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WEAR PERFORMANCE OF MG-5%SIC-5%AL_2O_3 METAL MATRIX COMPOSITES USING TAGUCHI METHOD

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Abstract

The present study deals with investigations relating to dry sliding wear behaviour of the Magnesium metal matrix composites, reinforced with Silicon carbide (SiC) and Alumina (Al_2O_3). The hybrid composites are produced through Powder metallurgy method. The amount of SiC and Al2O3 particles 5 wt%. Experiments were carried out on the basis of the experimental plan generated by Taguchi's technique. A L9 Orthogonal array was selected for analysis of the data. The investigation is to determine the effect of applied load, sliding speed and sintering temperature on wear rate of magnesium metal matrix composites and to find the optimum parameters to achieve the minimum wear rate.

Keywords:

Magnesium MMC's;
Wear rate;
Orthogonal Array;
ANOVA;
Taguchi Method.

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1. Introduction

In the view of excellent combination of strength, rigidity, density and toughness, conventional materials have certain deficiencies. Composites are extensively used to overcome these shortcomings and meet the demands of modern technology. Metal matrix composites (MMCs) have received considerable attention in aerospace & automobile industries due to their excellent strength, rigidity, light weight and wear resistance. Although MMCs have superior properties, they were not widely used due to manufacturing complexity. The conventional powder metallurgy technique is an attractive processing method for fabrication of composites, as it is relatively inexpensive and offers extensive selection of materials and processing conditions.

Wear is one of the major frequently encountered industrial problems, leading to frequent component replacement, especially abrasion. Abrasive wear happens when hard particles penetrate a softer surface and in the form of elongated chips displace material. Extensive studies already done by researchers on the wear characteristics of Aluminium metal matrix composites having various reinforcements such as alumina, silicon carbide, graphite, fly ash and titanium carbide. The parameters such as composition of the reinforcement and matrix, particle distribution, and interface between the reinforced particles and the matrix affect the wear behaviour of metal matrix composites.

The objective of this study is to investigate the dry sliding wear behaviour of magnesium metal matrix composites having 5 wt% of silicon carbide and 5 wt% alumina reinforcement using pin-on-disc wear testing machine. In addition, ANOVA was used to investigate which design parameters have a significant impact on the wear behavior composites.

2. Materials and Methods

The hybrid magnesium metal matrix composites are produced through powder metallurgy process. Magnesium used as a matrix material. Silicon carbide and Alumina used as a reinforcement. Pin-on-disk wear testing machine (as shown in fig 1) was used to study wear behavior of samples in accordance with the ASTM standard. The 10 mm diameter and 30 mm long wear test pins are prepared from the composites and held during the test against the rotating steel counter disc. The counter disc and the samples are thoroughly cleaned between each test to remove any wear debris attached to the sample or disc. Before testing, the surfaces of the pin samples were rubbed against emery paper to make sure effective contact with the steel disc of the flat surface. After thorough cleaning with the acetone solution, the weight of the sample is measured before and after the test using digital weighing balance with high precision. The wear rate is calculated from weight loss.

Taguchi technique enables to carry out the analysis of the effect of process variables on the response variables. The parameters selected for the experiment are applied load (L), sliding speed and (S) and sintering temperature (T). Table 1 shows the process parameters and their levels. The experiments are conducted according to the standard L9 orthogonal array based on the Taguchi method. The table 2 shows L9 orthogonal array having nine tests for different combination of parameters. In Orthogonal array, first column is assigned to load, second column is assigned to Sliding speed and third column is assigned to sintering temperature.

Figure 1. *Wear testing machine*

Table 1 Process Parameters and their Levels

Levels	**Process parameters**

	Load (N)	Speed (rpm)	Sintering Temperature (^{0}C)
1	19.62	200	500
2	39.24	400	530
3	58.86	600	550

Sl. No.	**Load (N)**	**Speed (rpm)**	**Sintering Temperature (^{0}C)**	**Volumetric Wear rate X 10^{-3} (mm^3/m)**
1	19.62	200	500	5.6455
2	19.62	400	530	3.4944
3	19.62	600	550	4.1869
4	39.24	200	530	13.8390
5	39.24	400	550	16.7329
6	39.24	600	500	18.8820
7	58.86	200	550	17.9270
8	58.86	400	500	25.0730
9	58.86	600	530	26.6450

Table 2 Orthogonal array

3. Results and Discussions

3.1 S/N Ratios Analysis

Depending on the type of characteristic being evaluate, the Signal to Noise (S/N) ratio condenses the multiple data points within a trial. The S/N ratio for wear rate is analyzed using characteristic 'smaller the better'. Further transforming the experimental observations into the signal-to-noise ratio. The response to be studied was the wear rate, which is calculated as a logarithmic transformation of the loss function and shown in table 3. The ranking of parameters has been obtained for different parameter levels for wear rate using signal to noise ratios and given in the response table 3. The control factors in the Signal to Noise ratio are statistically significant and it was observed that the applied load is a dominant on wear rate followed by sintering temperature and sliding speed. Figure 2 and 3 graphically illustrates the influence of process parameters on wear rate. Analyzing these experimental results using S/N provides optimal conditions resulting in minimum wear rate. The optimal wear rate condition are L1, S1 and T3.

Table 3 S/N ratio

L9 Array	S/N ratio (db)
1	44.9660
2	49.1325
3	47.5621
4	37.1779
5	35.5286
6	34.4790
7	34.9298
8	32.0159
9	31.4877

Table 4 Response table

Levels	**Factors**		
	Load (L)	**Speed (S)**	**Sintering Temperature (T)**
1	47.22	39.02	37.15

2	35.73	38.89	39.27
3	32.81	37.84	39.34
Delta	14.41	1.18	2.19
Rank	1	3	2

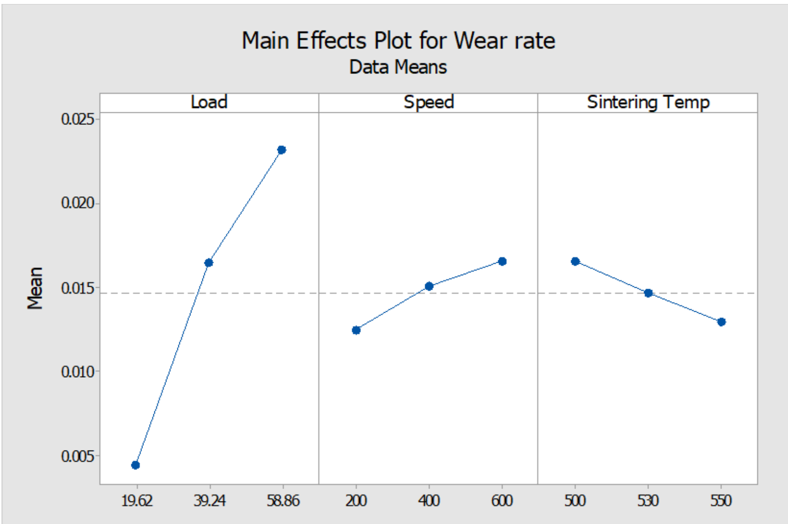

Figure 2. *Main Effects Plot for mean of Wear rate*

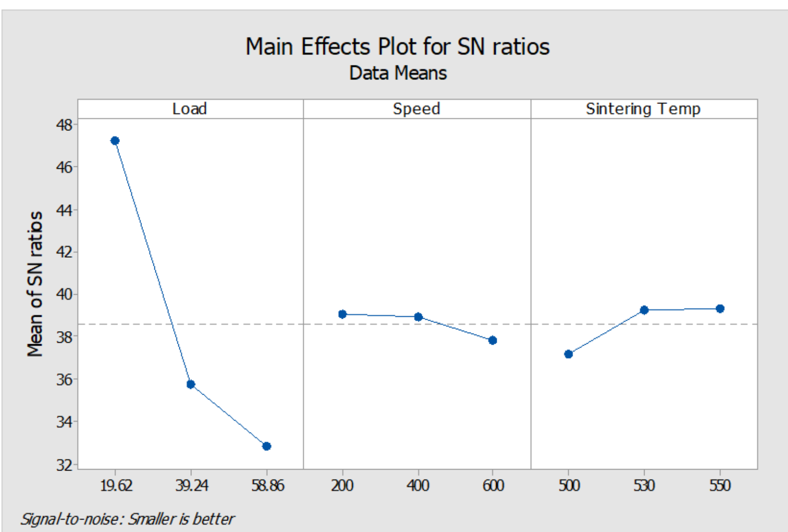

Figure 3. *Main Effects Plot for S/N ratio of Wear rate*

3.2 Analysis of Variance

ANOVA analyzed the experimental results, which is used to examine the influence of wear parameters, namely applied load, sliding speed and sintering temperature, which greatly affect the performance measurements. By performing ANOVA, it is possible to determine the independent factor that dominates the other and find out the percentage contribution of that particular independent variable. Table 5 shows the ANOVA results for wear rate for three factors varied at three levels and interactions of those factors. The last column in the Analysis of Variance tables shows the percentage contribution of each parameter on the total variation indicating their degree of impact on the outcome. From the Analysis of Variance results, it can be observed that load has the highest influence on the wear rate followed by sliding speed and sintering temperature.

Table 5 ANNOVA table for wear rate

Source	**DF**	**Adj SS**	**Adj MS**	**F**	**P**	**Contribution (%)**
Load (A)	2	0.000543	0.000271	41.06	0.024	90.34
Speed (B)	2	0.000026	0.000013	1.96	0.338	4.32
Sintering Temperature (^{0}C)	2	0.000019	0.000010	1.46	0.407	3.16
Error	2	0.000013	0.000007			2.16
Total	8	0.000601				

3.3 Linear Regression Model

Using the statistical software MINITAB 17, a Linear Regression model was generated for wear rate. By fitting a linear equation to observed data, this regression model provides the correlation between an independent variable and a response variable. The generated equation of Regression thus establishes a relationship between the significant terms obtained from the analysis of ANOVA, namely the load applied, the sliding speed and the sintering temperature. The regression equation for wear rate of composite is as follows.

Wear rate = 29.2 + 0.4784 L + 0.01025 S - 0.0710 T

It has been observed from the Regression equations that the wear rate associated with load and sliding speed has been positive and it indicates that, as load and sliding speed increase, wear rate of the composites also increases. In addition, the wear rate associated with sintering temperature has been negative, indicating that wear rate decreases as sintering temperature increases.

4. Conclusions

Magnesium matrix reinforced with 5 wt% silicon carbide and 5 wt % alumina was successfully prepared by powder metallurgy process and the wear behaviour of the composites was investigated using pin-on-disc wear testing machine. To determine the effects of operating parameters on the wear rate of composite, L9 orthogonal array was adopted. Results from ANOVA shows that the applied load is the most influencing parameter followed by sliding speed and sintering temperature. It has been observed from the Regression equations that applied load and sliding speed are positively associated; sintering temperature is negatively associated with wear rate.

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