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Dry sliding wear of in-situ synthesized Al-TiC composites

Abhishek Kumar, Rakesh K. Gautam, Rajnesh Tyagi*

Department of Mechanical Engineering, Indian Institute of Technology (BHU) Varanasi 221005 (UP) India.

*Corresponding e-mail: rtyagi.mec@iitbhu.ac.in

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ABSTRACT – Al-TiC composites containing three different amounts of TiC have been synthesized through in-melt reaction of titanium and SiC in the aluminum melt through stir casting. The TiC forms from reaction between Ti and carbon which is released by SiC at temperatures greater than 1100^0C. However, some amount of Al_3Ti is also formed. The friction and wear behavior has been examined at different loads of 9.8 N, 19.6 N, 29.4 N, 39.2 N and at a constant sliding speed of the 1 m/s using a pin-on-disc machine. The results indicate friction and wear performance gets improved with increasing amount of TiC.

1. INTRODUCTION

Aluminum based composites reinforced with SiC, TiC, TiB_2, B_4C, Al_2O_3 etc. find applications in aerospace and automotive industry due to their light weight, low cost and sufficient mechanical strength [1,2]. Traditionally, MMCs have been produced by addition of the particulate reinforcement to the molten metal, but, bonding between the matrix and the reinforcement is a major concern in this type of composites. Hence, *in-situ* processing techniques involving a chemical reaction resulting in the formation thermodynamically stable reinforcing ceramic phase within the matrix have been developed [3]. The use of hard ceramic particles as reinforcement in the metallic matrix has also been shown to reduce the wear loss [4].

Titanium carbide (TiC) has been used as reinforcement in matrix of aluminium alloys due to its high hardness, high melting point (3067^0C) and good thermal conductivity. However, the tribological behaviour of TiC in pure aluminum based composites has not been systematically investigated so far. Hence, in the present study Al-TiC in-situ cast composites containing different amounts of TiC have been synthesized and their friction and wear behavior investigated under dry sliding.

2. METHODOLOGY

High purity (99%) aluminum (Al), Silicon carbide (SiC) powder (≈ 25μm) and 98% , Ti powder (20-40) mesh size were used for composite preparation. A pre-calculated amount (480 g) of pure Al was weighed out of which 150 g Al was melted in a furnace in a graphite crucible and the remaining Al was melted in another furnace. To prepare a composite having approximately 6 wt.% TiC, calculated and preheated (up to 6000C) amounts of Ti (20 g) and SiC (17 g) were added to the 150 g Al melt at 1125 0C. Suitable time was given for the in-situ reaction to take place between SiC and Ti particles. This 150 g melt was then poured in another crucible having 330 g pure Al. The mixture was stirred for about 20 minutes at 300 rpm before pouring in a rectangular mold. Similar procedure was adopted for preparing other composites to obtain about 9 and 12 wt.% TiC in the composite. The composites have accordingly been designated as C6, C9 and C12.The composites were subjected to XRD analysis to reveal the formation to TiC. Standard procedures were adopted for microstructural and mechanical properties evaluation. Density of the composites was measured following Archimedes principle.

Cylindrical pin shaped samples (30 mm×ϕ8) with rounded corner were tested under dry sliding against a counterface of En-32 steel having a hardness of 65HRC using a pin-on-disk tribometer at different loads of 9.8, 19.6, 29.4 and 39.2 N and at fixed sliding speed of 1m/s. The mass loss of the pin specimens was measured with an analytical balance having an accuracy of 10−7 kg, at intervals of 10 min (600 m) and total sliding distance covered in a test was 3000 m. Sliding surfaces were examined under scanning electron microscopy (LEO Cambridge, England) to explore the possible wear mechanism.

3. RESULTS AND DISSCUSION

Fig. 1 represents the typical microstructure of the Al- 12% TiC composite showing the presence of TiC particles distributed uniformly in the matrix along with some larger flakes of Al3Ti. Similar microstructure has also been observed earlier by Birol et al [5]. The other composites have also shown the similar features. X- ray diffraction analysis of the composite confirmed the formation of TiC along with some Al3Ti.

Table 1 gives the mechanical properties of all the materials investigated in the present study. It could be seen that both the hardness and the strength of the composites increases with increasing volume fraction of TiC but at the expense of ductility, which is expected as TiC is a harder and stronger phase.

Table 1 Mechanical properties of Aluminum and composites.

Material	UTS (MPa)	% elongation	Hardness (HB)	Density (kg/m^3)
Pure Al	50	33	15	2705
C6	59	26	21	2810
C9	69	15	24	2990
C12	88	10	30	3130

Figure 2 shows the variation of wear rate, estimated from the slope of the variation of cumulative volume loss with TiC content at different loads. It could be seen from Figure 2 that the wear rate of pure Al is the highest at all the loads whereas it is the lowest for Al-0.12TiC. At a particular load wear rate decreases with increasing amount of TiC and this may be attributed to the higher hardness of the composite containing relatively higher amount of TiC [6].

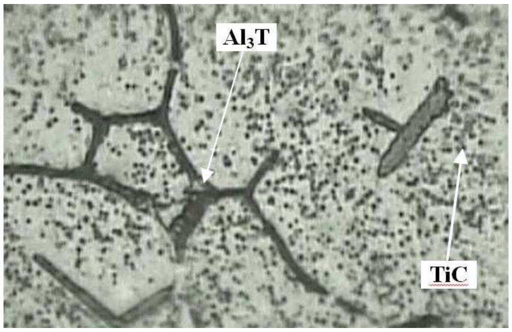

Figure 1 Optical micrographs of composites, 100 X.

The variation of friction coefficient, averaged over the total distance of sliding, with TiC content is illustrated in Fig.3. The average coefficient of friction is observed to decrease with both increasing load and TiC content at a particular load. It is interesting to note that the friction coefficient of pure Al drops at the highest load when it is almost equal to Al-0.06TiC, which may be attributed to the softening of the pure Al due to the frictional heat developed at the highest load. Amongst the composites, Al-0.12TiC has shown consistently a lower average coefficient of friction at all the loads as seen from Fig.3. The worn surfaces of all the materials showed presence of wear marks in the form of grooves along the sliding direction and the transfer layer. The transfer layer on the surface of pure Al appeared to be cracking whereas the surface of composites was covered by continuous transfer layer of loose wear debris However, the degree and extent of compaction was found to be more for composite containing relatively higher amount of TiC at relatively higher loads as depicted in Fig. 4 which shows a well compacted transfer layer on the surface of Al-0.12 TiC at the highest load used in the study. This layer inhibits metal-metal contact and helps in reducing both the wear rate and the friction coefficient [6].

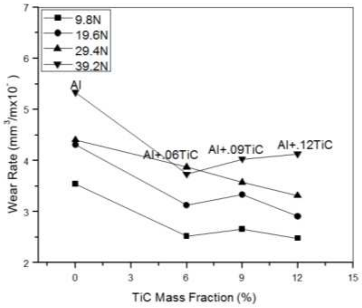

Figure 2 Variation in wear rate with TiC content.

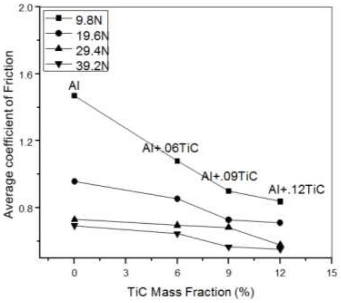

Figure 3 Variation in average coefficient of friction with TiC content.

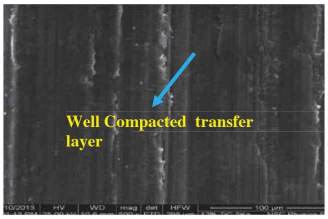

Figure 4 SEM Micrograph of worn surface of Al-0.12TiC at 39.2 N.

4. CONCLUSION

The present investigation on in situ synthesis and tribological behavior of Al-TiC composites confirms that TiC particles can be generated in-situ in Al-Ti-SiC system via melt reaction and technique results in almost uniform distribution of TiC particles in the aluminium matrix. However, something needs to be done to suppress the formation of intermetallic compound Al3Ti. The tribological performance of the composites got improved with increasing amount of TiC content within the range of amount used in the investigation.

5. REFERENCES

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