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Optimization of Wear Properties of A356 Metal Matrix Composite using Taguchi Calculation Method

Anil Kumar K N[1] ,Chandrashekar J R[2], Kiran Kumar R[3], Manjunath Prasad [4], Prasanna K K[5]

Lecturer, Department of Science, Government Polytechnic, KGF, Kolar, Karnataka, India[1]

Lecturer, Department of Mechanical Engineering, Government Polytechnic, KGF, Kolar, Karnataka, India[2]

Lecturer, Department of Computer Science Engineering, School of Mines, KGF, Kolar, Karnataka, India[3]

Lecturer, Department of Mechanical Engineering, Government Polytechnic, KGF, Kolar, Karnataka, India[4]

Lecturer, Department of Mechanical Engineering, Government Polytechnic, Mulbagal, Kolar, Karnataka, India[5]

ABSTRACT: In recent years, metal matrix composite (MMCs) have been capturing worldwide care on an account of their superior strength-to-weight ratio and stiffness. Among the several classes of composite materials, Aluminium matrix ceramic reinforcement composites have attracted increasing attention due to their unique properties such as better specific strength, specific stiffness, wear resistance, excellent corrosion resistance, high elastic modulus and light weight. The aim of the present investigation is to optimize the dry sliding wear parameters of Aluminum LM25 matrix reinforced with silicon carbide (SiC) (5 wt.%) and Copper(Cu) (3 wt.%) using Taguchi calculation based analysis. In this work, the composite is prepared using stir casting method. The specimens are prepared according to ASTM standard. Using pin-on-disc apparatus, wear tests are conducted as per Taguchi's L9 orthogonal array and optimum wear parameters are identified with an objective to minimise the wear rate and coefficient of friction based on the grey relational grade. The effect of parameters on the wear rate and coefficient of friction was determined using Analysis of variance (ANOVA).

KEYWORDS: Aluminium–MMC, optimization, Taguchi calculations, ANOVA

I. INTRODUCTION

Due to the advancement in science and technology, there is a demand of advanced engineering materials in the field of automotive and aerospace areas. These area demands materials having better mechanical and tribological properties than the conventional materials. In recent years, metal matrix composite (MMCs) are playing an important role in various applications due to their high temperature resistance and strength. The MMC is the combination of two or more constituents in which one is matrix and other is reinforcements. At present, aluminium based metal matrix composites are widely used in many engineering applications because of their improved wear resistance, low density, enhanced strength and stiffness. The tribological parameters such as applied load (Prasad et al. , Bai et al. sliding speed (Lee et al. , Sannino et al. , and percent of fly ash control the friction and wear performance. Sreenivasan et al. reported the wear behaviour aluminium reinforced with TiB2 that the increase in TiB2 results in decrease of the wear rate and the increase in applied load results in increaseof the wear rate of the MMCs. However, it was decreased with increase in speed. Gaitonde et al. Ravi Kumaret al. and Zhang et al. reported that the wear resistance of MMCs depends upon shape of the particle, distribution of reinforcement material and volume fraction. Shanawaz Patil et al. concluded that the wear rate for the metal matrix composite increases with increase in speed for a given constant load and time. Ravi et al. conducted the tribological tests on Al6061 reinforced with redmud and reported that red mud particles in Al-6061 increase the hardness and coefficient of friction decrease with increase in weight percent of red mud reinforcement. Amuthakkannan et al. investigated the wear rate of the composites with parameters such as percent of reinforcement, Sliding velocity and Normal load using Grey relation analysis. They found that all the parameters taken for the wear study are significant and the most significant parameter was on Normal load and the optimized parameters are Sliding velocity (m/sec) of 2, Normal load (N) of 20, Reinforcement of basalt fiber (percent) of 10. Arulraj et al. investigated the tribological behaviour of hybrid Metal Matrix (Al-Al2O3-B4C) Composites.

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II. MATERIALS AND METHODS

In this investigation, LM25 was used as a matrix material. Silicon carbide and copper were used as reinforcements. The chemical composition of the LM25 in weight percent is given in Table 1. The silicon carbide particle size ranges from 30 to 40 microns. The composite with 5 wt.% of SiC particles and 3 percent Cu was fabricated by the mechanical stir casting technique. Weighed amount of LM25 was melted at 850 °C in an electric resistance furnace using a graphite crucible. Before adding SiC and Cu particulates to LM25, they were preheated to a temperature of about 350 °C. Then they were added to the molten metal at 850 °C and stirred continuously for uniform distribution. The stirring was done at 750 rpm for 7–9 min. Then the molten material was poured into a permanent metallic mould and allowed to solidify. After solidification,

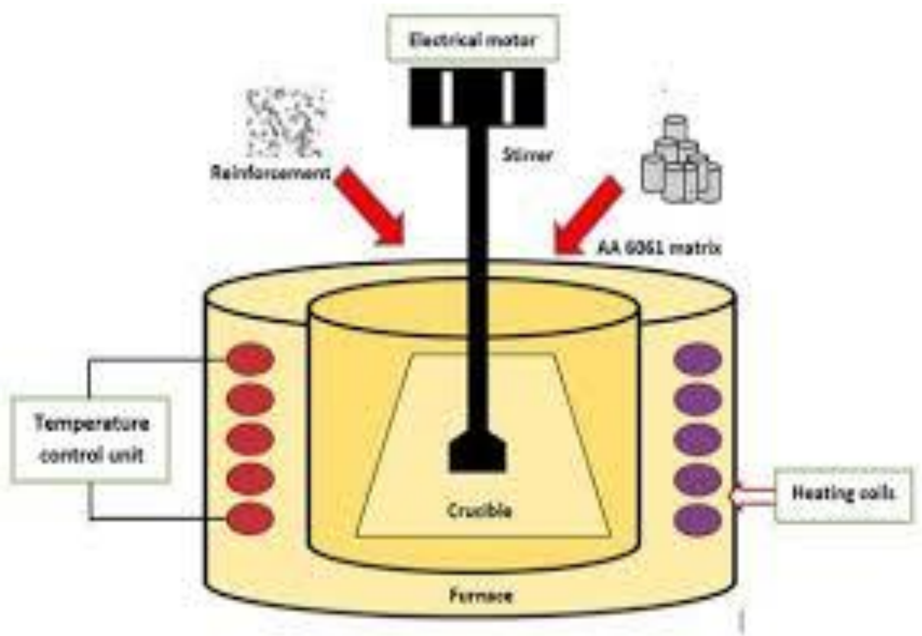

Figure-1 stir casting picture

Table 1. Chemical composition of LM25 (in weight %).

Element	Weight %
Si	7.12
Mg	0.34
Fe	0.13
Cu	0.049
Mn	0.026
Ni	0.031
Zinc	0.010

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Lead	0.050
Others	0.150
Al	Balance

Table 2. Parameters with their values at three levels.

factor	Level-1	Level-2	Level-3
Load N	10	20	30
Sliding velocity M/S	2.0	2.4	2.7
Sliding distance M	1000	1100	1200

the cast samples were taken away from the mould and machined to a dimensions of 10mm in diameter and 30mm in length as per ASTM G99-95 (2010).

III. PLAN OF EXPERIMENT

The Taguchi design method was developed by Dr. Genichi Taguchi. It is a simple and robust technique for optimizing the process parameters. In this method, load, sliding velocity and sliding distance are taken as main process parameters input parameters and the experiment is performed as per L9 orthogonal array. The levels of various input process parameters according to the L9 orthogonal array for the experiments are shown in Table 2. The signal-to-noise ratio is a logarithmic function used to optimize the process or product design, minimizing the variability. In general, signal to noise (S/N) ratio (h, dB) represents quality characteristics for the observed data in the Taguchi design of experiments. There are 3 signal-to noise ratios of common interest for optimization of Static Problems. They are lower-the-better, higher-the-better and nominal-the better. The S/N ratio with lower-the better characteristics (wear rate, coefficient of friction etc.,) can be calculated using equation (1)

Table 3. Experimental plan and results.

EXP NO	Load N	Sliding velocity m/s	Sliding distance m	Density g/mm3	Initial wt gm	Final wt gm
1	10	2	1000	0.0026688	6.360864	6.351364
2	10	2.4	1100	0.002688	6.370356	6.358111
3	10	2.7	1200	0.002688	6.430784	6.418751
4	20	2	1100	0.002688	6.440568	6.431701
5	20	2.4	1200	0.002688	6.150237	6.138626
6	20	2.7	1000	0.002688	6.400665	6.382087
7	30	2	1200	0.002688	6.090467	6.050778
8	30	2.4	1100	0.002688	6.265047	6.217758
9	30	2.7	1000	0.002688	6.390743	6.373643

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Following are the formula for calculating weare rate and co efficient of friction

1. Initial volume of the specimen = ¼ Initial weight of the specimen
Density of the specimen

2. Final volume of the specimen= ¼ Final weight of the specimen
Density of the specimen

3. Volume loss of the specimen= ¼ Final volume of the specimen _ Initial volume of the specimen

4. Wear rate = ¼ Volume loss mm3
Sliding distance m

5. Coefficient of friction = ¼ Frictional force
Normal force

IV. WEAR TEST

The pin on disc apparatus (Ducom, model No: ED-201, Bangalore, India) (see Fig. 1) is used to evaluate the wear rate and coefficient of friction of the specimens. Tests were conducted as per L9 orthogonal array under dry sliding conditions as per ASTM G99-95 (2010) at a room temperature. The counter-face disc is made of EN-31 steel with the hardness of 62 HRC. Initially, the test samples were polished metallographically. The initial weight of the specimen was measured using a single pan electronic weighing machine with least count of 0.0001 g. Then the test the pin was pressed against the counterpart rotating against EN-31 steel with the hardness of 62 HRC. After the test, the specimens were removed, cleaned with acetone, dried and the specimen was weighed to find the final weight of the specimen. From the initial and final weight of the specimen the initial and final volume of the specimen are calculated using the equations (2) and (3) and is shown in Table 3.

Fig-2 Pin-on-disc wear testing machine

Table – 4 Wear rate and co efficient of friction

EXP NO	Load N	Sliding velocity m/s	Sliding distance m	Wear rate mm3/m	Co efficient of friction
1	10	2	1000	0.003534	0.3521
2	10	2.4	1100	0.003961	0.4032
3	10	2.7	1200	0.003444	0.3781

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4	20	2	1100	0.002868	0.1105
5	20	2.4	1200	0.003323	0.6760
6	20	2.7	1000	0.006911	0.3605
7	30	2	1200	0.011358	0.2823
8	30	2.4	1100	0.017593	0.3916
9	30	2.7	1000	0.005532	0.3813

Table -5 main effect on the taguchi calculations

level	Load N	Sliding velocity m/s	Sliding distance m
1	0.4872	0.4654	0.6082*
2	0.5170	0.6652*	0.4556
3	0.6433*	0.5169	0.5838
delta	0.1561	0.1997	0.1526
rank	2	1	3

Table-6 result of ANOVA

RESULT OF ANOVA						
SOV	DOF	Adj SS	Adj MS	F- Value	P-Value	C %
load	2	0.041197	0.020598	114.70	0.009	28.14%
Sliding velocity	2	0.064535	0.032267	179.67	0.006	44.08%
Sliding distance	2	0.040308	0.020154	112.22	0.009	27.53%
Error	2	0.000359	0.000180			0.25%
Total	8	0.146399				100%

V. RESULTS AND DISCUSSION

From the Experimental plan and results. Value Table 3, the main effects are tabulated in Table 4 and the factor effects are plotted in. Since the taguchi calculations represents the level of correlation between the reference sequence and the comparability sequence, the greater value of the taguchi value means that the comparability sequence has a stronger correlation to the reference sequence. In other words, regardless of category of the performance characteristics, a greater taguchi value corresponds to better performance. Therefore, the optimal level of the machining parameters is the level with the greatest grey relational grade value. The reference sequence that was selected here had the "smaller-the-better" characteristic. Therefore, the comparability sequence with the larger value of the taguchi relational grade would induce smaller wear rate and coefficient of friction. Based on this premise, the level that gives the largest average response is selected. From Table 5, the optimum factors for both the wear rate and the coefficient of friction obtained for the hybrid composite are 30N load (level 3), 2.4 m/s sliding velocity (level 2), and 1000m sliding distance (level 1) combination. ANOVA, it is revealed that the sliding velocity (44.08 percent) influences more on the multi-performance characteristics of LM25/SiC/Cu hybrid composite followed by load (28.14percent) and sliding distance(27.53percent).

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VI. CONCLUSION

In the present work, the use of Taguchi's orthogonal array with grey relational analysis to optimize the multiple performance characteristics of LM25 hybrid composites such as wear rate and coefficient of friction has been reported. Based on the present experimental work, the following conclusions were drawn:

- The LM25 hybrid composites have been successfully produced by the stir casting route. The microstructural study clearly reveals a nearly uniform distribution of SiC and Cu in the LM25 matrix alloy.
- Taguchi method for the optimization of the multi response problems is a very useful tool for predicting the wear rate and coefficient of friction of LM25/SiC/Cu hybrid Metal Matrix Composites.
- From, ANOVA, it is revealed that the sliding velocity (44.08 percent) influences more on the multi-performance characteristics of LM25/SiC/Cu hybrid composite followed by load (28.14percent) and sliding distance(27.53percent).
- The wear rate is increased with load. The wear resistance of the alloy is improved significantly due to particle addition. The composite exhibited lower wear rate than that of the matrix alloy.

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