Hardness Patterns on Worn Surfaces of AA7020 Alloy/SiO_2 Particulate Metal Matrix Composites

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Abstract: *In the current work, the AA7020 alloy/SiO_2 metal matrix composites were manufactured at 10% and 30% volume fractions of SiO_2. The pin-on-disc wear test was carried out with different combinations of reinforcement, sliding distance, normal load, sliding speed. Based on the experimental results hardness patterns of worn surfaces were constructed. The wear resistance increases with increase of vol.% SiO_2 in AA1100 alloy matrix.*

Keywords: *Metal matrix composite, hardness patterns, AA7020 alloy, silicon oxide, wear, sliding distance, normal load, speed.*

1. INTRODUCTION

Particle reinforced materials are more attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technology used for monolithic materials. A large amount of work has been conducted in an effort to characterize the mechanical behavior of particle reinforced metal matrix composites [1-17]. Under an applied load, the load is transferred from the weaker matrix across the matrix-reinforcement interface, to the higher stiffness reinforcement. Composite strengthening takes place by the reinforcement carrying much of the applied load. The degree of wear is the result of several common factors viz., the rate of corrosion and load, sliding speed, coefficient of friction, hardness and tensile strength. Dry sliding contacts often contain wear particles and mechanically mixed deformed layers (third bodies) whose behavior needs to be understood. If poor bonding exists between matrix and particulate, the reinforced will get detached from the matrix. This detached particle can freely move on the contact zone resulting work hardening and increased material loss [18-22].

The aim of this paper was to develop hardness patterns for worn surfaces AA7020/silicon oxide metal matrix composites. To achieve the goals of the paper, the wear tests were conducted on pin-on-disc equipment. The design of experiments was based on Taguchi techniques [23, 24].

Table 1: Wear parameters and levels

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

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

2. MATERIALS AND METHODS

AA7020 alloy/SiO_2 composites were fabricated by the stir casting process. The T6 heat-treated samples were machined to get cylindrical specimens of 10 mm diameter and 30 mm length for the dry wear tests. The levels chosen for the controllable wear parameters are précised in Table 1. The orthogonal array, L9 was ideal to carry out wear experiments (Table 2). A pin-on-disc wear monitor (ASTM G99) was employed to assess the wear behavior of AA7020 alloy/SiO_2 composite specimens against hardened ground steel (En32) disc. Knoop microhardness was conducted before and after wear tests.

3. RESULTS

In the present work, the wear rate was as a function of the volume fraction of reinforcement V_f, applied load F, sliding speed N and sliding distance S. The Knoop microhardness was conducted to plot hardness contours of the composites after wear tests. The microhardness before wear test of AA7020 alloy/ SiO_2 composites was increased with increased in SiO_2 content as shown in figure 1.

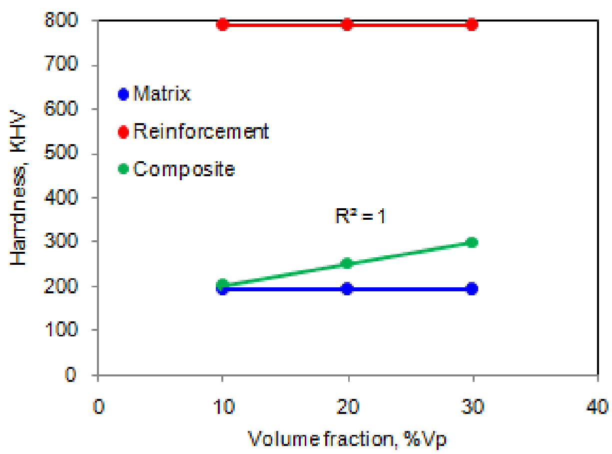

Figure 1: Effect of reinforcement on the hardness of composite before wear test.

Table 3: ANOVA summary of the effective stress

Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	P
A	61.69	61.11	54.88	9.50	1	9.50	8.36E+13	38.16
B	58.36	57.67	61.65	3.02	1	3.02	2.65E+13	12.11
C	59.40	59.47	58.81	0.09	1	0.09	7.71E+11	0.35
D	54.51	1210.42	177.68	12.29	1	12.29	1.08E+14	49.37
e				0.00	4	1.14E-13	1.00	0.00
T	233.96	1388.67	353.02	24.90	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.

All process parameters are acceptable as they satisfy Fisher's test at 90% confidence level. The analysis of variance (ANOVA) is presented in Table 3. The percent contribution identifies that the volume fraction of SiO_2 (A), gives 38.16%. The normal load (B) allocates 12.11% of variation in the wear rate. The sliding speed (C) allots 0.35% of variation in the wear rate. The sliding distance (D) affords 49.37% of the total variation in the wear rate. The R-squared values of %reinforcement, normal load, sliding speed and sliding distance are, respectively, 0961, 0.931, 0.657 and 0.999. The trend of mean values obtained by Taguchi techniques is same as that of R-squared values. The influence of sliding speed is nearly negligible on the wear rate of AA7020 alloy/SiO_2 composites. The wear rate was decreased with increase in volume fraction of SiO_2 in AA7020 alloy matrix as shown in figure 2a. As seen from figures 2b and 2d, an increase in wear rate is with increase of normal load applied and sliding distance.

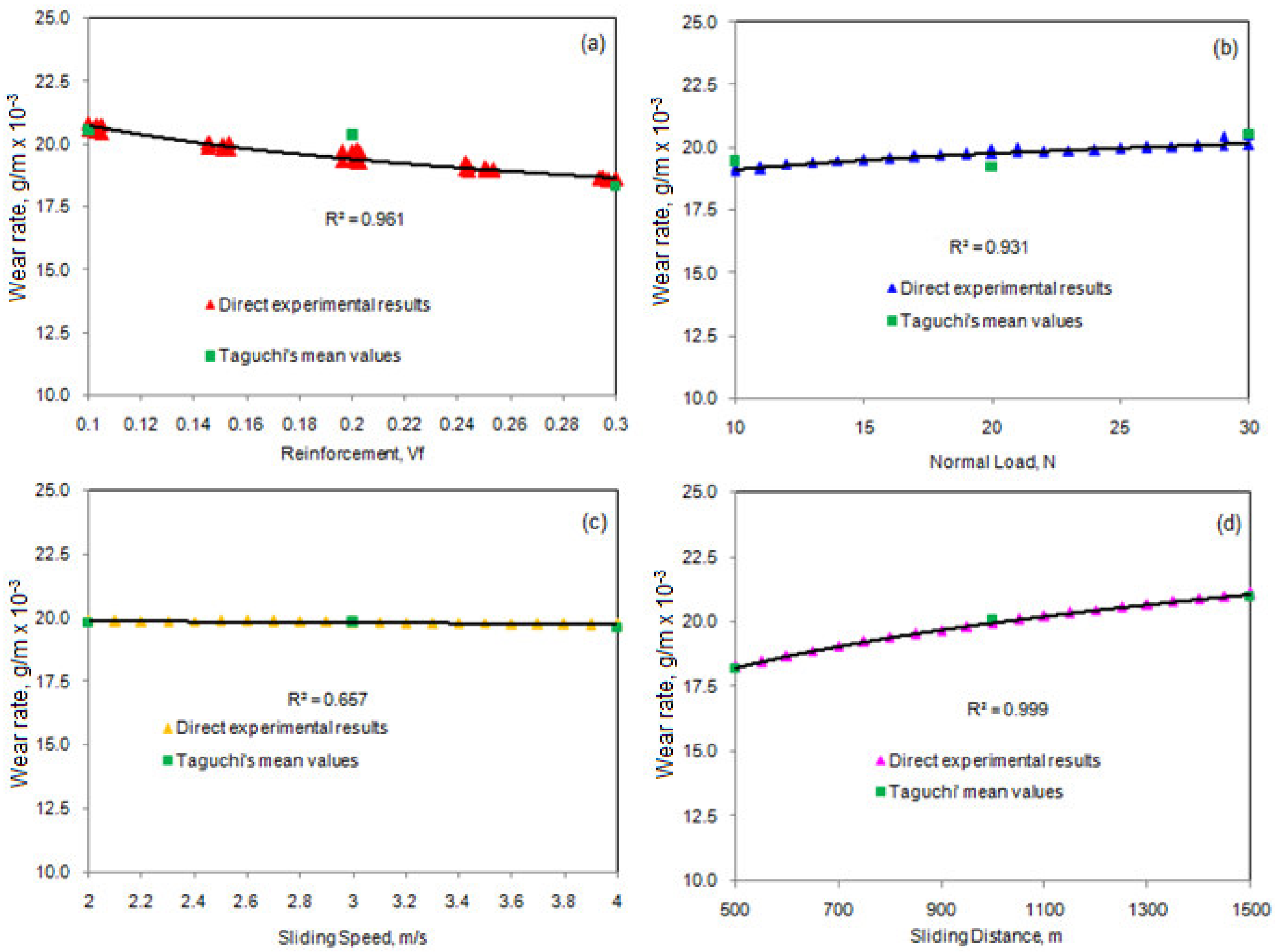

Figure 2: Wear rate as a function of (a) % reinforcement, (b) applied load, (c) sliding speed and (d) sliding distance.

4. DISCUSSION

For the composites produced by high volume fraction of SiO_2, the wear resistance was higher than those of low volume fractioned composites. This is owing to reduction of plastic deformation by SiO_2 nanoparticles on the wearing surface. The increase in the load promotes the stirring of AA7020 alloy surface at the pin/s surface and migrating it onto the steel disc. The stirring action increases the matrix deformation at the surface layers of pin samples. The deformed matrix material adheres to the steel disc surface, consequently raising the wear rate. For long sliding distances, the interface material between pin and disc will experience increased thermal energy due to prolonged dynamic friction. Subsequently, the shear stress at the interface exceeds the shear strength of the particle/matrix interface resulting particle debonding. Therefore, the debris consists of migrated matrix alloy and detached particles. The trapped SiO_2 nanoparticles promote ploughing effect.

The hardness contour of AA7020/10%SiO_2 composites indicates the formation of wear grooves and movement of matrix alloy onto the groove edges. In the groves the hardness values are high due to projection of SiO_2 nanoparticles as shown in figure 3. At groove edges the hardness values are low owing to the accumulated soft AA7020 matrix alloy. The hardness contour of AA7020/20%SiO_2 and AA7020/30%SiO_2 composites signify the matrix alloy removed patches and strain hardened regions due to applied load and long sliding distance (figure 3). Therefore, the hardness patterns replicate the worn surfaces of AA7020/SiO_2 composites.

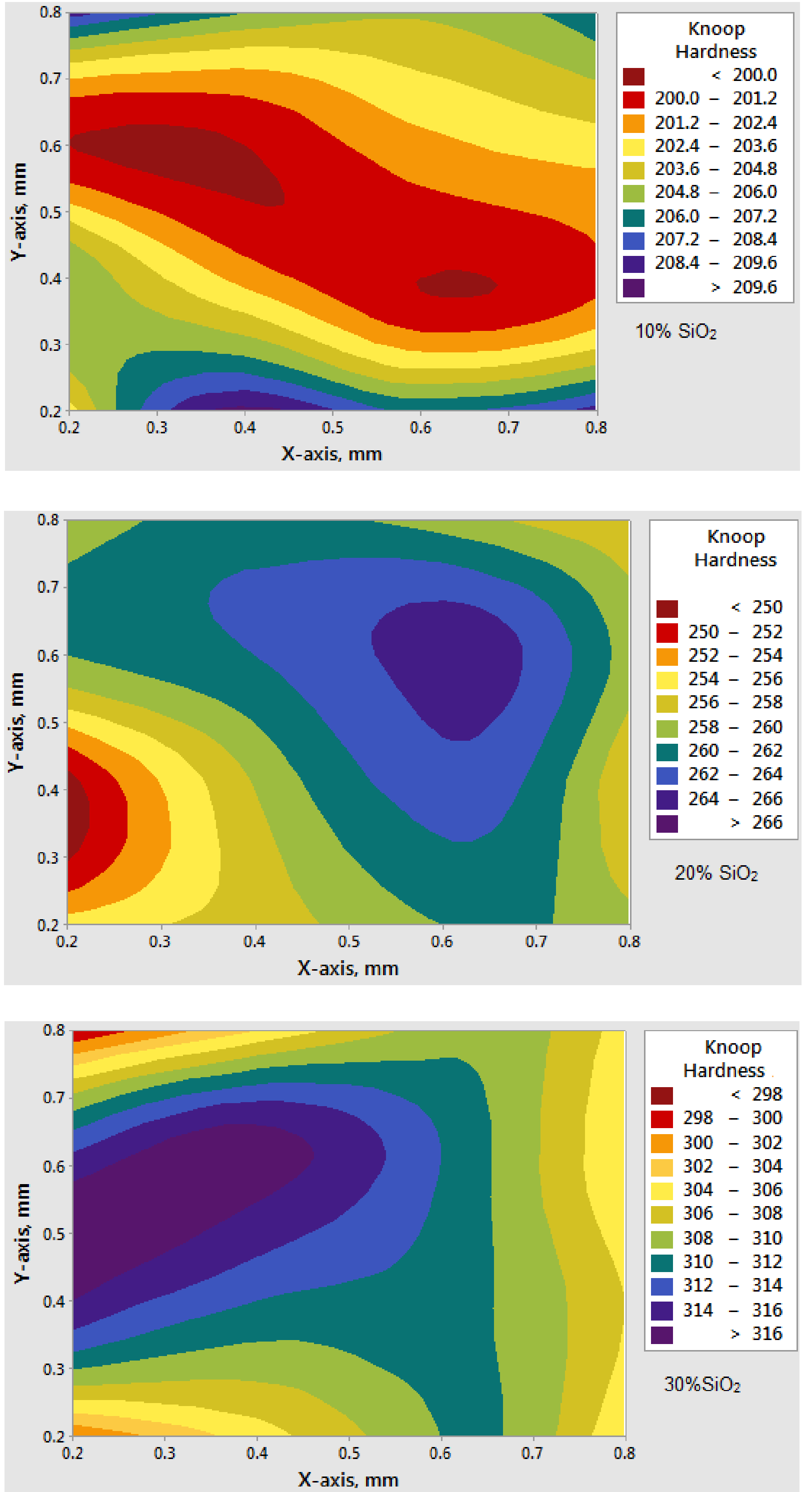

Figure 3: Hardness contours of AA7020/ SiO_2 composites after wear test.

4. CONCLUSIONS

The hardness patterns of AA7020/SiO_2 composites as the replicas of worn surfaces were successfully demonstrated. The wear resistance increases with increase of vol.% SiO_2 nanoparticles in AA7020 alloy matrix due to increased hardness of the composites.

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