Dry Sliding Wear Behavior of Al7075 Reinforced with Titanium Carbide (TiC) Particulate Composites

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Abstract. Aluminum Metal Matrix Composites have been prepared through stir casting route by employing Al7075 Alloy as the matrix material and Titanium carbide (2, 4, 6, 8 and 10 Wt%s) as reinforcement material with an average particulate size of 2µm. Dry sliding wear behavior of Al7075- Titanium carbide (TiC) composites was experimentally investigated by pin on disc apparatus. The wear rate in terms of weight loss per unit sliding distance as well as the specific wear rate have been obtained for the matrix material and composites. The results of composite were compared to that of matrix. The characteristics of worn surface were investigated using SEM. Weight loss of samples was measured and the variation of cumulative wear loss with sliding distance has been found to be linear for both the matrix and the composites. It was also observed that the low wear rate with composite compared to alloy. Further, it was found from the experimentation that the wear rate decreases with increasing weight fraction of TiC and average coefficient of friction decreases with increasing sliding velocity and weight fraction of TiC. The better wear properties (coefficient of friction, specific wear rate)have observed with 8 wt% TiC composite compared to other composites as well as matrix material.

Keywords: *Metal Matrix Composites,Al7075,TiC, Stir Casting, Wear*

1 Introduction

Particle reinforced MMCs have been the most popular over the last few decades. Metal matrix composites (MMCs) offer designers benefits, they are particularly suited for applications requiring good strength at high temperature, good structural rigidity, dimensional stability, and light weight [1].

The trend towards safe usage of the MMC parts in the automobile engine, which work particularly at high temperature and pressure environments has been increased. Now a day's researchers focusing mainly on Aluminum, because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. Aluminum matrix composites have been emerged as advanced materials for several potential applications in aerospace, automobile, defense and other engineering sectors[2-3] because of their high specific strength and stiffness, superior wear and seizure resistance as compared to the alloy irrespective of applied load and sliding speed.

A number of particulate phases have been employed in the Al-Alloy matrix. The introduction of the particulate phases in the Aluminum matrix provides a good wear resistance , antifriction properties with strength, ductility and stiffness. The choice of an optimum volume fraction of the particulate phase is essential to obtain an improved combination of properties. The addition of silicon carbide and Alumina to Aluminum alloys was reported to improve their wear resistance[2,3]. Various other types of reinforcements such as Aluminum nitride , granite , nickel Aluminide , garnet, glass , boron carbide , titanium dioxide , Aluminum diboride and cerium dioxide have also been reported as effective reinforcements for improving tribological properties of Aluminum based alloys[5]. It was reported that wear resistance increases with the increase of reinforcement content due to high hardness and strength of the reinforcement phase.

Several research works have been carried out to explore the wear behavior of composites. Wear is a material removal from one surface of the component to another during relative motion between them. Cerit et Al [6] have emphasized that wear behavior exhibited by composites are greatly influenced by the type, size, volume percentage of reinforcement and distribution of reinforcing particles in the metal matrix. Uyyuru and Surappa [7] clearly demonstrated the strong interaction between load and sliding velocity to cause wear of a material, both wear rate and friction coefficient vary with both applied normal load and sliding speed.

In-situ Al-TiC Aluminium metal matrix composite (AMMC) was synthesized and properties like hardness, tensile strength and wear characteristics were studied by S. Jerome et Al. [8].Tone [9] found that TiC phase in TiC/Al composites has a coherent or near coherent interface with α-Al and that the TiC particles may act effectively as active nucleation sites of α-Al during solidification. Rajnesh Tyagi and Roy have studied that Al metal matrix composites reinforced with TiC have lower wear rates than pure Aluminum [10-11]. The hardness shows increasing trend with increasing percentage of TiC particulates. This increase was observed from 181 VHN for Al7075 matrix to 202 VHN at 8 wt% TiC reinforced composite at T_6 condition[12].

In present work Al7075–TiC Composite was produced with 2 to 10 weight percentage as reinforcing phase and investigate the effects of sliding distance and velocity on the coefficient of friction and wear properties of Al7075-TiC composite material on Pin on Disc apparatus against a mild steel disc.

2 EXPERIMENTAL

2.1 Materials

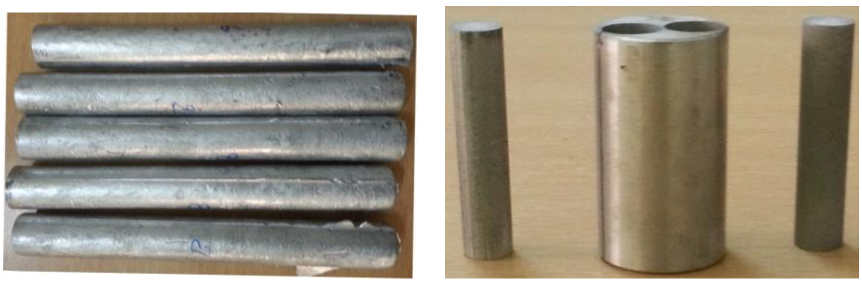
In the present investigation Al7075 as matrix material and TiC particulates of an average particle size of 2µm is used as a reinforcement material and the chemical composition of Al7075 Alloy is shown in table 1.

Table 1. Chemical composition of Al7075 Alloy (wt. %)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.0	0.2	1.5	0.0	2.4	0.2	5.8	0.0	Balance

2.2 Fabrication of Composites

Al7075 was fed into the electric furnace and was melted at 800^0C. The magnesium ribbons are added at high temperatures to increase the wettability of Aluminum so that the reinforcement added to the metal is evenly dispersed. An appropriate amount (2% of the wt. of base metal) of Titanium Carbide (TiC) powder was then added slowly to the molten metal. The TiC powder added to the molten metal was pre-heated up to 300^0C to remove the moisture (if any) in it. Simultaneously, the molten metal was stirred thoroughly at a constant speed of 300 rpm with a mechanical stirrer. After casting the composite specimens were obtained in the dimension of 150 mm X Ø15mm as shown in fig.1(a).The same procedure was followed to get the AMMC’s of different weight percentages - 4%, 6%, 8% and 10%.



(a) (b)

Figure 1 a) As Cast specimens b) Wear specimens

2.3 Heat Treatment(T_6)

The T_6 heat treatment is done by homogenizing the material at 450^0 C for two hours, and then ageing at 121^0 C for 24 hours. Standard wear specimens of 30mm length and 8mm diameter were retrieved through wire cut EDM process from the thoroughly homogenized ingots of Alloy and composites as shown in fig 1(b).

2.4 Testing

Dry sliding wear tests for the alloy and composites have been carried out using pin-on-disc machine (Model TR-20 LE supplied by M/s Ducom). Wear tests have been conducted using cylindrical samples that had flat surfaces in contact region and rounded at corner. The pin is held stationary against the counter face of a 100mm diameter rotating disc made of En-32 steel having a hardness of HRC60 as provided on pin-on-disc machine. The wear tests have been conducted under the fixed normal load of 19.62N and at three sliding velocities of 1.57m/s, 2.09m/s and 2.61m/s for a total sliding distances of 1, 2 and 3km. Pin weight before and after the test was measured to determine mass loss. The

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coefficient of friction(Frictional force/load) and specific wear rate(volumetric wear rate/sliding velocity x load) have been determined.

Microstructure and SEM analysis was carried out to study the worn out surfaces under different velocities and distances.

3. RESULTS AND DISCUSSION

3.1 Wear behavior

Fig. 3 shows the sliding wear behavior of Al7075 matrix and the composites with an applied load of 19.62N at a velocity of 1.57m/s for a sliding distance of 1Km. All the composites of Al7075 with TiC reinforcement exhibit better wear resistance compared to the matrix. Reinforced of TiC particles in matrix significantly reduces wear. This is evident from the amount of wear observed for Al7075 matrix and composite with 8 wt% TiC reinforced material. The reinforced of TiC material will change the wear mode from mild to severe.

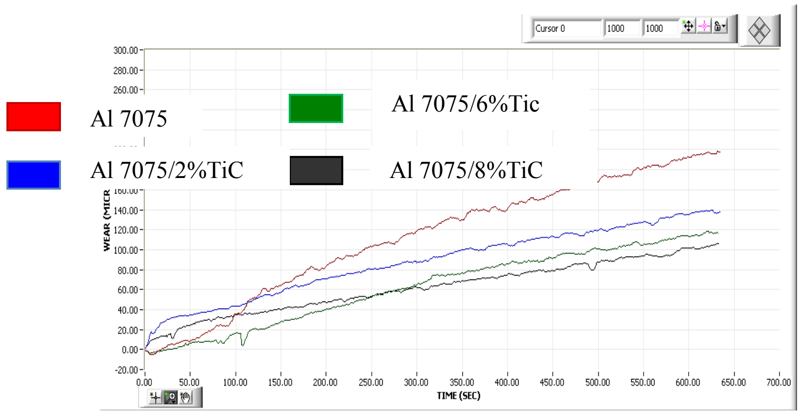
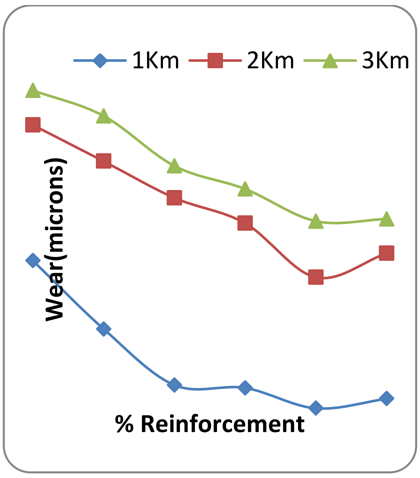


Fig.3. Comparative graph of Al7075 Alloy and composites showing the amount of wear as a function of sliding time for an applied load of 19.62N

The sliding wear response of Al7075 and composites on hardened die steel for different sliding distances (1Km,2Km and 3Km) and different velocities(1.57m/s,2.09m/s and 2.61 m/s) at a normal load of 19.62N is seen in fig. 4&5. From these figures, it is evident that the resistance to wear has increased with increase in TiC content. That is the addition of TiC content to Al7075 significantly reduces wear. From fig.5 it is noted that matrix exhibits higher wear, and the composite with 8 wt% of TiC reinforcement showed lower wear.



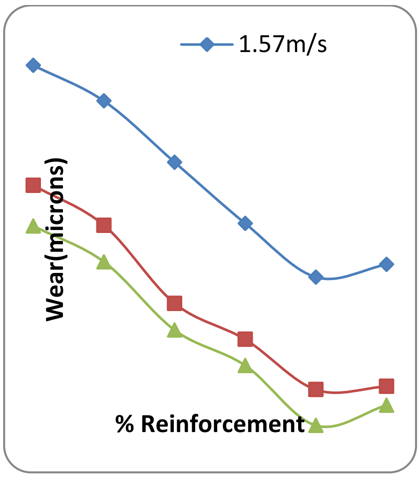
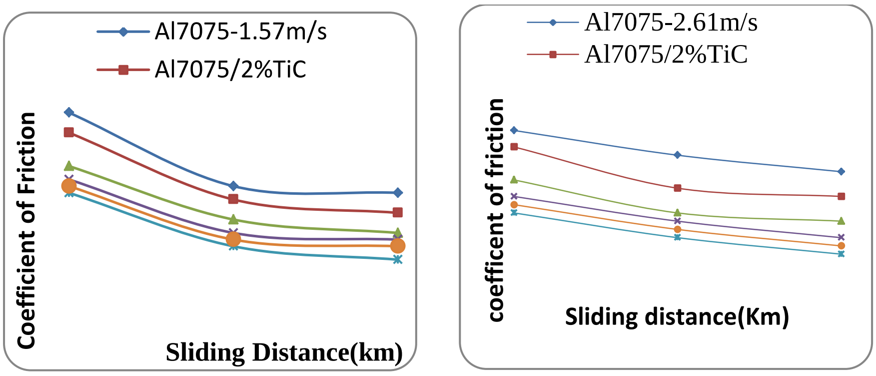


Fig.4. Effect of % of reinforcement on wear as a function of sliding

velocity of 2.09m/s for an applied of 19.62N

Fig.5 Effect of % of reinforcement on wear as a function of sliding distance 3Km for an applied of 19.62 N

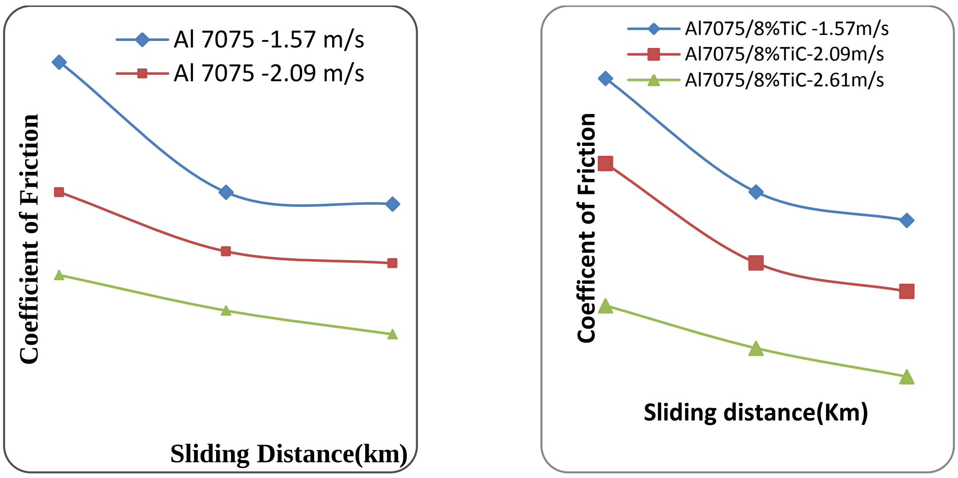
3.2 Effect of coefficient of friction



(a) (b)

Fig.6.variation of coefficient of friction with sliding distance at a velocity of (a)1.57m/s (b) 2.61m/s

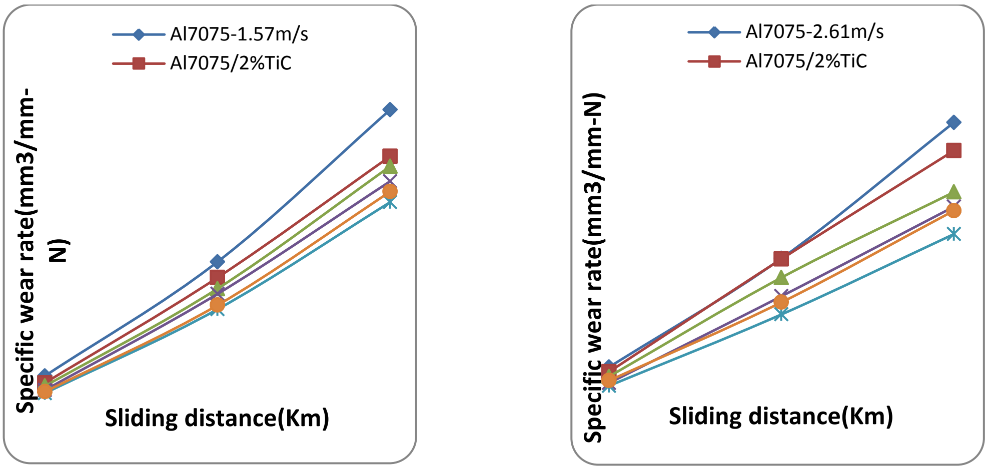
Fig.6(a&b) shows the average coefficient of friction of as Al7075 matrix and composite with sliding distances at different velocities at a fixed load of 19.62N. It is observed that composite represents a lower coefficient of friction then that of as Al7075 matrix. Thus coefficient of friction decreases significantly with the incorporation TiC in matrix and it is also noted that coefficient of friction decreases as the sliding distance progresses. This trend is similar in all the materials investigated. The coefficient of friction decreases with increasing sliding distance and decreased with increasing velocity was seen from figure 7 for Al7075 matrix and Al7075/8%TiC composite at different velocities as function of sliding distance.



(a) (b)

Fig.7.variation of coefficient of friction with sliding distance at different velocities of (a)Al7075 matrix and (b)Al7075/8% TiC composite

3.3 Effect of specific wear rate

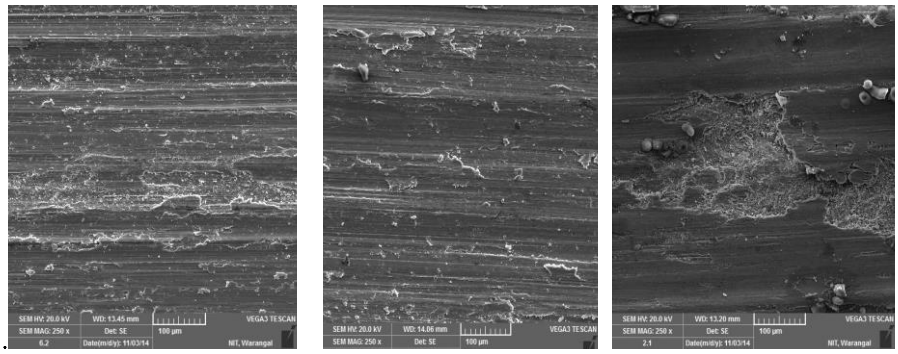


(a) (b)

Fig.8.variation of specific wear rate with sliding distance at a velocity of (a)1.57m/s (b) 2.61m/s

Fig.8(a&b)shows the variation of specific wear rate of Al7075 matrix and composite with different sliding distance at fixed velocity 1.57m/s and 2.61m/s respectively. It is noted that specific wear rate increases with increasing sliding distance. However specific wear rate of composite is less than Al7075 matrix and 8 wt% TiC reinforced composite got lower specific wear rate.

3.4 wear surface of matrix and composite



(a) (b) (c)

Fig.9.SEM micrographs of worn surfaces at sliding velocity 2.61m/s, sliding distance 3km and normal load 19.62N of (a)Al7075 (b)Al7075+2% TiC (c)Al7075+8%TiC

Scanning Electron Microscopic examinations of the worn pin surfaces were carried out to determine wear mechanism. Figure 9(a-c) shows the wear track photographs of the matrix and composites respectively. Matrix shows a rough and worn surface with coarser and deeper grooves. It is been observed that initially the wear happens to be adhesive wear in figure 9a. That is in matrix, where as small craters and grooves are visible throughout the SEM figure. From fig 9b,it is observed that with the addition of 2 wt% of TiC reinforcement the craters are reduced and some smooth wear tracks are noticed. which clearly indicates due to the reinforcement the hardness of the composite enhanced. When percentage of reinforcement increasing this adhesive wear turns out to be abrasive wear with more fine wear tracks visible at 8 wt% reinforcement in Fig 9c.This is clearly observed that with improving percentage of reinforcement the hardness of the specimen had greatly improved resulting in improving the wear resistance of the reinforced component. But further increases in reinforcement to10 wt% leads to the decrease in the wear resistance.

4 Conclusion

The experimental study reveals following conclusions:

1.with increase in the percentage of reinforcement the wear resistance has been decreased.

2.Wear appears to be decreases under the constant velocities at different sliding distances with % of reinforcement.

3.For a given velocities, the cumulative wear of composites and Al7075 matrix pins decreases with % of reinforcement at constant sliding distance under dry sliding.

4.The average coefficient of friction decreases with increasing velocities in Al7075 matrix and composites. However, the composites show a lower coefficient of friction than that observed in matrix.

5.Specific wear rate increases with increase in sliding distance for different velocities.

6.It has been further concluded that from above experimental conditions 8 wt% TiC reinforced composite shown better results in view of wear properties.

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