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DRY SLIDING WEAR BEHAVIOR OF DIFFUSION BONDED AZ-91 MAGNESIUM ALLOY REINFORCED WITH SIC PARTICLES

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ABSTRACT

Magnesium composites reinforced with 2, 4, 6 Wt.% of silicon carbide particles at different particle size of 10, 25 and 45 m was synthesized using diffusion bonding process. Further the samples for scanning electron microscopic analysis and tribological analysis were made from the composites. Dry sliding wear test was carried out with L_{27} orthogonal design array on pin on disc tribometer. Mass loss of the pins was measured and wear rate was calculated. A statistical analysis was performed with the measured wear rate, the optimal parameter combination level was identified with main effect plot. From ANOVA analysis the significant parameters was identified.

Indexing terms/Keywords

Magnesium; Diffusion bonding; Wear; Taguchi analysis; Optimization

Academic Discipline and Sub-Disciplines

Mechanical engineering; Production

TYPE (METHOD/APPROACH)

Experimental, Analysis

1. INTRODUCTION

Magnesium a light weight material has its own applications in both structural as well as non-structural fields. Applications in automotive, materials-handling, aerospace industries were comes under structural zones. The applications of non-structural fields are alloying elements, oxygen scavenger, desulfurizer, reducing agent, photoengraving etc. The most commonly using magnesium alloy is AZ91D due to its strength, good atmospheric stability, and outstanding corrosion resistance [1]. Different methods are available to manufacture a product or a component such as casting, molding, forming etc. Though a plenty of techniques, most preferred one is casting due to its ease of access in all the ways. The property of the material may be enhanced with the help of reinforcements either it may be in the form of oxides, carbides or borides. Several research findings were made on the composites through castings and powder metallurgy techniques. Diffusion bonding is the one which comes under the solid state process which has its own unique applications and advantages. In order to improve the wear and corrosion behaviour coatings by continuous intermetallic compounds was done on AZ91D Mg alloy with the help of diffusion reaction [2]. Al/Mg_2Si composite with copper interlayer was produced by transient liquid phase diffusion bonding and studied its metallurgical and mechanical behaviour of the composites [3, 4]. SiC_p/6063 metal matrix composites with Al–Si, Al–Cu and Al–Si–SiC powders as interlayers was produced by reactive diffusion bonding and studied strength of the composites [5]. Aluminium metal matrix composites with SiC particles was produced by diffusion bonding and studied its metallurgical and mechanical behaviour of the composites [6]. Addition of SiC_p influence on layer on bonding quality and properties of the bonded joints was investigated on Al/SiC_p metal matrix composites [7]. Wear behaviour of AZ91 and AZ91 + 3 wt% composite was investigated at elevated temperatures [8]. An in situ magnesium matrix composite with silicon particles as reinforcement was fabricated by solidification under ultrasonic vibrations and studied its metallurgical, mechanical and tribological behavior [9]. Magnesium, hyper and hypo eutectic Mg–Si alloys was produced through liquid metallurgy route and studied the microstructural and tribological behaviour [10]. Mg alloy AE42 was processed under cast and friction stir processing and investigated the metallurgical, mechanical and tribological behaviour [11]. From the earlier literatures, it was found that there is a minimum research work was processed with magnesium alloy AZ91 through diffusion bonding. Hence in the present research work it is proposed to synthesize the magnesium composite reinforced with SiC particles at different weight percentage and at different particle sizes through diffusion bonding process.

2. Experimentation

Magnesium alloy AZ91 was procured from the suppliers with the chemical composition as shown in Table 1 and the samples were made with 50mmx50mmx4mm dimensions. Then the samples were stacked in layered form by adding the SiC particles at varying weight percentage of 2, 4 and 6 with different particle size 10, 25 and 45 m to attain the required composites. The layer stacked magnesium with different particle size and different weight percentages of SiC particles were placed inside the diffusion bonding machine and the composites were produced to achieve the required compositions. Then the samples were made from the produced composites to investigate the metallurgical through scanning electron microscopic analysis.

Table 1. Chemical composition of AZ91 Alloy in Wt. %

Mg	Al	Zn	Mn	Si	Fe	Cu	Be
90.8	8.25	0.63	0.22	0.035	0.014	0.003	0.002

From the composites, wear pin samples of 8mm diameter with 20mm height were made to study the wear behavior with various input parameters and at different levels as shown in Table 2. The ends of the pins were mirror polished in order to have greater area of contact between the pins and discs. Before the experimental the end surface of the samples were cleaned with acetone. A Taguchi's L_{27} orthogonal array as was used to experiment the wear analysis. Before and after the run, mass of the pins were carefully weighed with high precision electronic weighing balance and with the mass loss the wear rate of the pins were calculated using the equation 1 and it is shown in Table 3.

Table 2. Control factors and their levels

Factors	Level 1	Level 2	Level 3
Percentage volume of SiC, Wt.%	2	4	6
Particle size, m	10	25	45
Load, N	9.81	18.62	27.43
Sliding velocity, m/s	1	2	3

$$Wear\ rate = \frac{(mass\ loss/density)}{sliding\ distance} \qquad equation\ (1)$$

Table 3. L_{27} orthogonal array with wear rate

Experiment Number	Percentage volume of SiC (Wt.%)	Particle size (m)	Load (N)	Sliding Velocity (m/s)	Wear rate (mm^3/m)
1	2	10	9.81	1	0.00978
2	2	10	18.62	2	0.02005
3	2	10	27.43	3	0.02691
4	2	25	9.81	1	0.01052
5	2	25	18.62	2	0.02170
6	2	25	27.43	3	0.02036
7	2	45	9.81	1	0.01249
8	2	45	18.62	2	0.02312
9	2	45	27.43	3	0.02318
10	4	10	9.81	3	0.02788
11	4	10	18.62	1	0.00348
12	4	10	27.43	2	0.01286
13	4	25	9.81	3	0.03999
14	4	25	18.62	1	0.00736
15	4	25	27.43	2	0.01406
16	4	45	9.81	3	0.03143
17	4	45	18.62	1	0.00733
18	4	45	27.43	2	0.01668
19	6	10	9.81	2	0.02273
20	6	10	18.62	3	0.03286
21	6	10	27.43	1	0.01156
22	6	25	9.81	2	0.02919
23	6	25	18.62	3	0.03588
24	6	25	27.43	1	0.00640
25	6	45	9.81	2	0.02815
26	6	45	18.62	3	0.03514
27	6	45	27.43	1	0.01399

3. RESULTS AND DISCUSSION

3.1 Scanning Electron Microscope

The diffusion bonded composites were subjected to scanning electron microscopic analysis in order to identify the metallurgical characterization. Figure 1 shows the scanning electron microscopic image of the diffusion bonded sample. The image shows the uniform distribution of the reinforcement over the matric material.

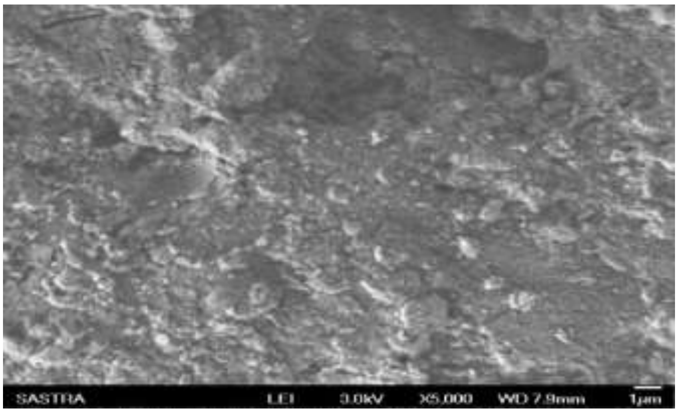


Figure 1. Scanning electron microscopic image of the diffusion bonded sample

3.2 Wear analysis

In order to attain the required objective of minimum wear rate, Taguchi's "lower the better" quality characteristics is used. A statistical analysis is performed to identify the significance of the parameters on the wear rate. From Table 4 the response table for wear rate, it is identified that the sliding velocity is the most influencing factor further in the sequence of load, percentage volume of SiC and particle size.

Table. 4 Response table for signal to noise ratio of wear rate

Level	Percentage volume of SiC	Particle size	Load	Sliding Velocity
1	0.018678	0.0185678	0.023571	0.009211
2	0.017896	0.020606	0.020769	0.020948
3	0.023988	0.021279	0.016223	0.030403
Delta	0.006092	0.002601	0.007349	0.021192
Rank	**3**	**4**	**2**	**1**

With the help of main effect plot as shown in figure 2 the optimal value for minimum wear rate is obtained as 4% volume of SiC, 10μm particle size, 27.43N of load and 1m/s sliding velocity. From the interaction plot we can identify the significance between the parameter interactions. Figure 4 shows interactions of volume percentages of SiC with particle size and sliding velocity at lower and medium levels volume percentages of SiC. When looking the interaction between particle size and load it shows significance for lower and medium levels of particle size for higher loads.

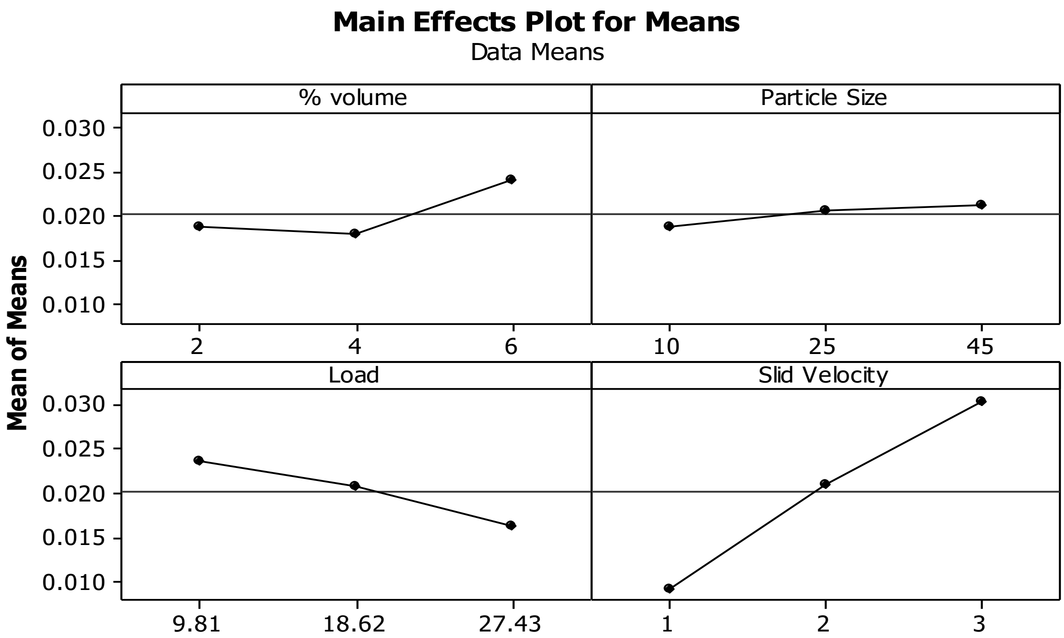


Figure 2. Main effect plot for mean of wear rate

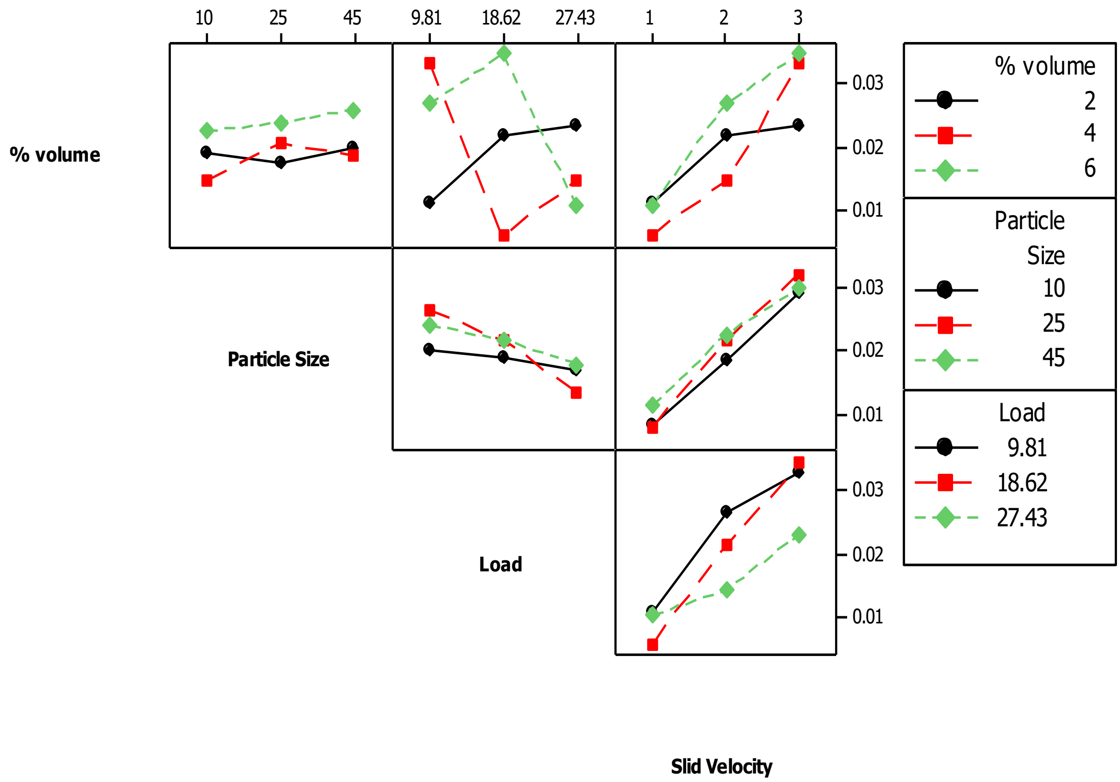
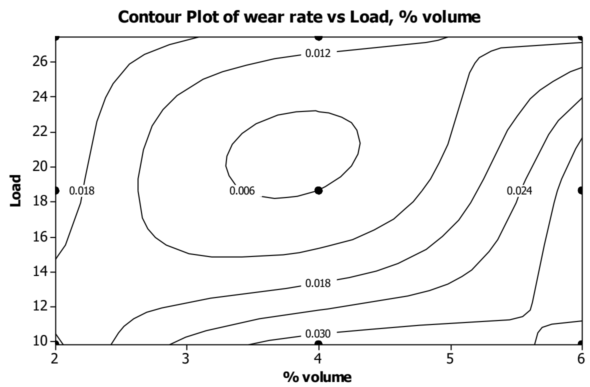
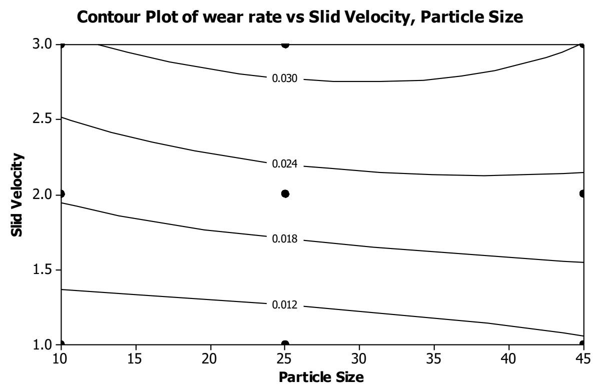
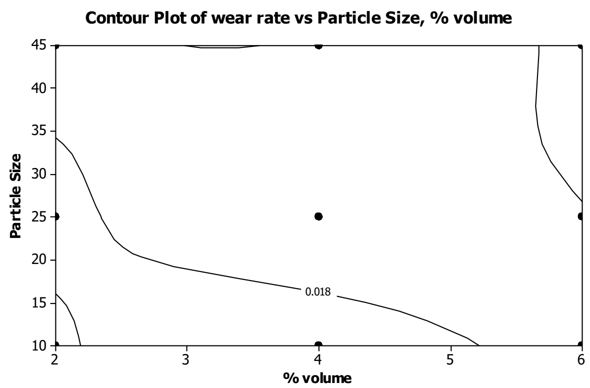
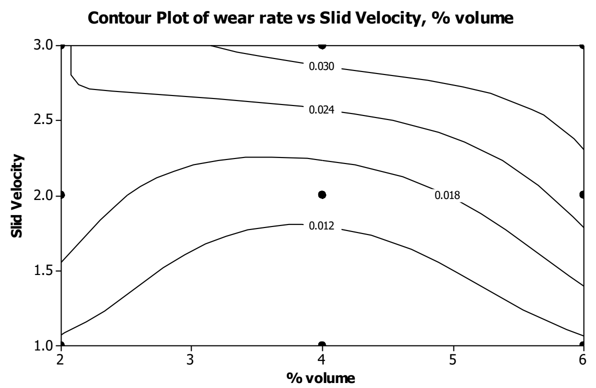


Figure 3. Interaction plot for wear rate









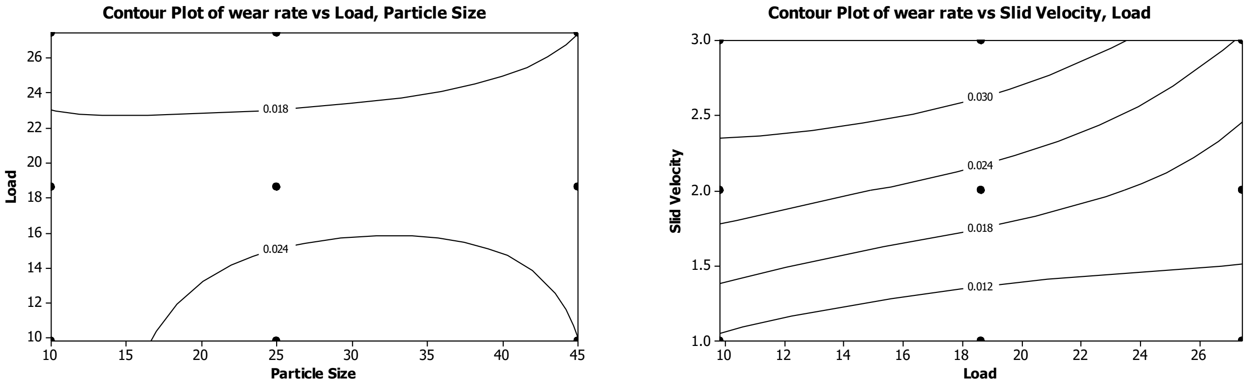


Figure 4. Contour plots for wear rate

Figure 4 shows the contour plot for load with % volume, sliding velocity with particle size, particle size with % volume, sliding velocity with % volume, load with particle size, sliding velocity with load. Contour plot of load with % volume shows a minimum wear rate of 0.006mm3/m at middle level of % volume and load in the range of 18 to 23N. Contour plot of sliding velocity with particle size shows a minimum wear rate of 0.012mm3/m for lower particle size and lower sliding velocity. Contour plot of particle size with % volume shows a minimal wear rate at lower particle size and % volume. Contour plot of sliding velocity with % volume shows wear rate of less than 0.012mm3/m for lower sliding velocity and at all levels of % volume. Contour plot of load with particle size shows a lower wear rate of 0.018mm3/m at higher levels of loads. Contour plot of sliding velocity with load shows a minimum wear rate of 0.012mm 3/m at lower sliding velocity and at all levels of load.

Table 5. Analysis of variance for signal to noise ratios of wear rate

Source	DF[a]	Seq SS[b]	Adj SS[c]	Adj MS[d]	F	P[e]
Percentage volume of SiC	2	0.0001978	0.0001978	0.0000989	9.19	0.002
Particle size	2	0.0000328	0.0000328	0.0000164	1.52	0.245
Load	2	0.0002476	0.0002476	0.0001238	11.5	0.001
Sliding Velocity	2	0.0020287	0.0020287	0.0010143	94.24	0
Error	18	0.0001937	0.0001937	0.0000108		
Total	26	0.0027006				

S = 0.00328071 R-Sq = 92.83% R-Sq(adj) = 89.64%

[a] Degrees of freedom [b] Sequential sums of squares [c] Adjusted sums of squares [d] Adjusted mean squares [e] Probability.

From the ANOVA analysis as shown in Table 5, it is identified that the sliding velocity is the most significant factor having lesser probability value followed by load and percentage volume of SiC with 92.83% R-sq value. Figure 5 shows a normal probability plot in which residues are distributed within the range by following the straight line.

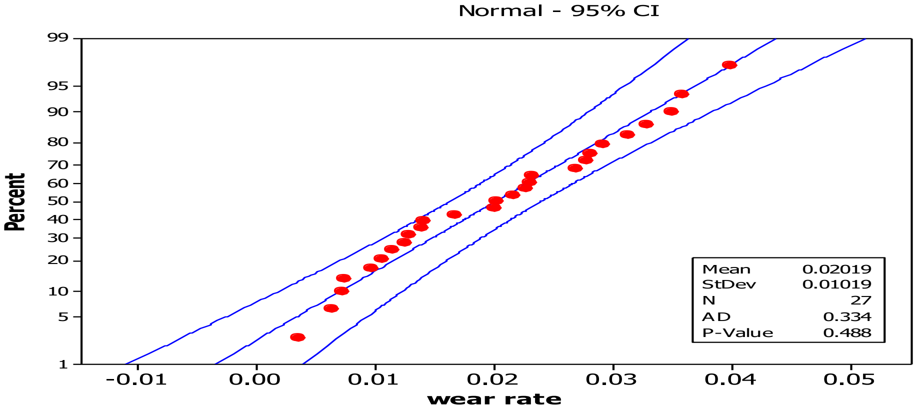


Figure 5. Normal probability plot for wear rate

4. CONCLUSIONS

Magnesium composite reinforced with SiC particle was successfully fabricated through the diffusion bonding process with varying particle size. The Scanning electron microscope revealed the uniform distribution of SiC particles. The optimal value of 4% volume of SiC, 10m particle size, 27.43N of load and 1m/s sliding velocity was obtained from the main effect plot. From the ANOVA analysis sliding velocity is identified as the most significant factor with 92.83% R-sq value.

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