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A Study of Microstructure and Wear Behaviour of Titanium Carbide Reinforced Aluminium Metal Matrix Composites

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ABSTRACT

Aluminium (Al) reinforced with Titanium Carbide (TiC) Metal Matrix composites find its application for elevated temperature operating conditions. The Metal matrix composites (MMCs) were prepared by using powder metallurgy technique, where the TiC is reinforced with Al matrix by 5, 10 and 15 weight percentage. The objective this paper is to study of microstructure and wear characteristics of TiN reinforced Al MMCs. The effect of sliding velocity on the wear behavior and tribo-chemistry of the wear surface of both matrix and composites has been studied. The pin-on-disc machine was employed to determine the rate of wear.The wear study was conducted by varying the load and speed. It is found that the rate of wear was increased with an increase in load and sliding speed for both Al and MMCs. However the rate of wear is less in MMCs than the Al. The Scanning Electron Microscopy equipped with EDS analysis were used to stud microstructure of composites.

Keywords: *Aluminium -TiC composites, compacting pressure, microstructure, wear.*

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1. INTRODUCTION

Composites have established their suitability in the field of automotive and aerospace industries and researchonmetal matrix composites (MMCs) has been showing tremendous promise in the recent past [1]. Aluminium alloys find its vast application due to their excellent properties such as high thermal conductivity and low density [2-4].However, it has high wear rate. To overcome this drawback, the aluminium has to be reinforcement with other materials so that it's young's modulus and hardness increases where as wear rate decreases.

The manufacturing methods like liquid metallurgy and powder metallurgy can be used to manufacture the particulate reinforced aluminium MMCs [5]. Aluminium MMCs processed though powder metallurgy technique are characterized by uniform properties in all directions and green density more than 90 % of theoretical density with the application of lower compacting pressure between 200 to 250 M. Pa [6].

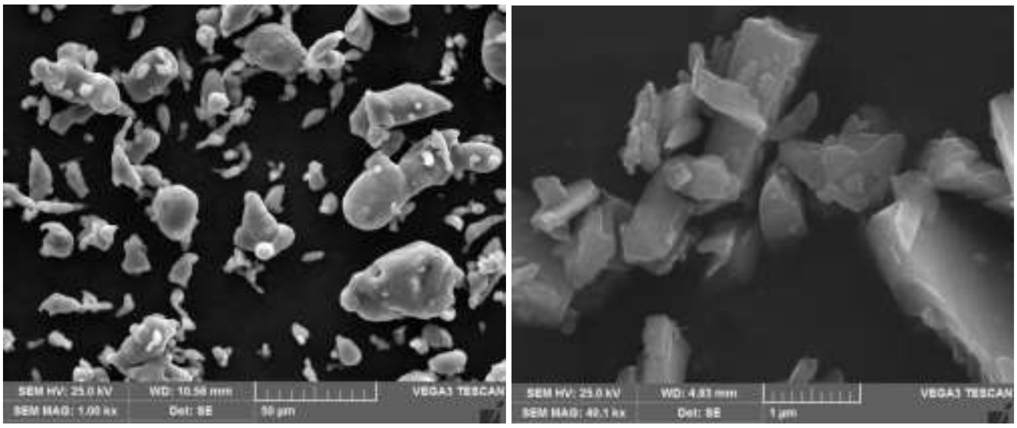
The metal oxides, carbides, nitrides and borides were used as reinforcement materials with most of the matrix materials of MMCs. The parameters like weight fraction, shape and size reinforcement particles, method of manufacturing influence the physical properties, microstructure and tribological properties of the MMCs [7].

Aluminium alloys exhibit high strength at room temperature. Use of aluminium alloys at high temperature is limited due to its reduction in strength and other mechanical properties. These problems can be overcome by reinforcing TiC in to aluminium matrix. Titanium Carbide (TiC) another reinforcement material is more attractive due to its high hardness, Elastic modulus, low density and low chemical reactivity. Aluminium alloys exhibit high specific strength and specific modulus but are limited to low temperature applications. This phenomenon could be improved by introducing the TiC reinforcement particles in to aluminium matrix [8, 9].

Both solid and liquid state processing techniques such as Powder Metallurgy (PM) and stir casting respectively are suitable to develop Particulate reinforced MMCs. It has been widely reported that to have better mechanical properties, MMCs must have homogeneous distribution of reinforcement particles in the matrix material. Further metal should not react with reinforcement during processing of MMC's [10,11]. The above said drawbacks can be avoided by using PM Processing technique. Hence the PM products normally have superior properties over that of their cast counterparts. It was also reported that aluminium matrix composites processed via powder metallurgy technique exhibit good isotropic properties and green density greater than 90 % of theoretical density by using low compacting pressures between 200 to 250 MPa [12, 13].The objective of this work is to develop aluminium MMCs containing 5, 10 and 15 weight percentage of TiC particles using powder metallurgy technique. An attempt has also been made to analyze the microstructure and study the wear behaviour of TiC reinforced aluminium MMCs.

2. MATERIAL AND EXPERIMENTAL PROCEDURES

2.1Materials. Titanium Carbide (TiC) and Aluminium (Al) powder (99.5 % pure) as supplied by Sigma Aldrich, Germany and Metal Powder Company Limited, India is used as reinforcement and matrix materials respectively. Figure 1.1 (a) and (b) shows the SEM images of Al and TiC powders. The properties and composition of Al is shown in Table 1.1 and the properties TiC powder are shown in Table 1.2.



(a) (b)

Figure 1.1SEM images of (a) Al powder and (b) TiC powder.

Table 1.1 Properties and composition of Al powder

Particle Size	Atomic weight	Arsenic	Lead	Iron
74 µm	26.98	0.0005%	0.03 %	0.5%

Table 1. 2 Properties of TiC powder

Particle Size	Molecular weight	Melting point	Density
< 4µm	59.87 g/mol	3140^0C	4.92 g/cc

2.2 Development ofMMCs

Initially, the reinforcement powder TiC in different weight fraction 5, 10 and 15 were mixed with aluminium powder is mixed for a duration of 30 minutes to get uniform mixture. To avoid agglomeration and cold welding of powder particles during mixing process a control agent was added. Each of the blended powders was compacted at a pressure of 300 MPa.

The cylindrical compacts developed were of 20 mm diameter and 15 mm in length and these compacts were sintered in nitrogen atmosphere at 450^0C for 4 hours using tube furnace. The diameter and length of cylindrical compacts were reduced to 6 mm and 12 mm. The suitable abrasive paper is used to ground the flat surface of cylindrical pins and subjected to polishing process. A pin-on-disc machine has been used to study the dry sliding wear behavior. The foreign particles deposited on the surfaces of cylindrical pin and disc was removed by using ethanol. During the test the cylindrical pin is pressed against the rotating AISI 4140 steel disc by putting the normal load. The wear test was conducted at room temperature using pin-on-disc as per ASTM G99 standards. The tests were conducted for a constant speed of 240 rpm at different load ranging from 5 to 15 N. The amount of wear was recorded at a regular interval of time at 2 min, 6 min and 10 min. The Scanning Electron Microscopy equipped with EDS analysis were used to study microstructure of composites.

3. RESULTS AND DISCUSSIONS

3.1Sintered Samples:

The scanning electron microscopy is used to get the micrograph of Al-TiC composites and respective micrographs are represented in the Fig.1.2. The analysis has made the parameters like porosity, pore size and distribution of reinforcement particles within the matrix using SEM equipped with EDAX facility.

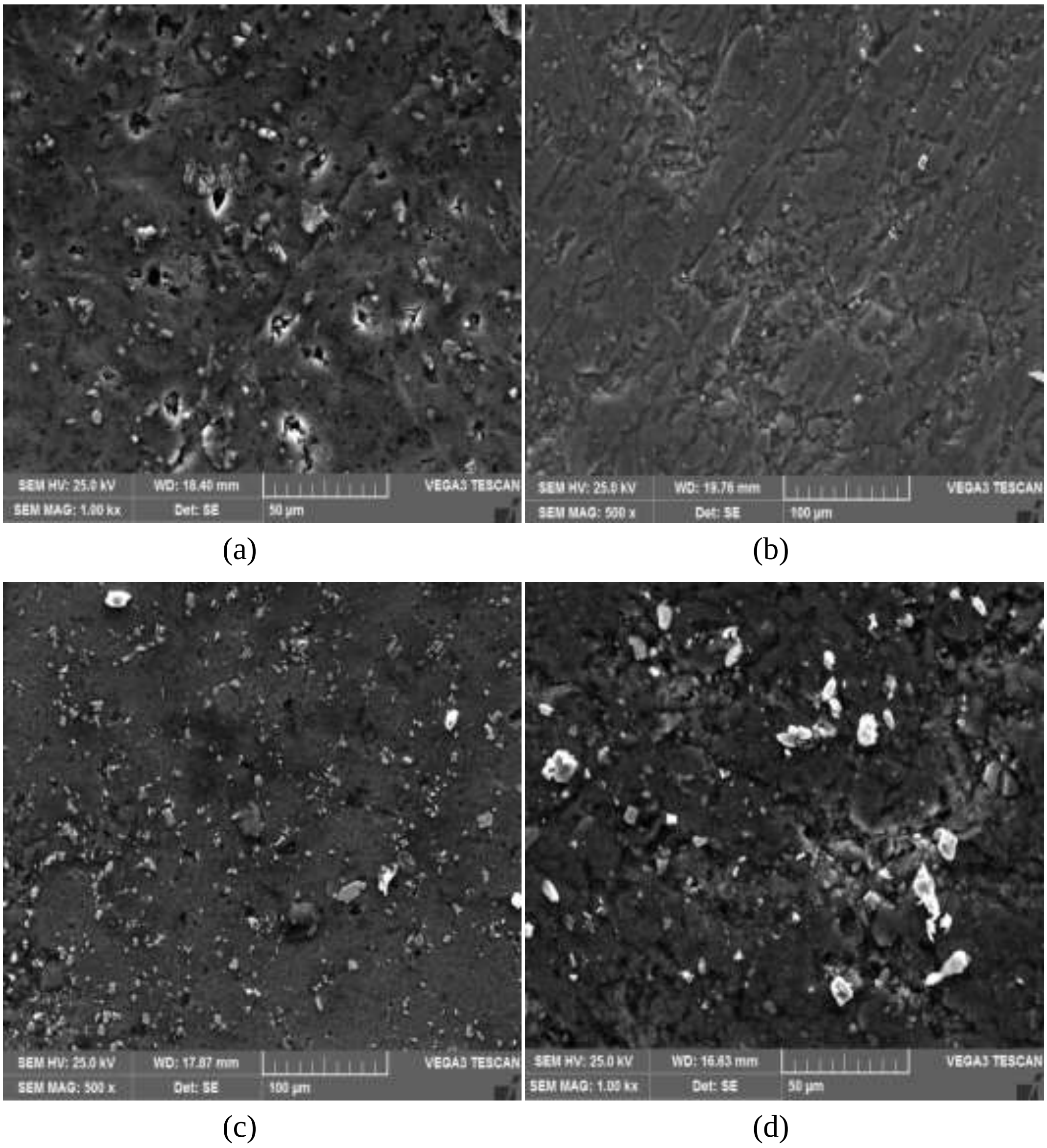


Figure 1. 2 SEM images of (a) pure Al and composites (b) Al-5TiC, (c) Al-10TiC and (d) Al-15TiC

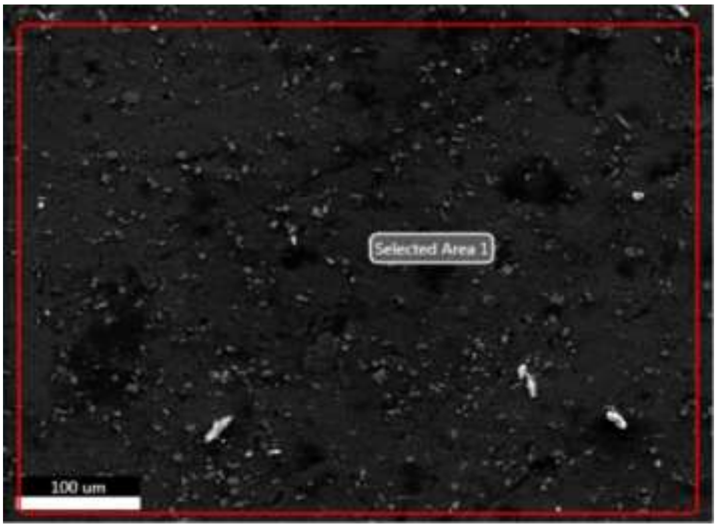


Figure 1.3 SEM image and EDAX analysis of Al- 5Wt % TiC

Table 1.3 EDAX report of composite

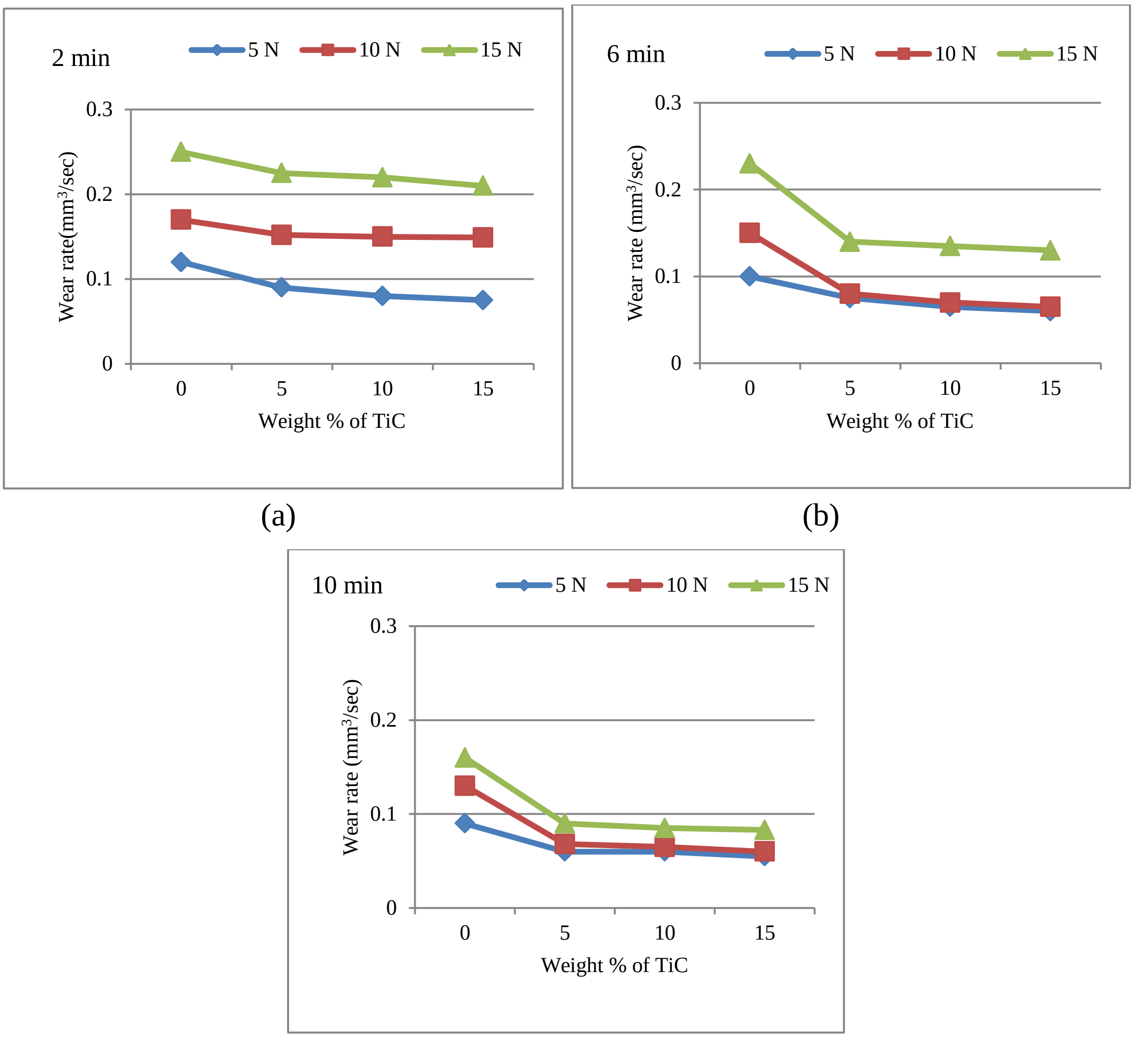
Composition in Weight percentage	C	O	Al	Ti
	21.56	6.71	65.69	6.44

The SEM images of composites revels that distribution of TiC particulates within the aluminium matrix is quite uniform. Figure 1. 2(b) with respect to composite with 5%TiC depicts the presence of TiC particles seen with brighter portion and uniformly in the Al matrix. As the amount of TiC increases from 5 to 15 wt%, it is observed that there is a further improvement in distribution of TiC particles within the matrix. However, the micrograph of the composites reveals the presence of porosity which could be due to improper compaction and particles pull out during grinding and polishing. Because of this porosity the density of sintered specimens being 86 to 94% of theoretical density. At grain boundaries, medium size pores and small interconnected micro pores were observed.

EDS analysis of the specimens is shown in Figure 1.3 and Table 1.3 depicts the structure contains basically Al, Ti and C. However, it can be seen that O is present due to high affinity of Al in the ambient temperature. The EDAX revels that formation of grain boundary was quite uniform for all the composition.

3.2Effect of weight percentage of reinforcement, load & sliding time period on wear rate

Fig.4 shows the variation of wear rates of both matrix and MMCs for different weight percentage of TiC and sliding time period as a function of load. The comparative wear study of both Al and Al-TiC MMCs are made and individual effects of weight percentage of reinforcement on their wear rate are discussed. In this work wear rate is determined after a sliding time period of 2, 6 and 10 min for all samples at three different loads with constant sliding speed of 240 rpm. It is found that there is reduction in wear rate with increase in weight percentage of TiC at all loads. This may due to the reason that an improved hardness of the composite, resulting from the incorporation of hard TiC particles, which acts as a harder phase into the matrix. The reason for better hardness may that the applied load was bared between reinforcement particles and matrix material. Hence increase in hardness results with higher wear resistance of the material. When hard TiC particles are strongly bonded with aluminium matrix, they protect surface against destructive action by the disk (counter face). This helps in transfer load from the matrix phase to reinforcement phase. Also it is clear that the specimens under the load of 15 N results with higher wear rate in comparison with the samples under a load of 5 and 10 N. The Al MMCs with 15 weight percentage of TiC results were higher wear resistant than the samples containing 10, 5 and 0 weight percentage of TiC owing to better metallurgical bonding of TiC particles with Al matrix. The wear résistance of all samples at any applied load increased with increase in sliding period. It is observed that rate of wear decreases from 0.25 mm^3/sec to 0.16 mm^3/sec when amount of wear determined at a sliding period of 2 min and 10 min respectively.

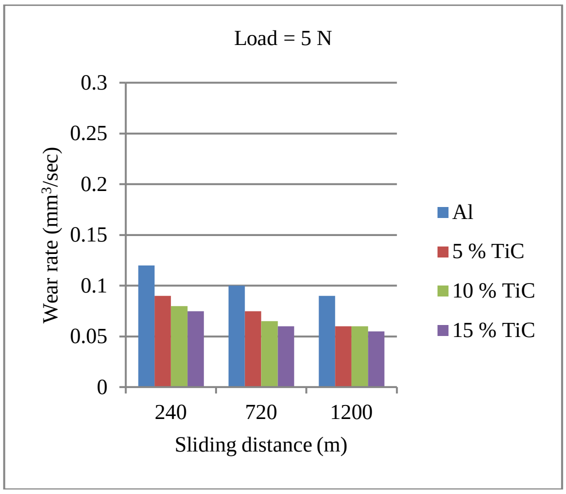


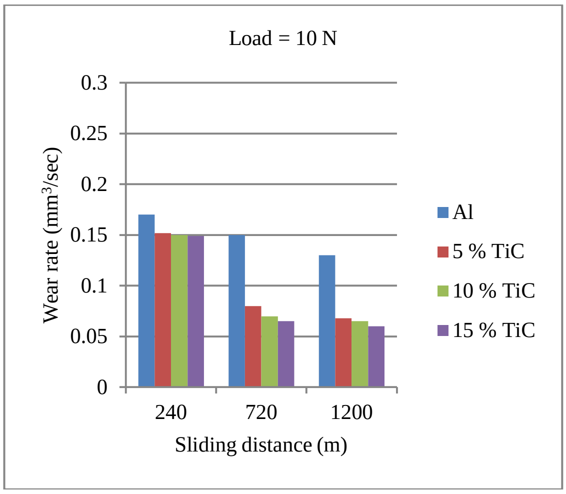
(a) (b) (c)

Figure 1.4 Variation of Wear rate with increasing weight percentage of TiC of Al-TiC MMCs at different load and sliding time period for a constant sliding speed of 240 rpm

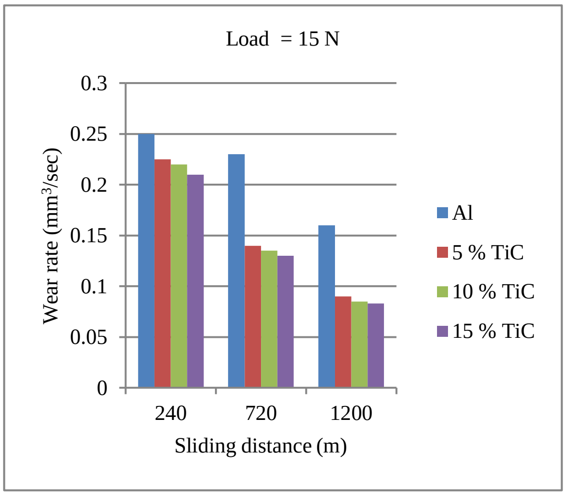
3.3Effect of sliding distance and load on wear rate

Figure 1.5 shows the variation of wear rates of both Al and Al-TiC MMCs as a function of sliding distance at different loads i.e. 5, 10 and 15 N. It is observed that, as the siding distance increases the wear rate was found higher for all samples with progressive deterioration of the surface by erosion. However, the amount of erosion is quite more in Al sample than Al-TiC MMCs. The Al-TiC sample containing 15weight percentage of TiC has minimum erosion rate. This due to the presence of TiC particles along the grain boundary. Beyond the sidling distance of 720 m, there is a reduction in the wear rate with increasing sliding distance due accumulation of debris, which reduce the wear rate due to delamination and decohesion of the particles. At 1200 m sliding distance wear rate reaches a steady value for the entire samples for each load. As the specimen surface eroded more and more, the matrix material will work hardened and provides necessary resistance against the abrasion.





(a) **(b)**

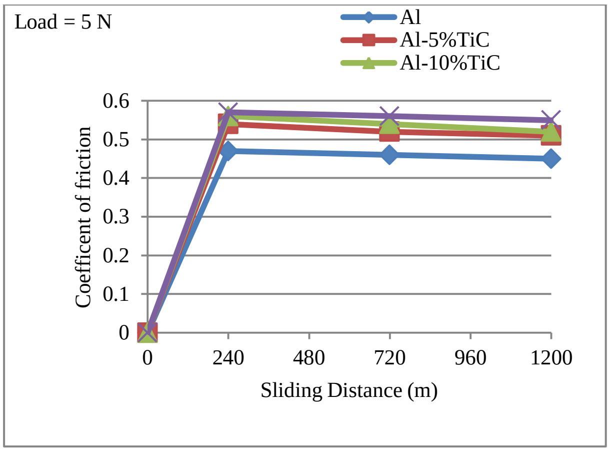


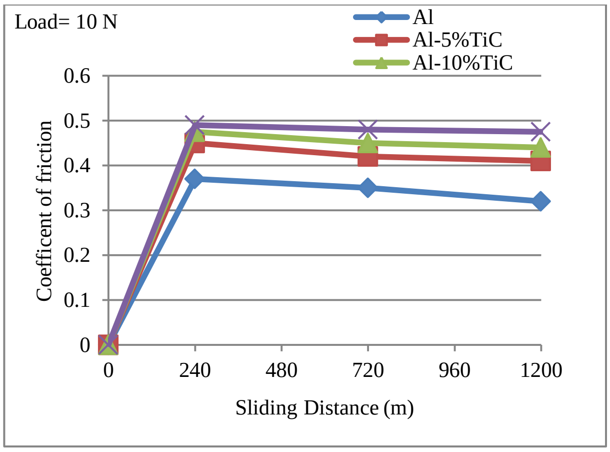
(c)

Figure 1.5 Variation of Wear rate as a function of sliding distance and load of Al and Al-TiC MMCs

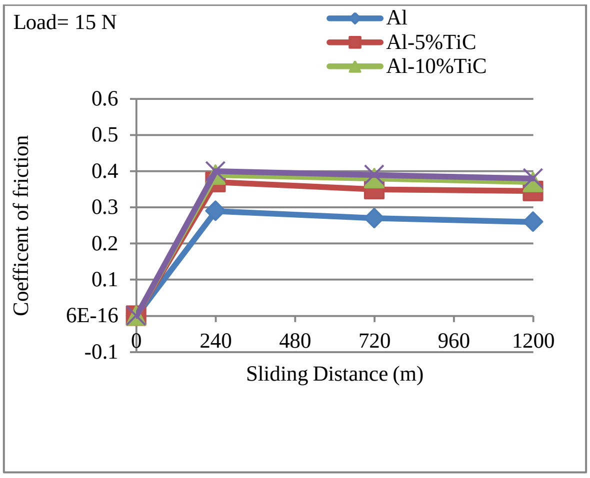
3.4Effect of load with increasing sliding distance on co-efficient of friction.

Figure 1.6 depicts the effect of weight percentage of reinforcement, sliding distance and load on coefficient of friction of Al-TiC MMCs. It is noticed that the rapid increase in the coefficient of friction between samples and disc up to a certain maximum value and remains constant up to a sliding distance of 1200 m. The coefficient of friction for the aluminium samples vary in the range of 0.48 to 0.35, which are comparatively lower than the Al-TiC composite samples (0.5 to 0.6). At higher loads, low coefficient friction values are obtained for all the samples.





(a) (b)



(c)

Figure 1.6 Variation of coefficient of friction of Al-TiC MMCs as a function of weight percentage of reinforcement, sliding distance and load.

3. CONCLUSIONS

Al MMCs containing 5, 10 and 15 weight % TiC have been successfully developed by using conventional powder metallurgy and sintering technique. The microstructure study revealed a uniform distribution of TiC particles within the Al matrix. The wear rate of unreinforced aluminum is found higher than that of Al-TiC MMCs. Increasing the content of TiC from 5 to 15 weight percentage showed higher wear resistance. The amount of wear rate is observed to be a function of hardness, delamination and decohesion of the particles. With the erosion of specimen's surface, the matrix tends to work hardened and provided necessary resistance against abrasion. At low loads, the specimens were demonstrated abrasion while delamination wear is dominant at higher loads.

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