Sliding Wear of AA7020/MgO Composites against En32 Steel Disc

[1]R. G. Math and A. Chennakesava Reddy[2]

[1]Research Scholar, Department of Mechanical Engineering, JNTU College of Engineering, Hyderabad, India
[2]Professor, Department of Mechanical Engineering, JNTU College of Engineering, Hyderabad, India
dr_acreddy@yahoo.com

Abstract: *In the present work, the AA7020/MgO metal matrix composites were manufactured at 10% and 30% volume fractions of MgO. The composites were subjected to mechanical and thermal loads. The microstructure of AA7020 alloy/MgO composite reveals the fracture of interphase and particle. The consequences of wear were work hardening, matrix fracture and particle removal.*

Keywords: *Metal matrix composite, AA7020, magnesium oxide, wear, sliding distance, normal load, speed.*

1. INTRODUCTION

The expansion of Al based metal matrix composites is drawing attention because of the low cost of aluminum based alloys in comparison with other potential metal matrices [1-7]. Al based composites offer high specific strength and stiffness, improved high temperature properties, controlled thermal expansion coefficient, improved wear and abrasion resistance [8-17]. There are different types of reinforcement such as whiskers, particle, fiber and filament. Mainly particle reinforcement is preferred over the other types of reinforcement for synthesizing the metal matrix composite. Modeling of tribology is an effective tool to forecast the performance of components like: piston liners, cutting tools, gears etc. The tribological characteristics of these composites depend upon the material morphology such as composition, size, shape and distribution of reinforcements and service conditions such as load, contact surface, contact time and sliding speed [18-24].

The present work is on the evaluation of wear characteristics and consequences of cast AA7020/magnesium oxide composites. The design of experiments was based on Taguchi techniques [25, 26].

2. MATERIALS METHODS

The design of experiments was carried out as per Taguchi techniques. The levels chosen for the controllable process parameters are summarized in Table 1. Each of the process parameters was planned at three levels. The orthogonal array, L9 was preferred to carry out experiments (Table 2). The reinforcement material was MgO nanoparticles of average size 100nm. AA7020 alloy/ MgO composites were fabricated by the stir casting process and low pressure casting technique with argon gas at 3.0 bar. The H18 heat-treated samples were machined to get cylindrical specimens of 10 mm diameter and 30 mm length for the wear tests. A pin on disc type friction and wear monitor (ASTM G99) was employed to evaluate the friction and wear behavior of AA7020 alloy/ MgO composites against hardened ground steel (En32) disc. An investigation has been carried out to study the effects of sliding speed, contact time, normal pressure, and volume fraction of MgO on the wear characteristics. Scanning electron microscopy analysis was also carried out to find consequence of wear test A7020/MgO composite specimens.

Table 1: Control parameters and levels

Factor	Symbol	Level–1	Level–2	Level–3
Reinforcement, Vol.%	A	10	20	30
Load, N	B	20	30	40
Speed, m/s	C	2	3	4
Sliding distance, m	D	500	1000	1500

Elastic modulus is a measure of the stiffness of a material and is a quantity used to characterize materials. Elastic modulus is the same in all orientations for isotropic materials. The upper-bound equation is given by

$$\frac{E_c}{E_m} = \left(\frac{1-v_v^{2/3}}{1-v_v^{2/3}+v_v}\right) + \frac{1+(\delta-1)v_p^{2/3}}{1+(\delta-1)(v_p^{2/3}-v_p)} \quad (3)$$

The lower-bound equation is given by

$$\frac{E_c}{E_m} = 1 + \frac{v_p - v_p}{\delta/(\delta-1) - (v_p+v_v)^{1/3}} \quad (4)$$

where, $\delta = E_p/E_m$.

where, v_v and v_p are the volume fractions of voids/porosity and nanoparticles in the composite respectively and E_m and E_p is elastic moduli of the matrix and the particle respectively.

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

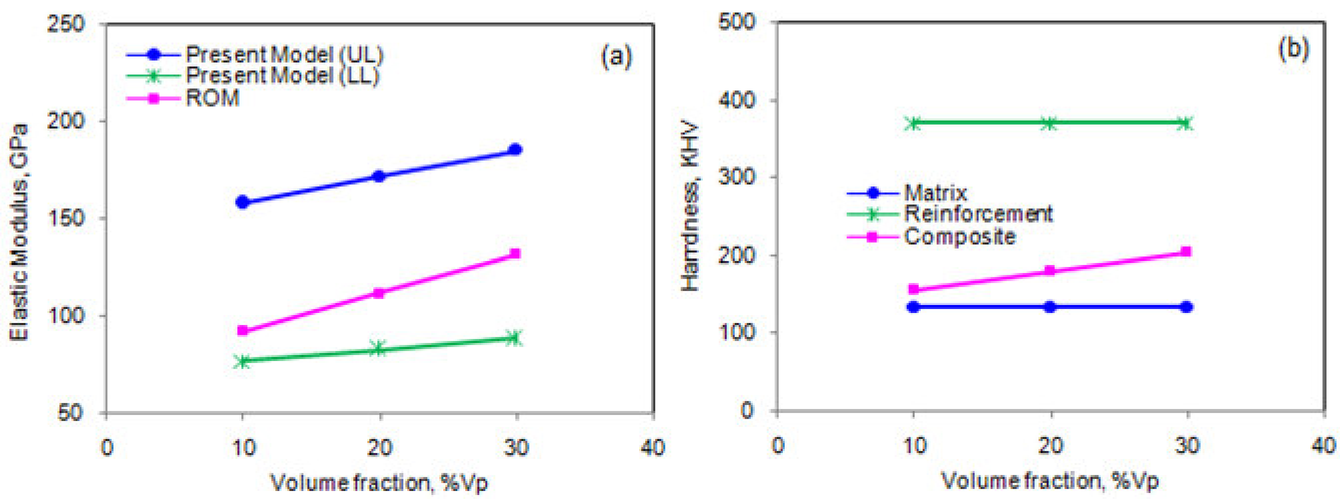

Figure 1: Elastic modulus and hardness of AA7020/MgO composites.

Table 3: ANOVA summary of the effective stress

Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	P
A	14.05000	12.37000	8.48000	5.44216	1	5.4421556	1.91E+14	67.19
B	10.04000	11.79000	13.07000	1.54242	1	1.5424222	5.43E+13	19.04
C	12.22000	11.94000	10.74000	0.41209	1	0.4120889	1.45E+13	5.09
D	10.83000	42.41280	34.90000	0.70269	1	0.7026889	2.47E+13	8.68
e				0.00000	4	0.0000	1.00E+00	0
T	47.14000	78.51280	67.19000	8.09936	8			100

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.

3. RESULTS AND DISCUSSION

Elastic modulus and knoop hardness were increased with volume fraction of MgO as shown in figure 1. The increase of hardness of composites was due to higher hardness of MgO nanoparticles than that of AA7020 matrix alloy.

3.1 Effect of volume fraction, Normal Load, Sliding Speed, Sliding distance on Wear Rate

The sufficiency of the experimental results was excellent as the percent contribution due to error was zero. For the analysis of variance (ANOVA), all parameters qualify Fisher's test at 90% confidence level. In Table 3, the percent contribution indicates that t volume fraction of MgO (A), contributes 67.19% of variation in the wear rate. The normal load (B) commits 19,04% of variation in the wear rate. The sliding distance (D) confers 5.09% of variation in the wear rate. The speed (C) affords 8.68% only of the total variation in wear rate.

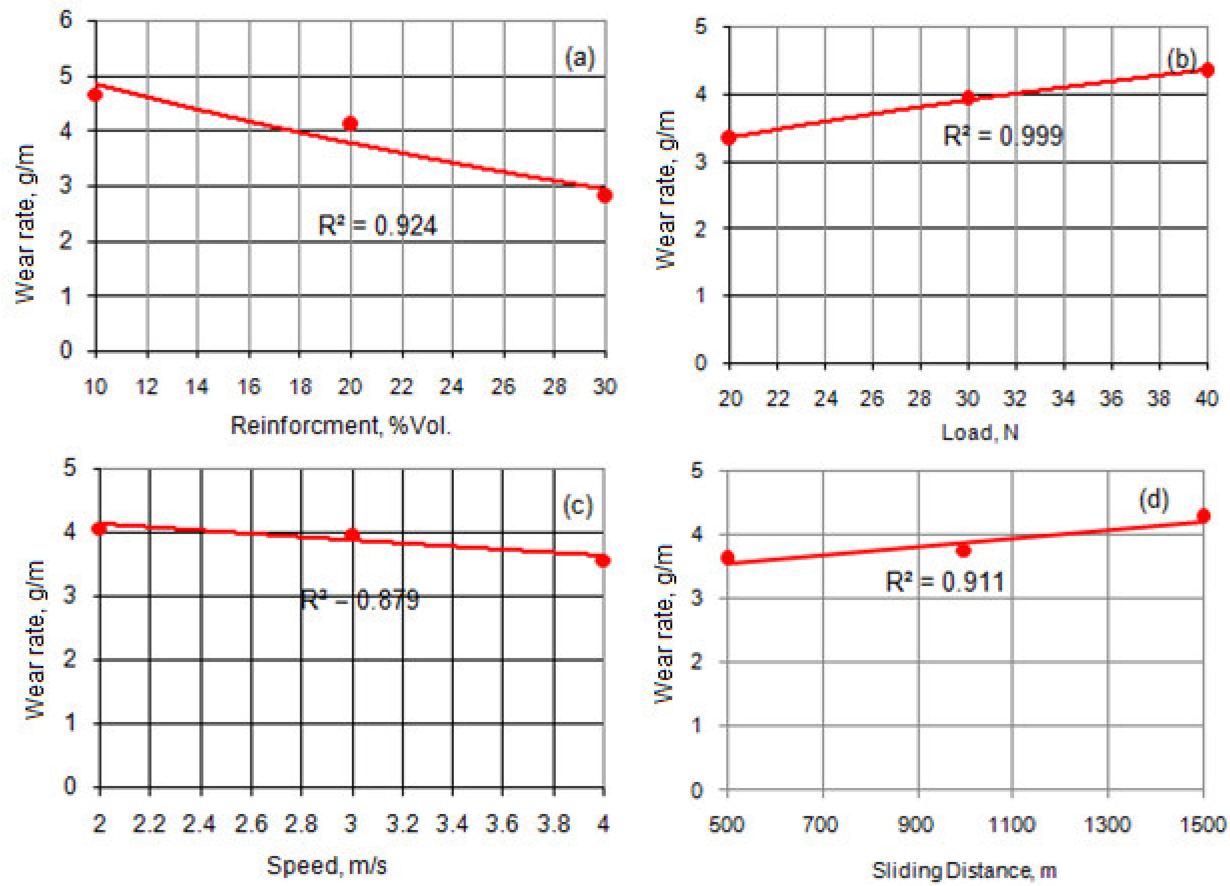

Figure 2: Influence of tribology parameters on wear rate.

It can be seen from figure 2a that the wear rate was decreased with increase in volume fraction of MgO in AA7020 alloy matrix. This is owing to high hardness of MgO as compared to soft AA7020 alloy matrix. Composites produced by low volume fraction of MgO, wear out faster than those produced by high volume fraction of MgO. The wear rate was increased with load as shown in figure 2b. This can be attributed to increase of friction with normal load applied on the wear specimen. The wear rate was decreased with increase of speed (figure 2c). From figure 2d it is observed that the wear rate was proportional to the sliding distance. The R-squared values, which are attributable to volume fraction of reinforcement, normal load, sliding speed and sliding distance, respectively, are 0.924, 0.999, 0.879 and 0.911. These values indicate the best fit of the trend.

3.2 Consequence of Wear in AA7020/MgO Composites

The purpose of post-wear evaluation is to focus the changes that are brought in the worn specimens in terms of mechanical properties, microstructure, and worn-surface pattern. The worn specimens are not length enough for tensile testing to evaluate tensile strength and %elongation. Therefore, the worn specimens were tested for hardness only. The change in hardness of the worn specimens is shown in figure 3. It can be seen that the hardness values increase after wear test. The increase in hardness in the worn specimens may be attributed to the work hardening mainly due to influence of volume fraction of MgO and normal load applied on the test specimens. When the reinforcement was increased to 30 %, a decrease in wear rate was detected. The removal of particles (A) from the matrix and scratches in the matrix regions (B) were observed. The particle removal was higher in the composites having 30% MgO than in the composites having 10% MgO.

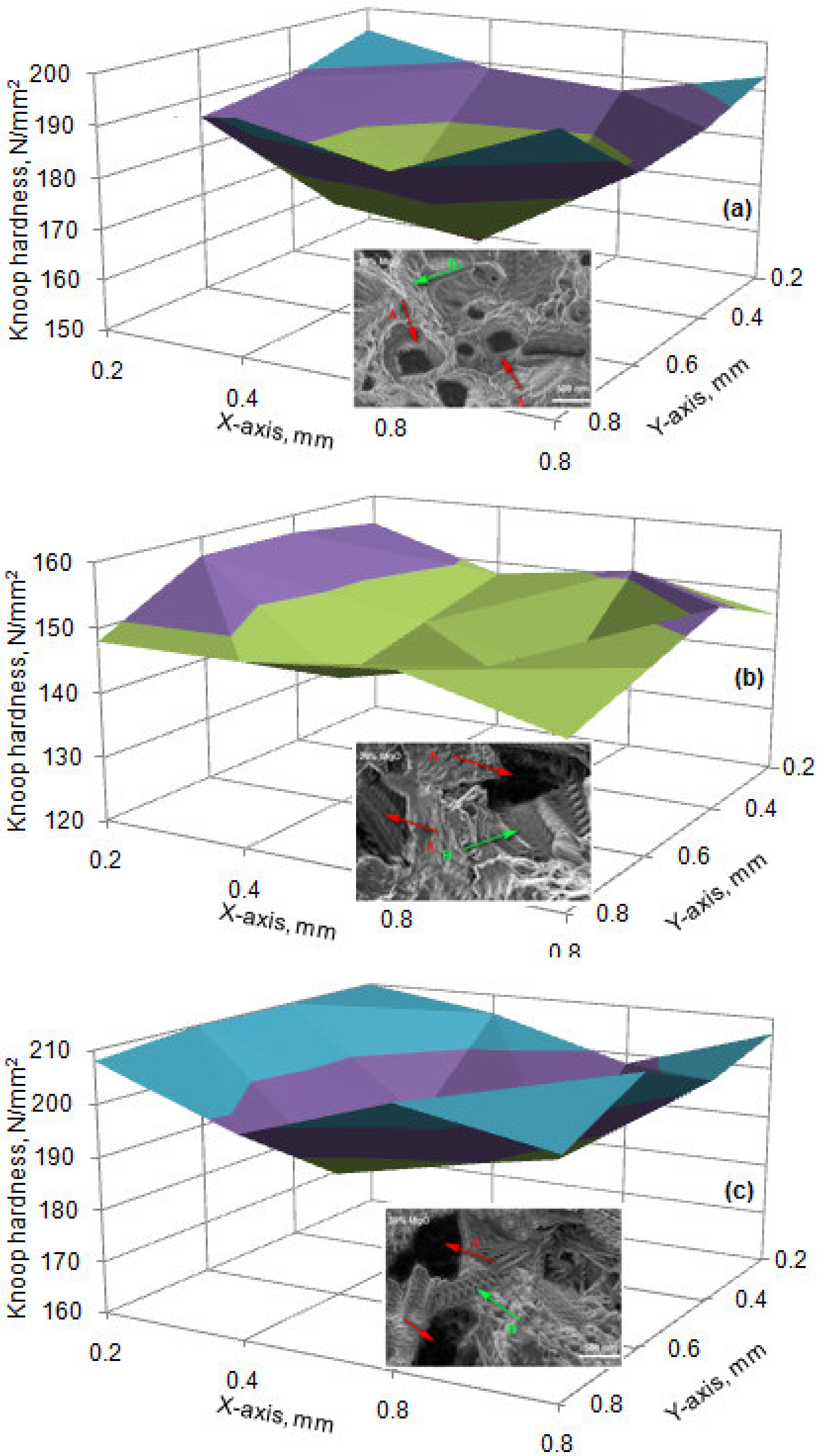

Figure 4: Harness of AA7020/MgO composites after wear test: (a) 10 vol.%MgO (b) 20 vol.%MgO and (c) 30 vol.%MgO.

4. CONCLUSION

The investigation on the wear behavior of the composites as the function of volume fraction of reinforcement, load, sliding speed and sliding distance using Taguchi's design of experiments was carried out successfully. The following are drawn from the present work as follows:

1. The wear resistance increases with increase of vol.% MgO in AA7020 alloy matrix.
2. The wear loss increases with increase in normal load and sliding distance.
3. The wear loss decreases with increasing speed.
4. The consequences of wear were work hardening, matrix fracture and particle removal.

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