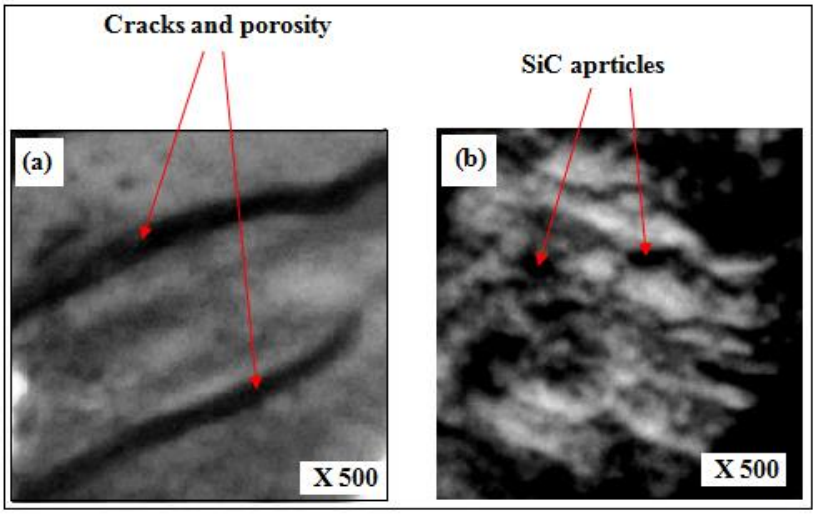

Figure 6. Microstructure image of; (a) AA6061/3 wt. % SiC composite with particle size 105 µm, (b) AA6061/3 wt. % SiC composite with particle size 35 µm

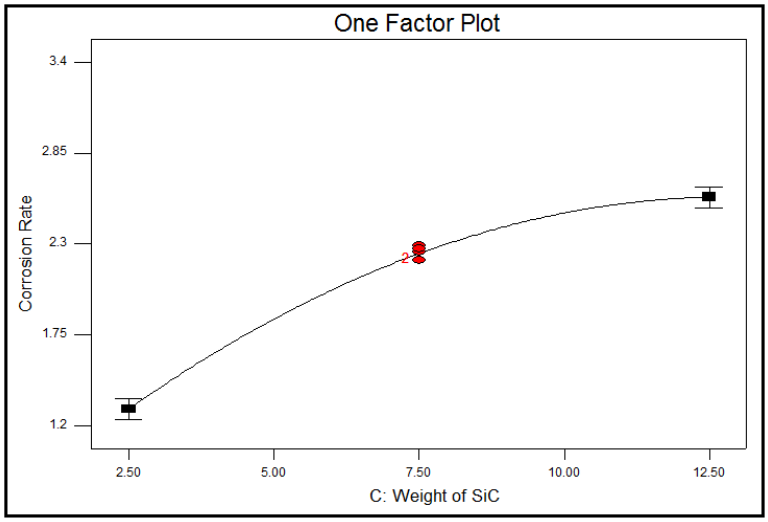

Figure 7. Effect of SiC wt. % on the corrosion rate

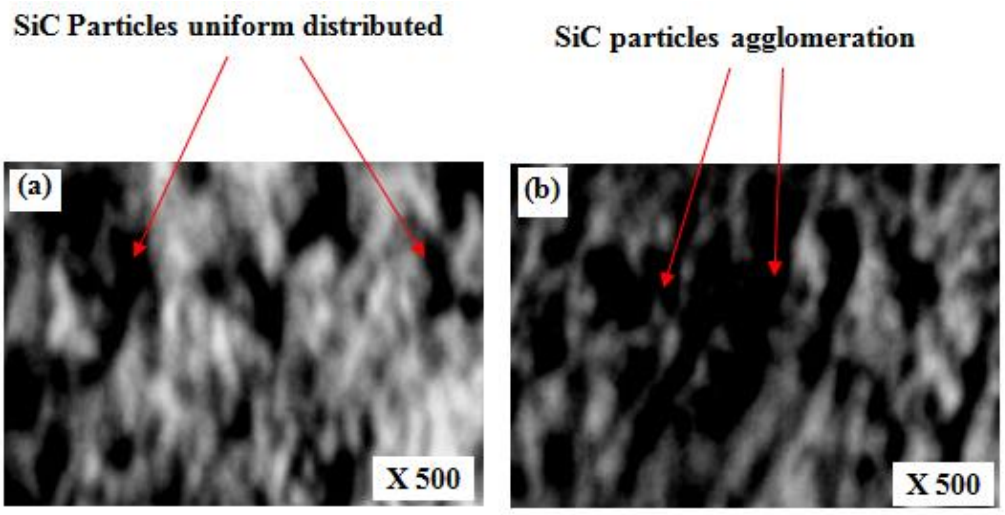

Figure 8. Microstructure image of; (a) AA6061/12.5 wt. % SiC composite, (b) AA6061/15 wt. % SiC composite

3.3. Three Dimensional Interaction of Eggshell parameters

Figure 9, Figure 10 and Figure 11 show the 3D interaction between SiC preheat temperature, SiC particle size and wt. % of SiC with corrosion rate. It can be observed from Figure 7 that with the increase in SiC temperature and size of SiC the corrosion rate decreases and increases respectively. Other interaction effects can be discussed in the same way.

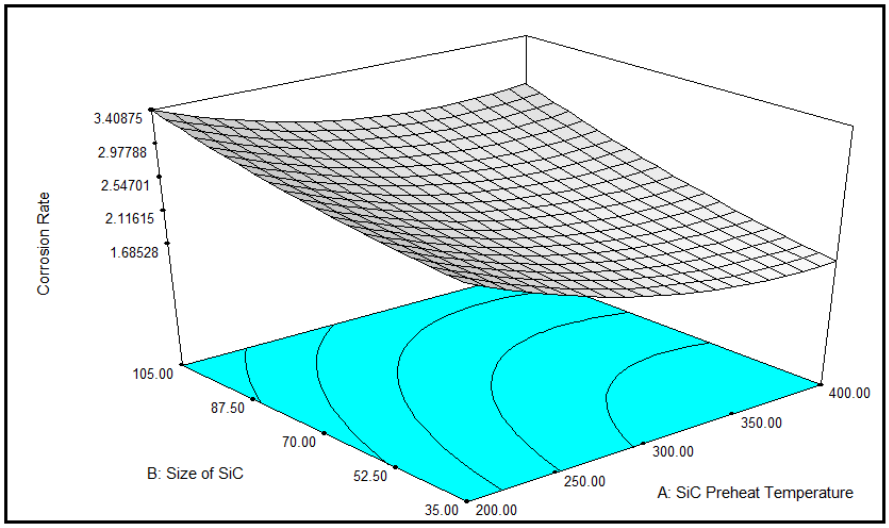

Figure 9. 3D interaction between SiC preheat temperature and SiC particle size with corrosion rate

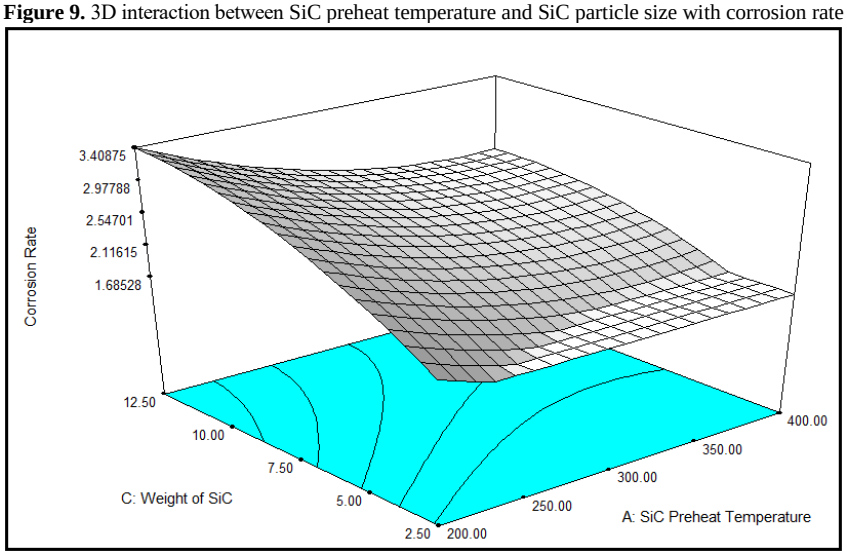

Figure 10. 3D interaction between SiC preheat temperature and wt. % of SiC with corrosion rate

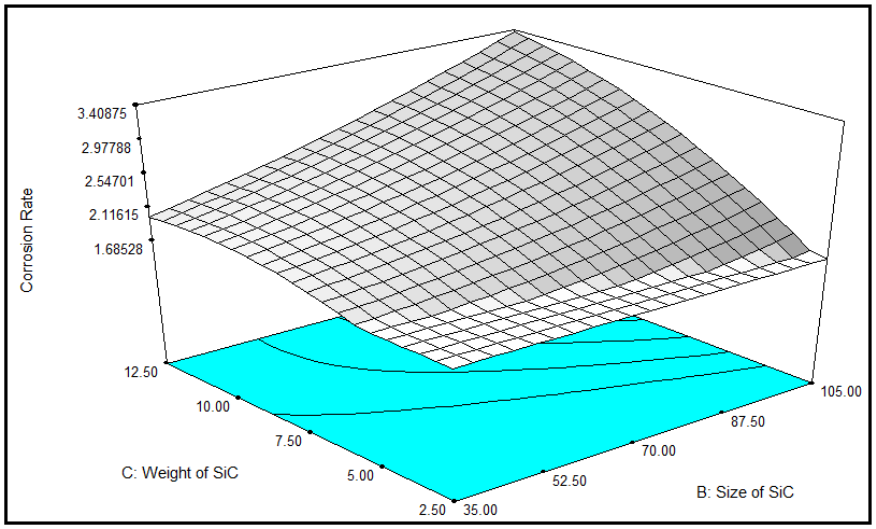

Figure 11. 3D interaction between SiC particle size and wt. % of SiC with corrosion rate

3.4. Validation of RSM Model Development

From the above analysis, optimum values of SiC particles parameters were obtained by using ramp function graph (Figure 12). Results showed that if SiC preheat temperature was kept 370.12^{0}C, size of SiC was kept 38.70 µm and weight of SiC was kept 2.94 % then minimum corrosion rate (1.16444) was obtained with desirability one.

3.5. Microstructure Analysis

From the ramp function graph, optimum SiC particles parameters were identified. At the optimum parameter, a composite sample was prepared. Microstructure of composite sample was taken to identify the distribution of SiC particles in the matrix material. Figure 13 shows the proper distribution of SiC particles in AA6061 aluminum alloy. This proper distribution is fully responsible in the enhancement of wear property, mechanical properties of the composite.

4. Conclusions

Aluminum based metal matrix composite successfully developed using SiC as reinforcement material through Electromagnetic stir casting route. Three parameters (preheat temperature, size, weight percent) of SiC were selected to reduce the corrosion rate of metal matrix composite. It was observed that by increasing the preheat temperature of SiC, corrosion rate decrease. By increasing the particle size and weight percent of SiC, corrosion rate increases. Optimum values of SiC preheat temperature, SiC particle size and wt. % of SiC were found to be 370.120C, 38.7 µm and 2.94 wt. % respectively for minimum corrosion rate 1.16444 mm/year with desirability one of metal matrix composite using Response Surface Methodology (Box-Behnken Design).

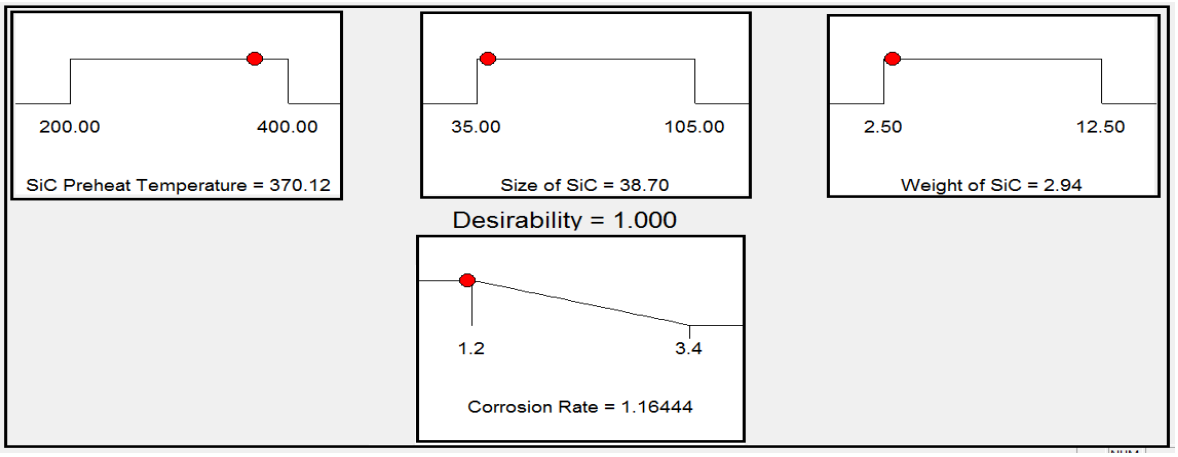

Figure 12. Ramp Function Graph

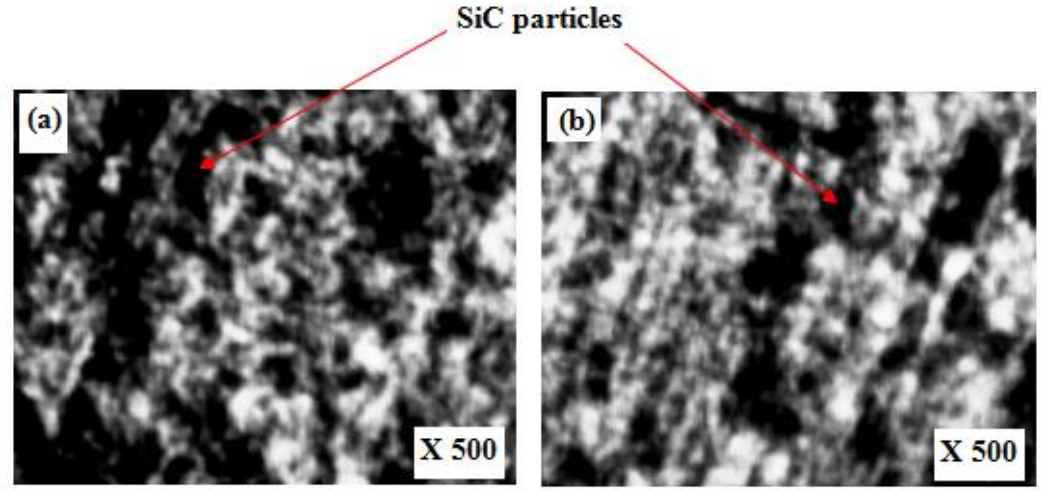

Figure 13. Microstructure of AA6061/3 wt. % SiC metal matrix composite

References

[1] C. S. Ramesh, R. Keshavamurthy, B. H. Channabasappa, S. Pramod, "Friction and wear behaviour of Ni–P coated Si_3N_4 reinforced Al 6061composites" Tribology International, Vol. 43, 2010, 623–634.

[2] D. Cree, M. Pugh, "Dry wear and friction properties of an A356/SiC foam interpenetrating phase composite" Wear Vol. 272, 2011, 88– 96.

[3] S. Gopalakrishnan, N. Murugan, "Production and wear characterization of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method" Composites: Part B , Vol. 43 ,2012,302–308.

[4] Pardeep Sharma, Dinesh Khanduna, Satpal Sharma, Parametric Study of Dry Sliding Wear of Aluminium Metal Matrix Composites by Response Surface Methodology, Material Today: Proceedings, Vol. 2, No. 4-5, 2015, 2687–2697.

[5] N. Mathan Kumar, S. Senthil Kumaran, L.A. Kumaraswamidhas, "Wear behaviour of Al 2618 alloy reinforced with Si3N4, AlN and ZrB_2 in situ composites at elevated temperatures" Alexandria Engineering Journal, Vol. 55,2016, 19–36.

[6] N.Ch. Kaushik, R. N. Rao, "Effect of applied load and grit size on wear coefficients of Al6082–SiC–Gr hybrid composites under two body abrasion" Tribology International, Vol. 103 2016,298–308.

[7] A. Pramanik, "Effects of reinforcement on wear resistance of aluminum matrix composites" Transactions of Nonferrous Metals Society of China, Vol. 26, Issue 2, 2016, 348-358.

[8] H.Y. Yue, B. Wang, X. Gao, S.L. Zhang, X.Y. Lin, L.H. Yao, E.J. Guo, "Effect of interfacial modifying on the microstructures, mechanical properties and abrasive wear properties of aluminum borate whiskers reinforced 6061Al composite" Journal of Alloys and Compounds, Vol. 692, 2017, 395–402.

[9] Hu¨lya Kac¸ar Durmus, Cevdet Meric, "Age-hardening behavior of powder metallurgy AA2014 alloy" Materials and Design, Vol. 28, 2007, 982–986.

[10] R. Senthilkumar, N. Arunkumar, M. Manzoor Hussian, "A comparative study on low cycle fatigue behaviour of nano and micro Al_2O_3 reinforced AA2014 particulate hybrid composites" Results in Physics, 2015. http://dx.doi.org/10.1016/j.rinp.2015.09.004

[11] S. Ugender, A. Kumar, A. Somi Reddy, "Experimental investigation of Tool Geometry on Mechanical Properties of Friction Welding of AA2014 Aluminium Alloy" Procedia Materials Science, Vol. 5, 2014, 824 – 831.

[12] Ramanjaneyulu Kadaganchi, Madhusudhan Reddy Gankidi, Hina Gokhale, "Optimization of process parameters of aluminum alloy AA 2014-T6 friction stir welds by response surface methodology" Defence Technology, Vol. 11, 2015, 209-219.

[13] Aziz, I., Qi, Z. and Min, X., "Corrosion Inhibition of SiCp/5A06 Aluminum Metal Matrix Composite by Cerium Conversion Treatment," Chinese Journal of Aeronautics, Vol. 22, 2009, 670-676.

[14] Zakaria, H.M., "Microstructural and corrosion behavior of Al/SiC metal matrix composites," Ain Shams Engineering Journal, Vol. 5, 2014, 831–838.

[15] Seyed Reihani, S.M., "Processing of squeeze cast Al6061–30vol% SiC composites and their characterization" Materials and Design, Vol. 27, 2006, 216–222.

[16] Feng, Y.C., Geng, L., Zheng, P.Q., Zheng, Z.Z., Wang, G.S., "Fabrication and characteristic of Al-based hybrid composite reinforced with tungsten oxide particle and aluminum borate whisker by squeeze casting", Materials and Design, Vol. 29, 2008, 2023–2026.

[17] Ankita Swati, Subrata Hait, "Greenhouse Gas Emission During Composting and Vermicomposting of Organic Wastes– A Review", Clean Soil Air Water, Vol. 46, 2018 https://doi.org/10.1002/clen.201700042.

[18] Haitao Su, Peiyong Guo, Yuxuan Zhang, Jun Deng, Meixian Wang, Yinshi Sun, Yanmei Wu, HongLei Chen, "Effects of Planting Patterns on Trace Metals in Soils Following Wet land Restoration" Clean Soil Air Water, Vol.46, 2018, https://doi.org/10.1002/clen.20170038

[19] Lina M. Shehadeh, Issam S. Jalham, "The Effect of adding Different Percentages of Manganese (Mn) and Copper (Cu) on the Mechanical Behavior of Aluminum", Jordan Journal of Mechanical and Industrial Engineering, Vol. 10, 2016, 19-26.

[20] Saadat Ali Rizvi, S.P. Tewari, "Optimization of Welding Parameters by Using Taguchi Method and Study of Fracture Mode Characterization of SS304H Welded by GMA Welding", Jordan Journal of Mechanical and Industrial Engineering, Vol. 12, 2018, 17-22.

[21] Pen Jin, Chufeng Sun, Chunyu Zhou, Lei Shi, C. Liu, "Effect of SiC particle size on structures and properties of Ni–SiC nanocomposites deposited by magnetic pulse electrodeposition technology", Ceramics International, Vol. 45, 2019, 20155-20164.

[22] Reza Zare, Hassan Sharifi, Mohammad Reza Saeri, Morteza Tayebi, "Investigating the effect of SiC particles on the physical and thermal properties of Al6061/SiCp composite", Journal of Alloys and Compounds, Vol. 801, 2019, 520-528.

[23] D. Ahmadkhaniha, F. Eriksson, P. Leisner, C. Zanella, "Effect of SiC particle size and heat-treatment on microhardness and corrosion resistance of NiP electrodeposited coatings", Journal of Alloys and Compounds, Vol. 769, 2018, 1080-1087.

[24] S.Vijayabhaskar, T. Rajmohan, T.K.Vignesh, H.Venkatakrishnan, "Effect of nano SiC particles on properties and characterization of Magnesium matrix nano composites", Materials Today: Proceedings, Vol. 16, 2019, 853-858.

[25] Pham Van Trinh, Junho Lee, Phan Ngoc Minh, Doan Dinh Phuong, Soon Hyung Hong, "Effect of oxidation of SiC particles on mechanical properties and wear behavior of SiCp/Al6061 composites", Journal of Alloys and Compounds, Vol. 769, 2018, 282-292.

[26] Łukasz Rogal, Damian Kalita, Anna Tarasek, Piotr Bobrowski, Frank Czerwinski, "Effect of SiC nano-particles on microstructure and mechanical properties of the CoCrFeMnNi high entropy alloy", Journal of Alloys and Compounds, Vol. 708, 2017, 344-352.

[27] Li Zhang, Qudong Wang, Guoping Liu, Wei Guo, Haiyan Jiang, Wenjiang Ding, "Effect of SiC particles and the particulate size on the hot deformation and processing map of AZ91 magnesium matrix composites", Materials Science and Engineering: A, Vo. 707, 2017, 315-324.

[28] Benamar Balegh, Habib Trouzine, Youcef Houmadi, "Finite Element Simulation and Prediction of Mechanical and Electrochemical Behavior on Crevice Corrosion in Sheet Pile Steel", Jordan Journal of Mechanical and Industrial Engineering, Vol. 12, 2018, 23-31.

[29] Sivaraos, K.R.Milkey, A.R.Samsudin, A.K.Dubey, P.Kidd, "Comparison between Taguchi Method and Response Surface Methodology (RSM) in Modelling CO_2 Laser Machining", Jordan Journal of Mechanical and Industrial Engineering, Vol. 8, 2014, 35-42.