WEAR INVESTIGATION OF Al2024/SiC COMPOSITES BY RESPONSE SURFACE METHODOLOGY

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Abstract: The effect of SiC particles and applied load on the dry sliding wear behavior of Al2024 alloy composites produced by hot pressing method has been investigated. The percentage of reinforcement and was varied from 0% to 60%. The applied load was changed from 10 N to 20 N. The wear behavior of composites was investigated by ball on disc wear tests. Response surface methodology has been used to plan and analyze the experiment. The regression model was developed for wear rate of dry sliding wear. The results concluded that the amount of SiC reinforcement into the Al2024 matrix is the most important parameter and the decreasing of applied load improves the wear rate.

Keywords: Metal matrix composites, Ball-on-disc wear, Response surface methodology.

1. Introduction

Aluminum metal–matrix composites (AMCs) are currently regarded as a group of advanced materials, due to lightweight, high strength, their perfect physical, mechanical and wear properties while a combination of these desirable properties can be hardly achieved by conventional materials. Al2O3, SiC, B4C, WC, and TiB2 are generally used as reinforcing materials in AMCs. [1,2]. Silicon carbide (SiC) continuous network structure ceramics are a very promising material for use in semiconductor processing, nuclear fusion reactors, heat-sink plates, and high temperature thermo mechanical applications because of their excellent chemical and thermal stability, high thermal conductivity, and good mechanical properties [3]. It is known that in order to get the optimum properties of a composite, especially a suitable combination of strength and ductility, a small size and large volume fraction of the reinforcement(s) are required. Nonetheless, there is a challenge of effectively and simultaneously taking advantage of these two requirements, since small reinforcing particulates in MMCs usually tend to be agglomerated and inhomogeneously distributed through the matrix. A problem of Al/SiC composites is that the microstructure is non-uniform distribution of SiC particles. The most significant detrimental property change may be the decrease in ductility and fracture toughness, which is true for all the AMCs and process histories; a major obstacle preventing their extensive use. The mechanism of reinforcement affecting the fracture toughness of AMCs s is not well understood. Several models have been proposed to characterize the relationship between fracture toughness and microstructure [4]. This problem can be overcome by using mechanical milling method, high-pressure torsion, equal channel angular pressing, and accumulative roll-bonding [5-7].

The aim of this research is to use the response surface methodology on the optimization of characteristics. SiC content (%) an load (N) were selected as the parameters and face centered composite design was used to determine the experimental data and to analyze the effect of parameters on the wear rate.

2. Experimental Procedure

Al2024 alloy powders and SiC particles used as raw materials to fabricate the FGMs. The as-atomized Al2024 powders were supplied commercially with the chemical composition (in wt.%) of 4.85 Cu, 1.78 Mg, 0.385 Si, 0.374 Fe, 0.312 Mn, 0.138 Zn, 0.042 Cr, 0.005 Ti and Al (balance). Al2024 alloy powders with an average particle size of 54 μm were used as the matrix materials and SiC powders with an average particle size of 10 □m (Alfa Aesar, Germany) were used as the reinforcement material. Al2024 matrix powders and SiC particles (30, 40, 50, and 60 wt. %) were blended in a planetary ball-mill (Fritsch Gmbh, model "Pulverisette 7 Premium line") at room temperature using a tungsten carbide bowl and a high argon atmosphere for 2h in order to break up the hard agglomerates. The milling medium was tungsten carbide balls with diameters of 10mm. The ball-to-powder weight ratio and rotational speed were selected to be 5:1 and 400rpm, respectively. The milling atmosphere was argon which was purged into a bowl before milling. Hot pressing at 560 oC and 500MPa in an argon atmosphere was used for preparation of the Al2024/SiC composites.

Wear behavior of the composites was examined by using a ball on disc wear tester. For wear test, the composite samples were ground with a #2000 SiC abrasive paper and further washed in acetone. The initial average surface roughness (Ra) of a polished sample was 0.2 μm. A H11 hot-work tool steel ball with diameter of 10 mm and mirror-like surface was contacted on the surface of disc at either 5 or 10 mm from the disc center under the loads of 10, 15 and 20 N. The disc was concurrently rotated for 10 min with a rotation speed of 0.5 m/s at room temperature. The wear weight losses were measured from the weight differences of specimens before and after the wear tests using a digital scale in an accuracy of 0.0001 g. The wear rates were calculated by converting the mass loss measurements to volume loss by using the respective densities:

W (mm3mm-1) = mass loss (g) / [density (g/mm3 x sliding distance (m)]
[Eq. 1]

The central composite design (CCD) a standard RSM design of experimental technique is used for minimal combinations of independent variables to determine complex response. For two parameters such as SiC content and load each with three levels 13 experiments were used and the specimens were fabricated according to the experiments. Table 1 shows the independent variable set for running the design matrix and their levels.

Table 1. Controlling Parameters involved and their levels.

Parameters	Levels		
	-1	0	1
SiC content (%)	0	30	60

Load (N)	10	15	20

3. Results and Discussion

In this sudy, optimization of the wear properties of Al2024/SiC composites was carried out using the CCD method. Table 2 shows the designed experiments and corresponding results of the CCD method. The wear rate of Al2024 alloy and Al2024/SiC composites changes from 0,02364 mm^3/m to 0,11 mm^3/m. The mathematical models obtained for determining the effects of the important parameters on the wear rate are indicated by Equations (2);

Wear rate (mm3 /m)

C7 = 0,0342 - 0,001855 sic + 0,00152 load + 0,000032 sic*sic

+ 0,000105 load*load - 0,000041 sic*load (Eq. 2)

An analysis of variance (ANOVA) of the generated regression models is presented in Tables 3. The related p value for the model is less than 0,05. The low p value indicates the significance of both models at a confidence level greater than 95%. The obtained regression correction coefficient (R^2) is 0,989. From Table 3, the SiC content and load with a contribution of 25,8% and 26,7%,respectively are close to unity.

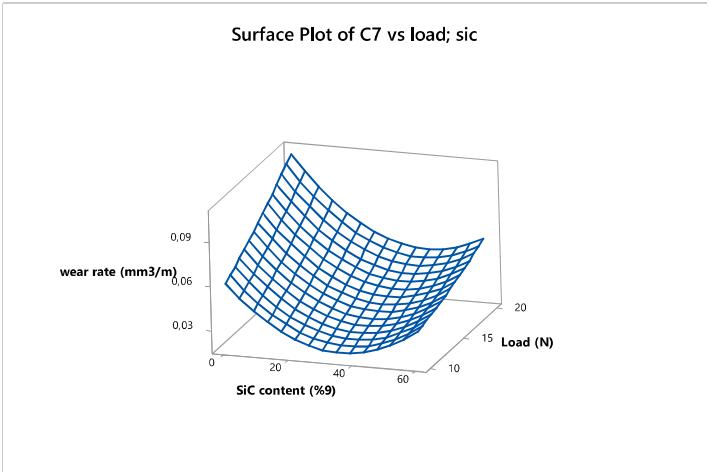
Table 2. Wear rate results based on generated experimental design by CCD.

Exp. No	SiC content (%)	Load (N)	C_7 : Wear rate (mm^3/ m)
1	0	10	0,05925
2	60	10	0,03628
3	0	20	0,11000
4	60	20	0,06220
5	0	15	0,07770
6	60	15	0,04762
7	30	10	0,02364
8	30	20	0,04946
9	30	15	0,03546
10	30	15	0,03497
11	30	15	0,03556
12	30	15	0,03687
13	30	15	0,03454

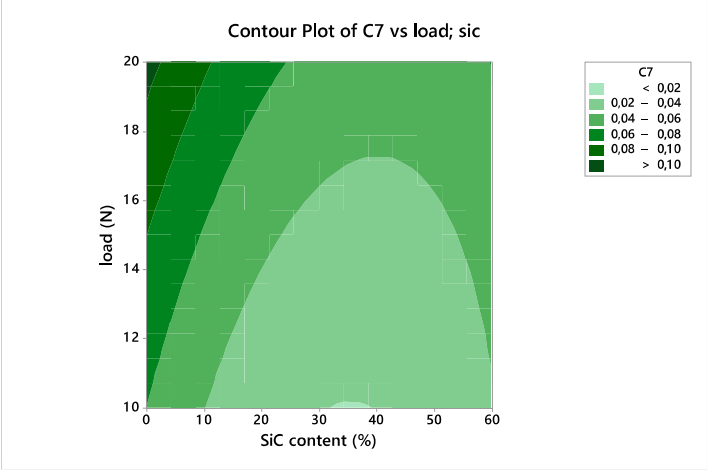
Table 3. ANOVA results for Response Surface Model for specific wear rate.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	0.006473	0,001295	126,31	0,000
sic	1	0,001695	0,001695	165,39	0,000
load	1	0,001751	0,001751	170,81	0,000
sic*sic	1	0,002279	0,002279	222,36	0,000
load*load	1	0,000019	0,000019	1,84	0,217
sic*load	1	0,000154	0,000154	15,04	0,006
Error	7	0,000072	0,000010		
Total	12	0,006545			
R^2 = 98,90%					

As the reinforcement content increases, load carrying capacity of metal matris composite increases, but the weaker bonds can also form between the reinforcement and matris materials. The distribution of reinforcement material can also determine to wear behaviour of composite. Fig. indicates the effect of the SiC content (%) and the load (L) on the wear rate (mm3 /m). The surface and contour curves showed that the value of the wear rate was minimized when the mean values of the SİC and the lowest values of load were used. A increase in SiC content up to 35,75 wt.% was resulted in decrease with wear rate (fig.1). As compared with composite samples, composite that have 60 wt.% SiC was exhibited lower wear resistance. But , the highest wear rate was observed in Al2024 alloys. This can be attributed to their lower hardness values. As the applied load change from 10 to 20 N, the wear rate of the composite and Al2024 alloy increased significantly and wear mechanism transformed from mild to severe wear regime. For each SiC content, the lowest wear rate was obatined to 10N looad.



a)



b)

Fig.1. Surface and contour for interaction SiC content and load on the wear rate.

Figs. 2 show the relation between the experiment sets and RSM prediction for specific wear rate of Al2024/SiC composites. The results also show that the experimental and predicted values remain constant at about 1,1 %. This means that RSM model predicts accurately, and these models can be used for advance prediction for the purpose of time and cost reduction.

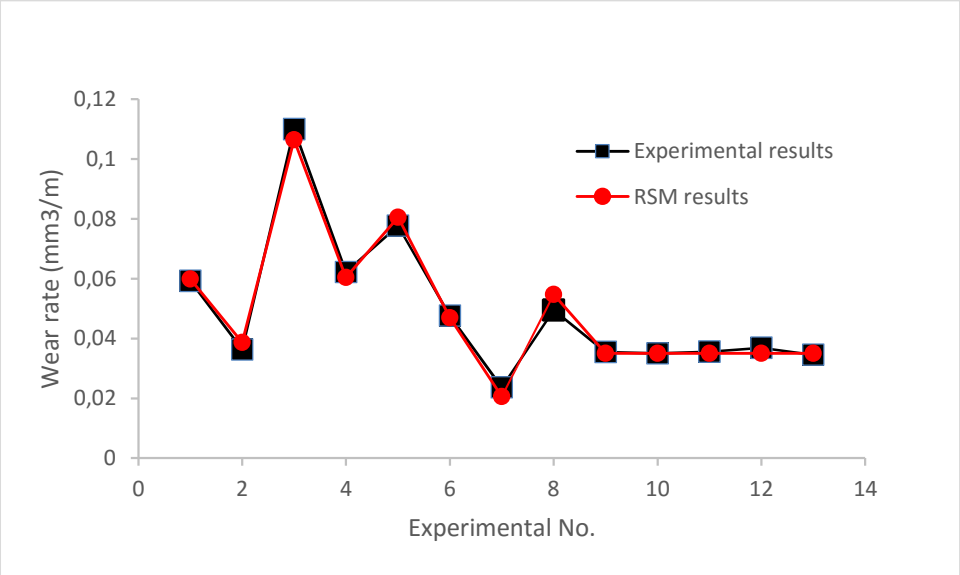


Fig.2. Experiment sets and RSM prediction on wear rate for Al2024/SiC composites.

Fig.3 shows that SiC content is 35,75 %, and applied load is 10N. Wear rate can achieve to 0,0196 mm^3 /m. acording to the optimized parametric combination.

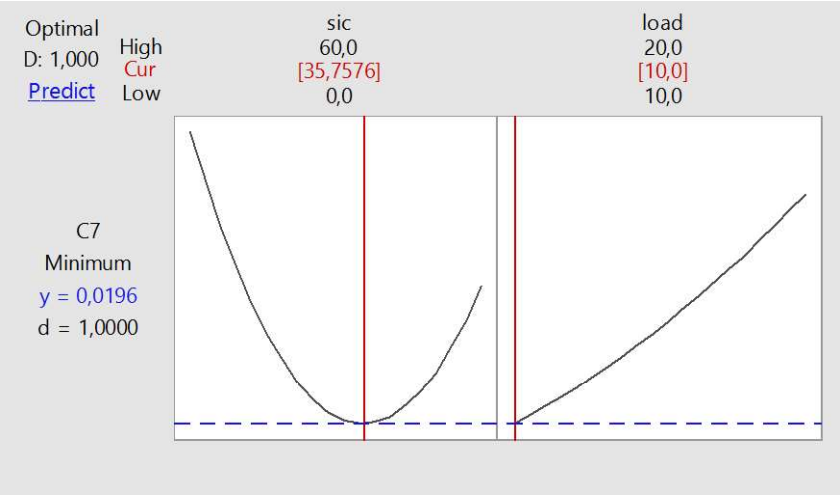


Fig.3. Optimum results for minumun wear rate.

4. Conclusions

In this study, the main parameters of SiC content and applied load were analyzed by applying a The central composite design a standard RSM design. The experimental results indicated that the effect of the SiC content and load on the wear rate is similar. The main parameters were optimized as the 35,75 wt. % SiC content and 10N load.

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