Surface Profiles of Dry Worn Surfaces of AA2024 Alloy/TiC Metal Matrix Composites

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Abstract: *In the present work, the AA2024 alloy/TiC metal matrix composites were manufactured at 10% and 30% volume fractions of TiC. 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 surface roughness profiles of worn surfaces were constructed. The wear resistance increases with increase of vol.% TiC in AA2024 alloy matrix.*

Keywords: *Metal matrix composite, surface profiles, AA2024 alloy, titanium carbide, wear, sliding distance, normal load, speed.*

1. INTRODUCTION

Particulate-reinforced composites have become increasingly attractive in recent years for their high-strength and wear-resistant properties. When an external load applied to a composite is partly borne by the matrix and partly by the reinforcement. The reinforcement may be regarded as acting efficiently if it carries a relatively high proportion of the externally applied load. 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 [1-17]. Wear is one of a number of processes which occur when the surfaces of engineering components are loaded together and are subjected to sliding motion. In general, machine component parts can fail by breakage or by wear, the former being spectacular and sudden, the latter inconspicuous yet insidious. Particularly high wear can occur in mechanisms which operate in conditions of dry friction or in marginally lubricated conditions. Wear is a process of gradual removal of a material from surfaces of solids. The detached material becomes loose wear debris. This detached particle can freely move on the contact zone resulting work hardening and increased material loss [18-21].

The objective of this paper was to develop surface profiles for worn surfaces AA2024/titanium carbide metal matrix composites. To achieve the objective of the paper, the wear tests were conducted on pin-on-disc equipment. The design of experiments was based on Taguchi techniques [22, 23].

Table 1: Wear parameters and levels

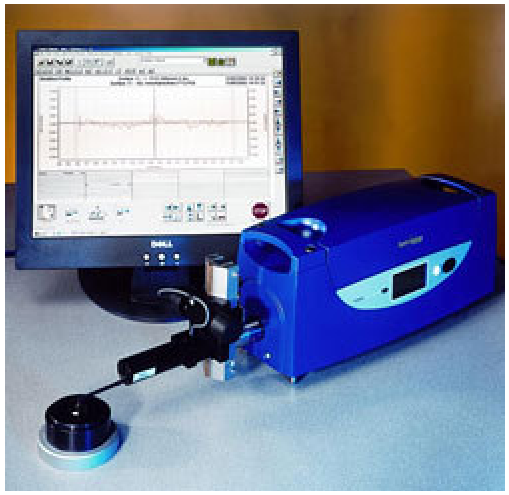
Factor	Symbol	Level–1	Level–2	Level–3
Reinforcement, Vol.%	A	10	20	30
Load, N	B	20	30	40
Speed, m/s	C	2	3	4
Sliding distance, m	D	500	1000	1500

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

AA2024 alloy/TiC 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 AA2024 alloy/TiC composite specimens against hardened ground steel (En32) disc. Knoop microhardness was conducted before and after wear tests. The surface roughness of worn samples was measured using Talysurf surface roughness tester as shown in figure 1.



3. RESULTS AND DISCUSSION

The Knoop microhardness was conducted before and after wear tests. The microhardness before wear test of AA2024 alloy/TiC composites was increased with increased in TiC content as shown in figure 2.

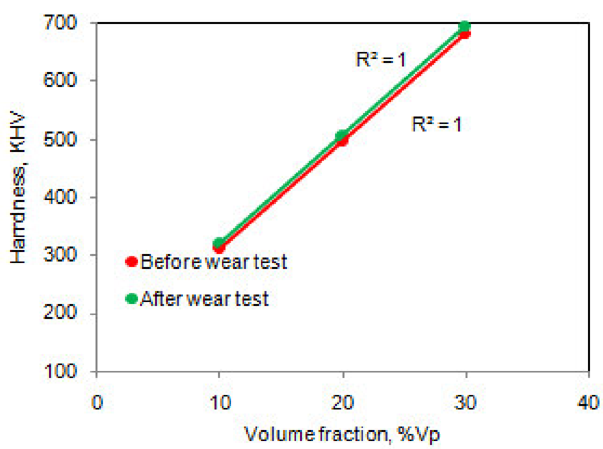


Figure 2: Effect of reinforcement on the hardness of composite before and after wear test.

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 volume fraction of TiC (A) provides 25.60%. The normal load (B) assigns 20.07% of variation in the wear rate. The sliding speed (C) allocates 2.95% of variation in the wear rate. The sliding distance (D) contributes 51.38% of the total variation in the wear rate. The R-squared values of %reinforcement, normal load, sliding speed and sliding distance are, respectively, 0870, 0.855, 0.052 and 0.944. 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 AA2024 alloy/TiC composites. The wear rate was decreased with increase in volume fraction of TiC in AA2024 alloy matrix as shown in figure 3a. This is owing to reduction of plastic deformation by TiC nanoparticles on the wearing surface. As seen from figures 3b and 3d, an increase in wear rate is with increase of normal load applied and sliding distance. Due to increased applied load, the deformed AA2024 alloy matrix disengages from the pin's surface. The deformed matrix material adheres to the steel disc surface, consequently raising the wear rate. For long sliding distances, the shear stress at the interface exceeds the shear strength of the particle/matrix interface resulting particle debonding. The wear debris consists of matrix alloy and detached particles.

Table 3: ANOVA summary of the effective stress

Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	P
A	0.10	0.09	0.08	9.27E-05	1	9.27E-05	2.14E+14	25.60
B	0.08	0.09	0.10	7.27E-05	1	7.27E-05	1.68E+14	20.07
C	0.09	0.09	0.09	1.07E-05	1	1.07E-05	2.46E+13	2.95
D	0.08	0.00	0.27	1.86E-04	1	1.86E-04	4.29E+14	51.38
e				-1.73E-18	4	-4.34E-19	1.00	0.00
T	0.35	0.27	0.54	3.62E-04	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.

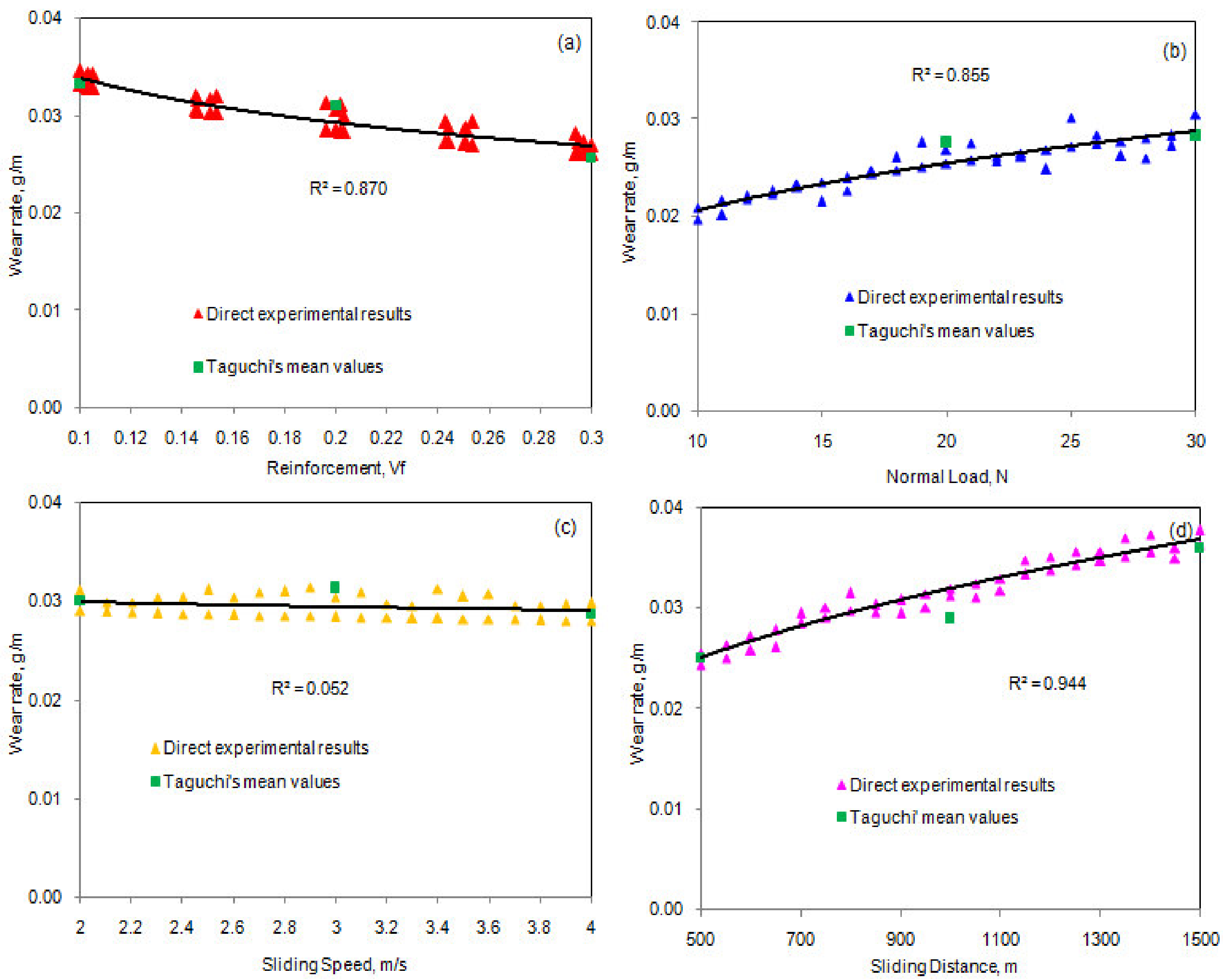


Figure 3: Wear rate as a function of (a) % reinforcement, (b) applied load, (c) sliding speed and (d) sliding distance.

The surface contour of AA2024/10%TiC composites is due to removal of the matrix alloy from the surface and movement of matrix alloy onto the groove edges. In the groves the surface roughness values are high due to projection of TiC nanoparticles as shown in figure 4. The surface roughness contours of AA2024/20%TiC and AA2024/30%TiC composites represents the improvement of wear resistance due to addition of TiC nanoparticles (figure 4). Therefore, surface roughness profiles are representatives of the worn surfaces of AA2024/TiC composites.

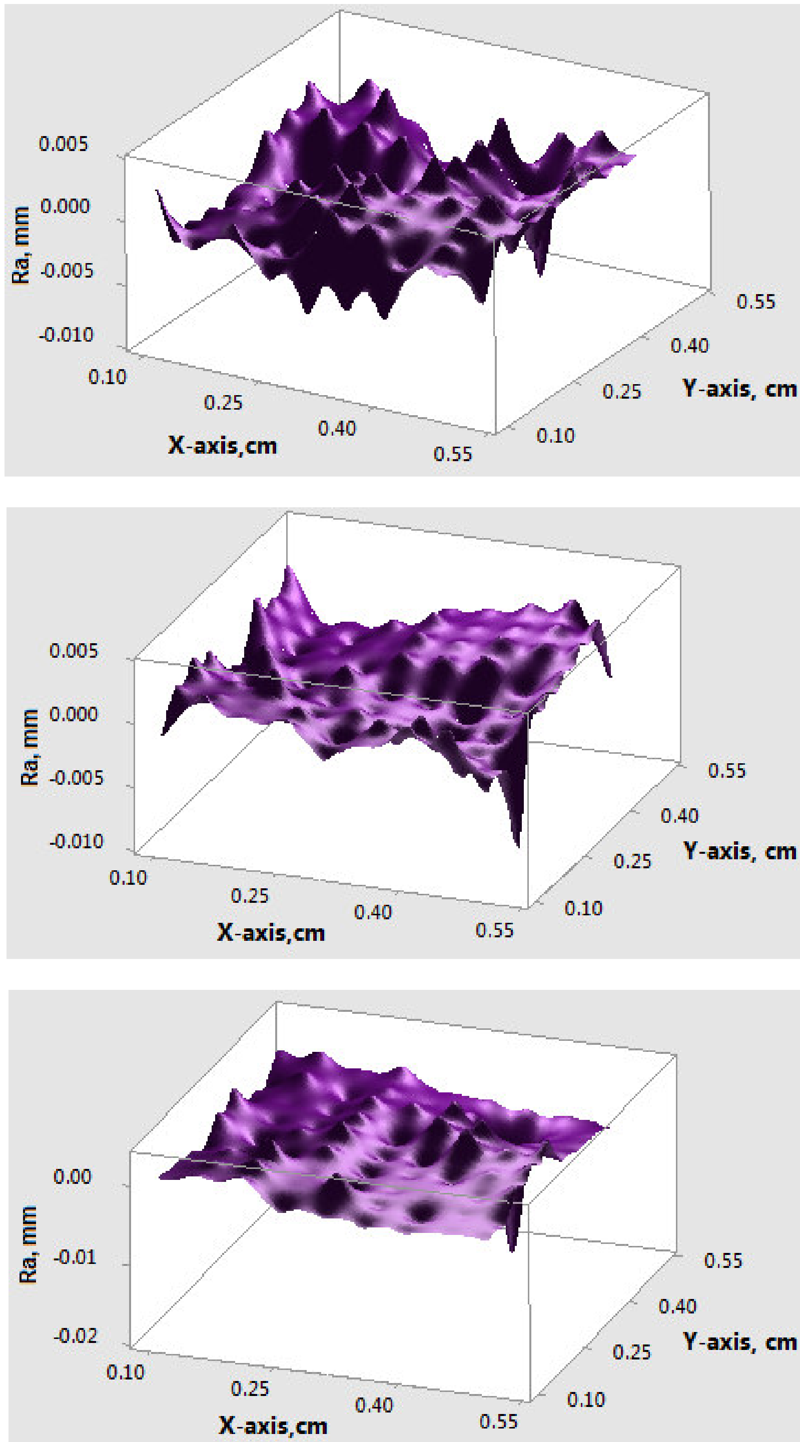


Figure 4: Hardness contours of AA2024/TiC composites after wear test.

4. CONCLUSIONS

The surface profiles of AA2024/TiC composites as the replicas of worn surfaces were successfully verified. The wear resistance increases with increase of vol.% TiC nanoparticles in AA2024 alloy matrix due to increased hardness of the composites.

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