On the Wear of AA4015 – Fused Silica Metal Matrix Composites

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Abstract: Materials possessing high wear resistance (under dry sliding conditions) are associated with a stable tribolayer on the wearing surface and the formation of fine equiaxed wear debris. For adhesive wear, the influence of applied load, sliding speed, wearing surface hardness, reinforcement fracture toughness and morphology are critical parameters in relation to the wear regime encountered by the material. By using pin on disc apparatus the test was conducted by taking parameters like volume fraction of reinforcement, sliding distance, sliding velocity and loads. Based on the experimental results empirical models were established. Hardness increases with increasing % of reinforcements because due to condition of SiO_2 nanoparticles cuts as the obstacles to motion of dislocation.

Keywords: AA4015, fused silica, wear, sliding distance, normal load, sliding speed.

1. INTRODUCTION

Particulate reinforced aluminum matrix composites have received considerable attention because of their high specific strength, high specific modulus, low CTE (coefficient of thermal expansion) value and good wear resistance [1-8]. The reduced size of the reinforcement phase down to the nano-scale is such that interaction of particles with dislocations becomes of significant importance and, when added to other strengthening effects typically found in conventional MMCs, results in a remarkable improvement of mechanical properties [9-18]. Small powder aggregates are in fact prone to form clusters, losing their capability to be homogeneously dispersed throughout the matrix for an optimal exploitation of the strengthening potential.

The degree of wear is the result of several common factors applied in certain cases, particularly the relationship among the rate of corrosion and load, speed, coefficient of friction, and adhesion, as well as hardness and tensile strength. Hardness increases with continuous or intermittent increase in reinforced particles and is related to friction and adhesion. Thus, the wear rate for each metal is affected by heavy load conditions and is not associated with resistance to corrosion under less severe conditions [19, 20].

An attempt is made in the present work to study the wear behavior of AA4015/SiO_2 composites. The effect of sliding velocity, load, and sliding distance and volume fraction of reinforcement on the wear behavior of the composites is studied. The experiments were executed as per the Taguchi's design of experiments [21, 22].

2. MATERIALS METHODS

The matrix material was AA4015 alloy. The reinforcement material was fused silica (SiO_2) nanoparticles of average size 100nm. AA4015/SiO_2 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 H14 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 AA4015/SiO_2 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 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

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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 SiO_2, contributes 75.09%. The normal load gives 7.17% of variation in the wear rate. The sliding speed influences 1.24% of variation in the wear rate. The sliding distance supplies 16.51% of variation in the wear rate. The R-squared values of %reinforcement, normal load, sliding speed and sliding distance are, respectively, 0.9678, 0.7499, 0.5378 and 0.9156. 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	7.97E-02	6.90E-02	6.59E-02	3.49E-05	1	3.49E-05	8.06E+13	75.09
B	7.00E-02	7.05E-02	7.41E-02	3.34E-06	1	3.34E-06	7.69E+12	7.17
C	7.05E-02	7.18E-02	7.23E-02	5.76E-07	1	5.76E-07	1.33E+12	1.24
D	6.85E-02	1.68E-03	2.15E-01	7.68E-06	1	7.68E-06	1.77E+13	16.51
e				1.73E-18	4	4.34E-19	1.00	0.00
T	2.89E-01	2.13E-01	4.27E-01	4.65E-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.

Within an increase in the percentage addition of SiO_2, the wear rate decreased, suggestive of improved wear resistance (figure 1a). An increase in wear rate is with increase of normal load applied on the test specimen (figure 1b) because pressure at pin and disc interface become more. The wear rate is independent of the increase of sliding speed (figure 1c). The wear rate increased with the sliding distance as shown in figure 1d. As the sliding distance increases the wear rate increases and as the % of reinforcement increases wear rate decreases because SiO_2 nanoparticles are crushed and form work harden layer between pin and the counter face thus reduces the wear rate of composites.

The mathematical relation between wear and contact time is given by

$$W_{rp} = 0.01326 v_f{}^{-0.2921} \quad (1)$$

$$W_{rf} = 0.00204 F^{0.0534} \quad (2)$$

$$W_{rn} = 0.0226 N^{0.0469} \quad (3)$$

$$W_{rd} = 0.083 d^{0.1608} \quad (4)$$

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.

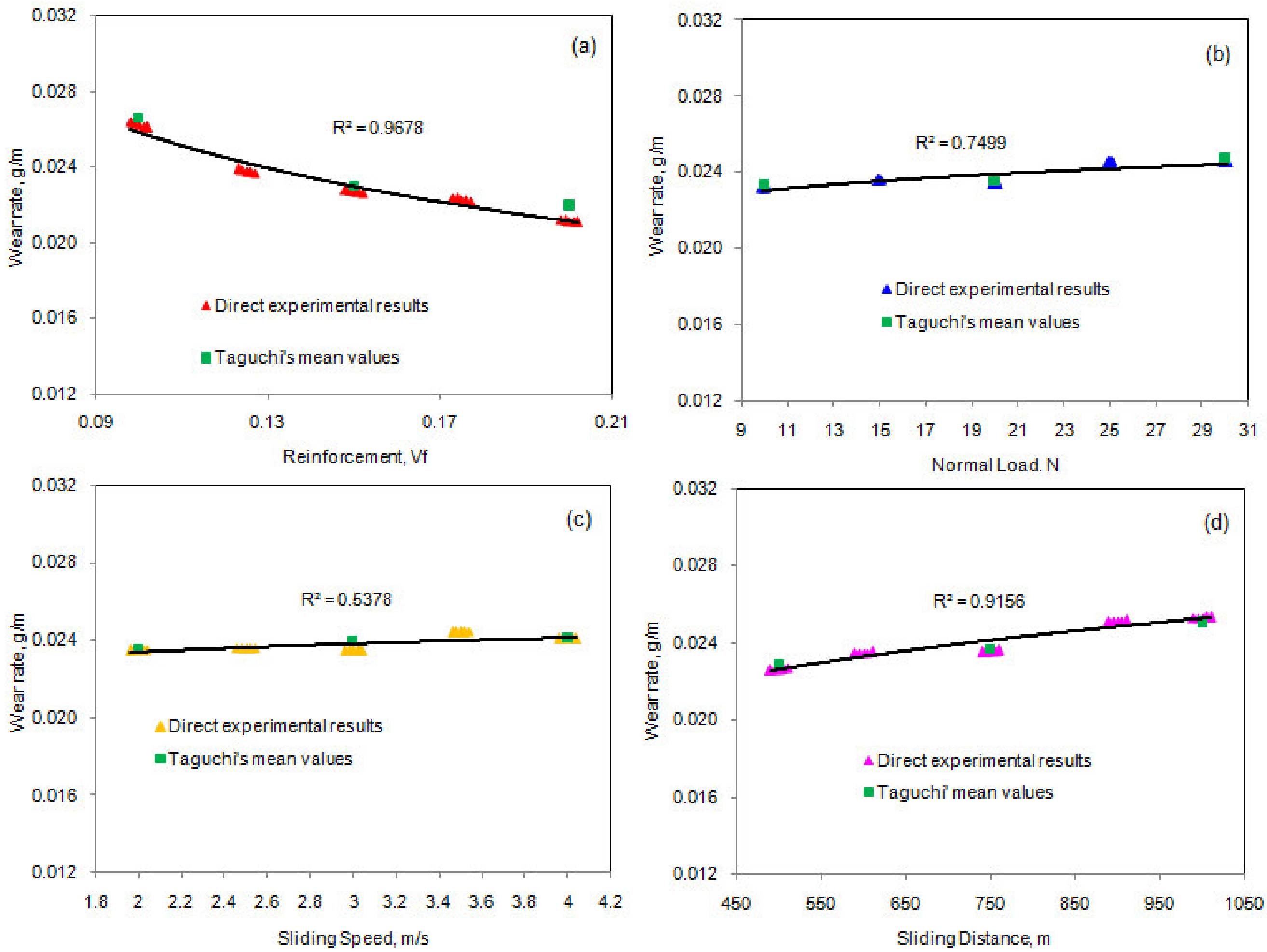

Figure 1: Influence of process parameters on wear rate.

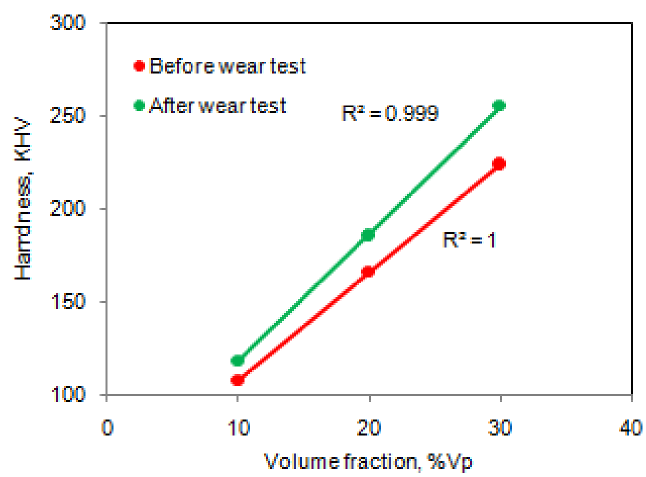

Figure 2: Hardness of AA4015/SiO_2 composites after wear test.

The change in hardness of the worn specimens is shown in figure 2. 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.

4. CONCLUSION

The study on the wear behavior of AA4015/SiO_2 composites as the function of vol.% of SiO_2, normal load, sliding speed and sliding distance using Taguchi's design of experiments was carried out successfully. The wear resistance increases with increase of vol.% SiO_2 nanoparticles in AA4015 matrix. Hardness increases with increasing % of reinforcements because due to condition of SiO_2 nanoparticles cuts as the obstacles to motion of dislocation.

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