WEAR BEHAVIOUR OF SiC REINFORCED Al6061 ALLOY METAL MATRIX COMPOSITES BY USING TAGUCHI'S TECHNIQUES

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Abstract

In this present work, an attempt has been made to optimize the wear properties of Al6061- SiC particulate composites. The composites containing 6 to 9 wt% of Silicon Carbide in steps of 3 wt% were prepared using liquid metallurgy route in particular stir casting technique. For each composite, reinforcement particles were preheated to a temperature of 300˚C and then dispersed in steps of two into the vortex of molten Al6061 alloy to improve the wettability and distribution. Dry sliding wear test method was used to conduct the experiments by using Ducom made pin-on-disc wear testing machine. Twenty seven experiments were carried out with the help of Taguchi L_{27} Orthogonal array. The influence of applied load, sliding speed and sliding distance on volumetric wear loss was estimated. Smaller the better parameter was chosen to optimize the wear process of prepared composites. Results show that applied load has the highest influence followed by speed and sliding distance.

Keywords: *Al-6061Alloy, SiC, Wear Properties, Metal Matrix Composites, Stir Casting*

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1. INTRODUCTION

Aluminium Metal Matrix Composites (AMMCs) are popular materials for several applications in the field of automobile and aerospace industries. The main advantages of using these Al based composites materials are mainly due to strength to weight ratio and low density. In particular particulate reinforced MMCs have recently found special interest because of their specific strength and specific stiffness at room or elevated temperatures. It is well known that the elastic properties of the metal matrix composite are strongly influenced by micro-structural parameters of the reinforcement such as shape, size, orientation, distribution and volume or weight [1]. Several aluminium alloys are available from 1XXX series to 8XXX, among all these alloys Al6061 is having good cast-ability, formability and also weldabilty. Very hard ceramic particles like B_4C, TiC, WC, SiC and Alumina can be used as the reinforcements in the base alloy matrix [2].

In all the engineering products and assemblies material loss is the major problem to decrease the efficiency of the equipment. So it is necessary to develop advanced materials which are good in wear and seizure resistance. It has been reported by several researchers that the volumetric wear loss of the particle reinforced composites decrease with the increasing weight percentage of particles [3]. The composites prepared by using Al as matrix and hard ceramic particles as reinforcements will perform better than steel made components. Therefore, aluminium alloy based composites will replace many engineering components in several industries [4]

Many researchers studied the effect of ceramic particles on wear properties of aluminium based composites [5]. The performance of metal matrix composite reinforced with ceramic particles has been reported to be superior that of their unreinforced matrix alloy [6]. Sahin et al. [7] reported that the introductions of SiC particle into the aluminium alloy shown greater effect on wear resistance. Limited attempts have been made to examine the effect of micro size SiC particulates on the sliding wear properties of Al based composites. It was observed that as the SiC content was increased in the matrix the wear or seizure resistance of pure aluminium could be increased significantly [8]. Lim et al [9] studied the tribological properties of SiC reinforced Al-Cu metal matrix composites and found that there was enhanced in mechanical and wear resistance capacity of composites.

Sahin et al. [10] studied wear behavior of Al2011 alloy reinforced with different weight percentages of SiC with varying particle size. The design of experiments was used to know the influence of applied load, sliding distance, particle size and volume fraction of reinforcement. As applied load increases the volumetric wear loss was more and also the wear rate increases with increase in sliding distance. There was good bonding between matrix and filler material as particle size of the filler material decreases [11].

In view of the above, an attempt is made in this investigation to study the effect of applied load, sliding speed and sliding distance on dry sliding wear behavior of the Al6061-SiC composites using Taguchi design of experiments. The Signal-to-Noise ratio was employed to find the effect of each parameter on wear.

2. EXPERIMENTAL DETAILS

2.1 Materials

Table -1: Chemical composition of Al6061 Alloy

Element	Wt. Percentage
Magnesium	0.80
Silicon	0.64
Iron	0.23
Copper	0.17
Zinc	0.031
Manganese	0.072
Titanium	0.015
Chromium	0.014
Others	0.15
Aluminium	Bal

Metal matrix composites containing 6 and 9 wt. percentages of SiC particles were produced by liquid metallurgy route. For the production of MMCs, an Al6061 alloy was used as the matrix material while SiC particles with an average size of 100-125μm were used as the reinforcements. The chemical composition of the Al6061 alloy is shown in Table- 1.

2.2 Composite Preparation

In stir casting method before the casting reinforcements, stirrer, permanent mould preheated to 250oC to remove moisture and gases from the surface of the reinforcements, and equipments before casting.

Now the required amount of Al6061 is weighed and placed in the graphite crucible and heated to 750oC using resistance furnace then the degassing tablet is added to minimize the coating film defects by expelling the volatile components present in the melt during casting. The tablet helps in the removal of entrapped air in the melt and thus prevents casting defects like porosity and blow holes. Then the matrix Al6061 is reinforced with SiC particulates with different weight percentages (6 and 9). The micro particle of SiC was added at the temperature of 750℃ and a constant vigorous stirring was done for 15mins until a clear vortex is formed.

Before the addition of reinforcements the magnesium was added to decrease the surface tension and viscosity of the melt. At the pouring temperature of 730℃ the molten mixture was poured into the cast iron mould and allowed to solidify for few minutes. After complete solidification and then it is withdrawn from the mould and machined according to ASTM standards. Now the produced composite is subjected to dry sliding wear tests.

2.3 Wear Behaviour

A pin-on-disc tribometer is used to perform the wear experiment. The wear track, alloy and composite specimens are cleaned thoroughly with acetone prior to test. Each specimen is then weighed using a digital balance having an accuracy of ±0.0001 gm. After that the specimen is mounted on the pin holder of the tribometer ready for wear test. Specimens of size 8mm diameter and 25mm length were cut from the cast samples, machined and then polished. During the test, the sample is held pressed against a rotating EN32 steel disc (hardness of 65HRC) by applying load that acts as counter weight and balances the pin. The track diameter was chosen as 80mm and the parameters such as the load, sliding speed and sliding distance were varied in the range given in Table-2. Once the surface in contact wears out, the load pushes the arm to remain in contact with the disc. This movement of the arm generates a signal which is used to determine the maximum wear. Weight loss of each specimen was obtained by weighing the specimen before and after the experiment by a single pan electronic weighing machine with an accuracy of .0001g after thorough cleaning with acetone solution.

Table -2: Process Parameters and Levels

PARAMETERS				
LEVEL	A: SPEED	B: LOAD	C:SLIDING DISTANCE	D:MATERIAL
1	200	1	2000	0
2	400	2	3000	6
3	600	3	4000	9

2.4 Plan of Experiments

Dry sliding wear rate test was performed with three parameters: applied load, sliding speed, and sliding distance and varying them for three levels. According to the rule that degree of freedom for an orthogonal array should be greater than or equal to sum of those wear parameters, a L27 Orthogonal array which as 27 rows and 13 columns was selected as shown in Table-3[12]. A total of 27 experiments were performed based on the run order generated by Taguchi model. The response for model is wear rate. In Orthogonal array, first column is assigned to sliding speed, second column is assigned to load, fifth column is assigned to sliding distance and ninth column is assigned to material composition. The objective of model is to minimize the wear rate.

The Signal to Noise (S/N) ratio, which condenses the multiple data points within a trial, depends on the type of characteristics being evaluated. The S/N ratio characteristics can be divided into three categories, viz. 'nominal is the best', 'larger the better', and 'smaller the better' characteristics. In this study, 'smaller the better' characteristics was chosen to analyze the dry sliding wear resistance.

Table -3: L27 Orthogonal Array Used In Taguchi Method

RUN	X1	X2	X5	X9
1	1	1	1	1
2	1	1	2	2
3	1	1	3	3
4	1	2	1	2
5	1	2	2	3
6	1	2	3	1
7	1	3	1	3
8	1	3	2	1
9	1	3	3	2
10	2	1	1	2
11	2	1	2	3
12	2	1	3	1
13	2	2	1	3
14	2	2	2	1
15	2	2	3	2
16	2	3	1	2
17	2	3	2	2
18	2	3	3	3
19	3	1	1	3
20	3	1	2	1
21	3	1	3	2
22	3	2	1	1
23	3	2	2	2
24	3	2	3	3
25	3	3	1	2
26	3	3	2	3
27	3	3	3	1

3. RESULTS AND DISCUSSIONS

3.1 Results of Statistical Analysis of Experiments

The results for various combinations of parameters were obtained by conducting the experiments as per the orthogonal array. The measured results were analyzed using the commercial software MINITAB 14 specifically used for design of experiments applications. Table 4 shows the experimental results of wear rate.

Table -4: Results of Wear Test

RUN	A	B	C	D	Vol. Wear Loss	S-N Ratio
1	200	1	2000	0	0.003702	48.631
2	200	1	3000	6	0.002941	50.63
3	200	1	4000	9	0.002564	51.821
4	200	2	2000	6	0 .004779	46.413
5	200	2	3000	9	0.004395	47.15
6	200	2	4000	0	0.005555	45.114
7	200	3	2000	9	0.004861	46.267
8	200	3	3000	0	0.006662	43.53
9	200	3	4000	6	0.005882	44.715
10	400	1	2000	6	0.003676	48.692
11	400	1	3000	9	0.003296	49.642
12	400	1	4000	0	0.004454	47.024
13	400	2	2000	9	0.004761	46.446
14	400	2	3000	0	0.006292	44.024
15	400	2	4000	6	0.005147	45.768
16	400	3	2000	0	0.007407	42.607
17	400	3	3000	6	0.006251	44.081
18	400	3	4000	9	0.005128	45.801
19	600	1	2000	9	0.003076	50.24
20	600	1	3000	0	0.004221	47.491
21	600	1	4000	6	0.003676	48.692
22	600	2	2000	0	0.007407	42.607
23	600	2	3000	6	0.006613	43.592
24	600	2	4000	9	0.005201	45.678
25	600	3	2000	9	0.00783	42.124
26	600	3	3000	6	0.006813	43.333
27	600	3	4000	0	0.009629	40.328

To measure the quality characteristics, the experimental values are transformed into signal to noise ratio. The influence of control parameters such as load, sliding speed, and sliding distance on wear rate using signal to noise response and also the ranking of process parameters using signal to noise ratio obtained for different parameter levels for wear rate are given Table 5. The control factors statistically significant in the signal to noise ratio and it could be observed that the load is a dominant parameter on the wear rate.

Table -5: Response Table for S/N ratios smaller is better for Volumetric Wear Loss

LEVEL	A	B	C	D
1	47.13	49.21	46	44.59
2	46.01	45.2	45.94	46.07
3	44.9	43.63	46.09	47.37
DELTA	2.23	5.58	0.15	2.78
RANK	3	1	4	2

Fig. 1 and 2 shows the influence of process parameter on wear rate graphically. The analysis of these experimental results using S/N gives the optimum condition resulting in minimum wear rate. The optimum condition for wear rate is as shown in fig. 2.

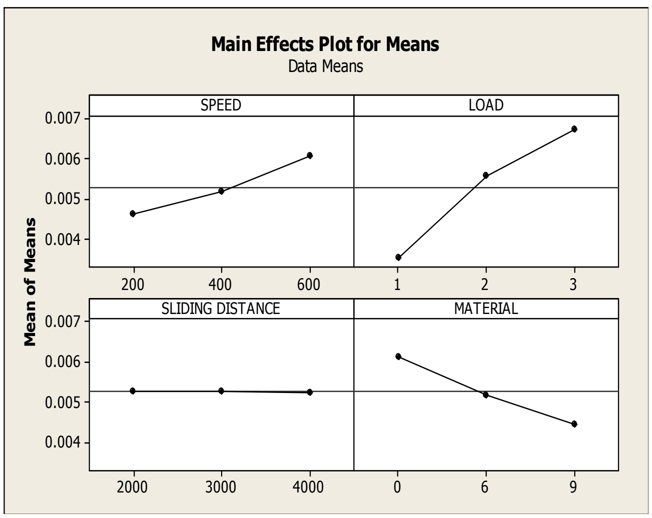

Fig -1: Main Effect plot for Mean-Volumetric Wear Loss

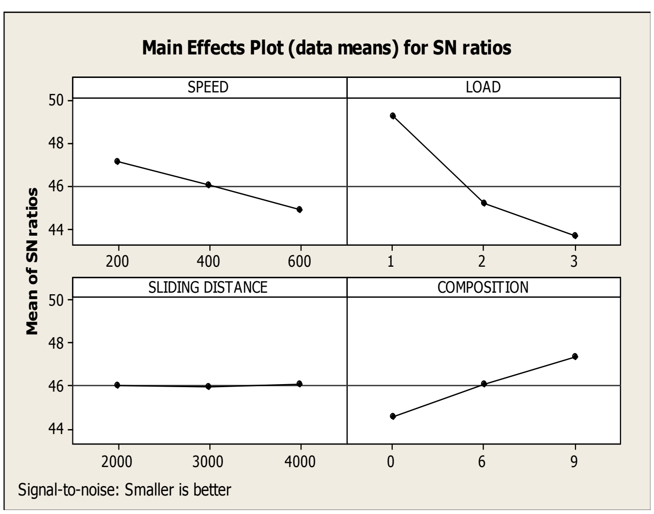

Fig -2: Main Effects plot for S/N ratio Volumetric Wear Loss

CONCLUSIONS

The present work on SiC particulate reinforced Al6061 composite by two stage addition using melt stirring method has led to the following conclusions.

- Aluminium based metal matrix composites have been successfully fabricated by Melt stirring method by two stage addition of reinforcement combined with preheating of particulates.
- From experimental details it was revealed that as percentage of SiC increases the wear rate decreases.
- Based on Taguchi L_{27} Orthogonal Array wear test experiments were conducted successfully and calculated wear rate was substituted in MINITAB 14 and analysed the effect of each parameter on wear rate.
- From response table signal to noise ratio for smaller is the better option, it was found that Load is affecting more on wear rate.
- Design of experiments by Taguchi method was successfully used to optimize the tribological behaviour of Al6061-SiC composites.
- Finally from our work by using Taguchi L_{27} Orthogonal Array, we found that Test Run No. 3 is the optimized RUN.

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