Tribological Behavior of AA8090/MgO Composites

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Abstract: In the present study, the AA8090/MgO metal matrix composites were investigated under dry sliding wear test as for ASTM G 99 standard. AA8090 base matrix reinforced with Mgo nanoparticles were fabricated using stir casting technique. By using pin on disc apparatus the test was conducted by taking parameters like sliding distance, sliding speed, load and volume fraction of reinforcement. The result reveals that the addition of MgO slightly reduces wear rate of composites. As the sliding distances and load increases the wear rate drastically increases.

Keywords: AA8090, magnesia, wear, sliding distance, normal load, sliding speed, volume fraction.

1. INTRODUCTION

Al alloy based ceramic particulate composites have been characteristic as futuristic materials for a number of engineering purposes. The metal matrix composites (MMCs) being of very high interest for the aerospace industry, particularly to build up thermal-structural components, it is important to have available technique which are easy and simple to conduct for characterization of the mechanical strength of the material. Different types of ceramic nanoparticles such as SiC [1-4], SiO_2 [5], Al_2O_3 [6, 7], ZrO_2 [8], ZrC [9], TiO_2 [10], TiB_2 [11, 12], TiN [13], BN [14], B_4C [15], Carbon [16], graphite [17-19], Si_3N_4 [20], MgO [21-23] and $Al_2O_3.3H_2O$ [24] have been implemented for Al matrix composites. Magnesia [MgO] due its high melting point (Tm = 2800^{o}C), compressive strength, hardness, and also excellent thermodynamic stability is an appropriate choice for reinforcement.

Modeling of tribology is an effective tool to predict the tribological behavior of mechanical components (e.g., piston ring, piston, liners, machine tools, cutting tools, gears etc.). The empirical approach of a model involves characterization of surfaces, collection of tribological data in laboratory tests, correlation of data with field tests, and sorting out of data to build an empirical model [25-28].

In the present work, AA8090 was reinforced with 10%, 20% and 30% volume percentage of MgO nanoparticles through stir casting technology. The tribological behavior was investigated using pin-on-disc equipment. The wear rate and micro hardness were analyzed at varying volume percentage ratios. The effect of sliding velocity, load, and sliding distance and volume fraction of reinforcement on the wear behavior of the composites was studied. The experiments were executed as per the Taguchi's design of experiments [29].

Table 1: Control parameters and levels

Factor	Symbol	Level–1	Level–2	Level–3
Reinforcement, vf	A	0.1	0.2	0.3
Load, N	B	10	20	30
Speed, m/s	C	1	2	3
Sliding distance, m	D	500	750	1000

2. MATERIALS METHODS

The matrix material was AA8090 alloy. The reinforcement material was magnesia (MgO) nanoparticles of average size 100nm. AA8090/MgO composites were fabricated by the stir casting process and low pressure die casting technique with argon gas at 3.0 bar. The composite samples were given T3 heat treatment. The heat-treated samples were machined to get cylindrical specimens for the wear tests. The design of experiments was carried out as per Taguchi techniques. The levels chosen for the controllable process parameters are summarized in Table 1. The orthogonal array, L9 was preferred to carry out wear tests experimentally (Table 2). A pin on disc type wear monitor (ASTM G99) was employed to evaluate the wear behavior of AA8090/MgO composites against hardened ground steel (En32) disc. To determine hardness before and after wear test, the Knoop hardness was conducted. The worn surfaces were examined microscopically.

.**Table 2:** Orthogonal array (L9) and control parameters

Treat No.	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

3. RESULTS AND DISCUSSION

The analysis of variance (ANOVA) is presented in Table 3. The percent contribution indicates that the volume fraction of MgO, contributes 29.91%. The normal load gives 11.62% of variation in the wear rate. The sliding speed influences 1.48% of variation in the wear rate. The sliding distance supplies 56.98% of variation in the wear rate. The R-squared values of %reinforcement, normal load, sliding speed and sliding distance are, respectively, 0.9829, 0.9763, 0.6210 and 0.9964. The trend of mean values obtained by Taguchi techniques is same as that of R-squared values.

Table 3: ANOVA summary of the wear rate

Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	P
A	4.06E-02	3.88E-02	3.29E-02	1.08E-05	1	1.08E-05	6.65E+13	29.91
B	3.53E-02	3.68E-02	4.02E-02	4.20E-06	1	4.20E-06	2.58E+13	11.62
C	3.64E-02	3.80E-02	3.79E-02	5.36E-07	1	5.36E-07	3.29E+12	1.48
D	3.24E-02	4.44E-04	1.12E-01	2.06E-05	1	2.06E-05	1.27E+14	56.98
e				-6.51E-19	4	-1.63E-19	1.00	0.00
T	1.45E-01	1.14E-01	2.23E-01	3.62E-05	8			100.00

Note: SS is the sum of square, v is the degrees of freedom, V is the variance, F is the Fisher's ratio, P is the percentage of contribution and T is the sum squares due to total variation.

With an increase in the percentage addition of MgO, the wear rate decreased as shown in figure 1a. The addition of MgO nanoparticles supported and protected the matrix from the counterface material and minimized the establishment of severe adhesive surface shear strain that was associated with the unreinforced matrix. The predominant wear mechanism was identified as delamination, due to poor particle/matrix interfacial bonding. Wear rate increased linearly with applied pressure (figure 1b) but was independent of sliding velocity (figure 1c). With increasing applied pressure the wear behavior of the unreinforced alloy was dominated by extensive plastic flow of the alloy surface and significant wear debris formation. The addition of MgO nanoparticles reduced the wear for the applied pressure range examined. MgO nanoparticles were reported to minimize this plastic deformation on the wearing surface and promoted the formation of an iron-rich layer on the composite's surface. The wear rate increased with the sliding distance as shown in figure 1d.

The mathematical relation between wear and contact time is given by

$$W_{rp} = 0.00686 {v_f}^{-0.3032} \quad (1)$$

$$W_{rf} = 0.0083 F^{-0.1428} \quad (2)$$

$$W_{rn} = 0.0116 N^{0.0652} \quad (3)$$

$$W_{rd} = 0.0006 d^{0.4506} \quad (4)$$

where,
W_{rp} is the wear rate due to vol.% of reinforcement (v_f), g/m
W_{rf} is the wear rate due to normal load (F), g/m
W_{rn} is the wear rate due to speed (N), g/m
W_{rd} is the wear rate sliding distance (d), g/m.

As seen from figure 2, the hardness values increase after wear test. The increase in hardness in the worn specimens may be attributed to the work hardening. The reinforcement particles act as load bearing elements.

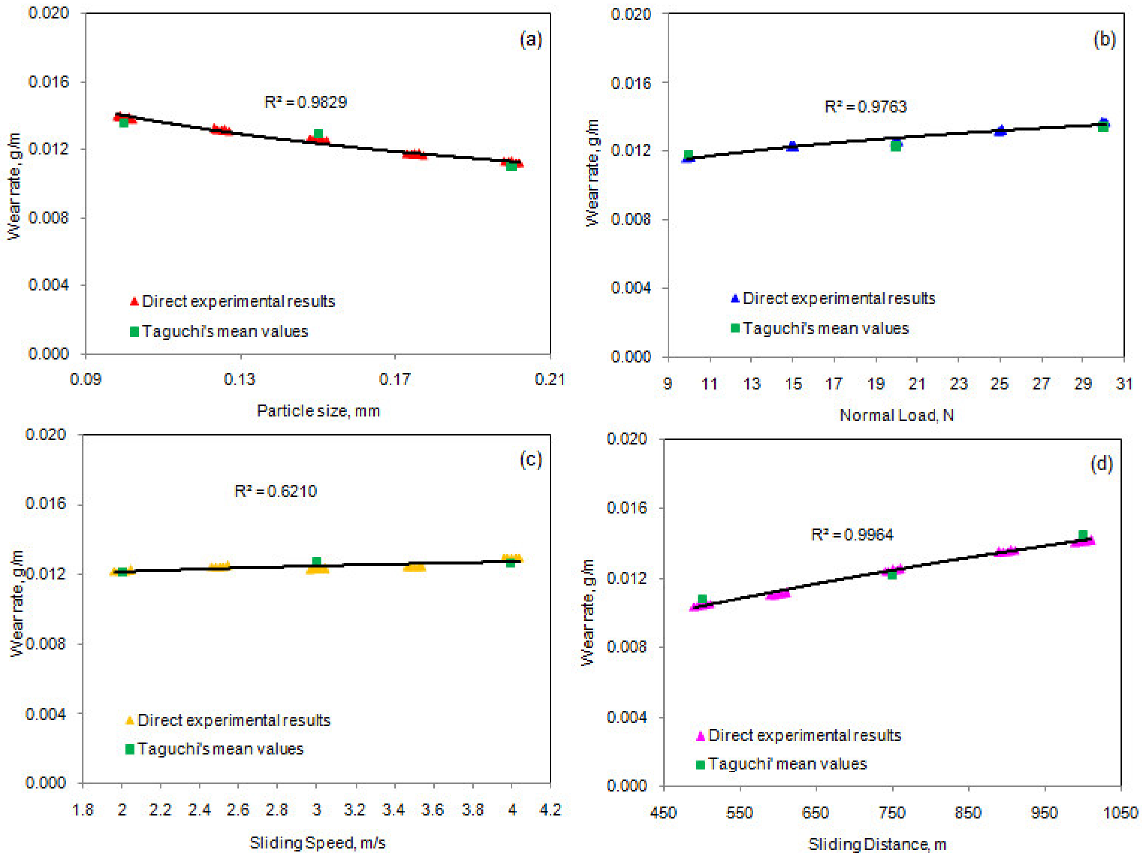

Figure 1: Influence of process parameters on wear rate.

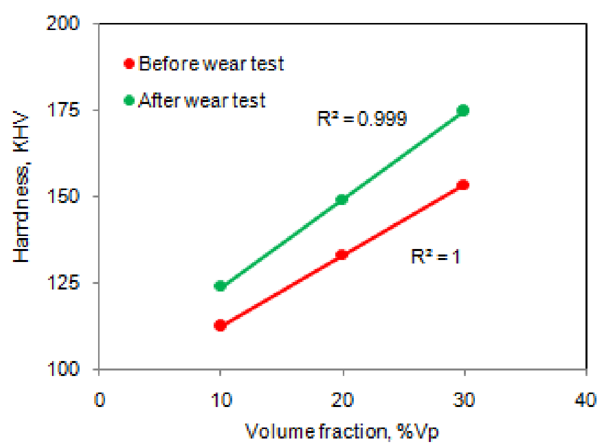

Figure 2: Hardness of AA8090/MgO composites after wear test.

4. CONCLUSION

The purpose of this paper was to investigate the tribological behavior of AA8090/MgO metal matrix composites. An optimum reinforcement content, for which the adhesive wear rate corresponds to a minimum, is dependent upon dry sliding conditions. For adhesive wear, the influence of applied load, sliding speed, sliding distance, wearing surface hardness and reinforcement volume fraction are critical parameters in relation to the wear regime encountered by the material. Under dry sliding conditions, materials possessing high wear resistance are associated with a stable tribolayer on the wearing surface.

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