IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

A Study On Hardness And Tribological Properties Of Aluminum-7068 Alloy Based Metal Matrix Composite Reinforced With Titanium Carbide (Tic) Particles

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Abstract— In this attempt of research work synthesis, hardness and tribological properties of aluminium metal matrix composites (AMMCs) are produced as Al-7068 matrix metal and reinforcements as TiC particulates through stir casting. Experiments were conducted by varying weight fraction of TiC (0%, 3%, 6%, 9% and 12%). Wear characteristics of Al-TiC composites have been investigated under dry sliding. Dry siding wear tests have been carried out using pin-on-disk wear tester at different loads (2 Kg & 3 Kg) and different speeds (200RPM, 400RPM, 600RPM). The tests were carried out making possible combination of load and speed with each weight fraction of TiC. The results indicate that on addition of TiC reinforcement in Al-7068 Alloy has improved the wear performance. The effect of load indicates that as load increases the wear increases and while speed increases the wear performances decreases. The hardness of the composite materials was measured using Brinell hardness tester and found that as weight fraction increases the hardness of the composite increases.

Keywords— Aluminium composite, Al-7068, Tribological properties, Dry sliding Wear, Titanium Carbide, Stir casting, Hardness.

I. INTRODUCTION

Al-7068 alloy is a 7000 series aluminium-zinc alloy registered with the US Aluminium Association and produced to AMS 4331 (chemical composition and mechanical properties) and AMS 2772 (heat treatment). 7068 alloy 'A' and 'B' tensile data and fatigue properties have been ratified for inclusion in MIL Handbook 5 / MMPDS. An Aluminum7068 alloy provides the highest mechanical strength of all aluminum alloys and matching that of certain steels. This outstanding alloy combines yield strength of up to 700 MPa (up to over 30% greater than that of 7075 alloy) and good ductility with corrosion resistance similar to 7075 and other features beneficial to high performance component/equipment designers. 7068 alloy responds well to all the different standard anodising techniques and it is generally similar in behaviour to 7075 but in hard anodising 7068 alloy tends to form a more abrasion resistant surface. An aluminium 7068 alloy can typically used in Connecting rods, Auto sport gearbox actuators, Automobile shock absorbers, Fuel pumps for racing engines, Rocker arms for racing engines, Motorcycle gears, Racing motorcycle chain tensioners, Bearing caps in high performance engines. Titanium Carbide is a fully dense, hot pressed, electrically conductive ceramic with exceptional hardness. Titanium Carbide has high wear resistance and high strength at elevated temperatures. Owing to low density, low melting point, high specific strength and thermal conductivity of aluminium, a wide variety of ceramic particulates such as SiC, B_4C, Al_2O_3, TiB2 and graphite have been reinforced into it. Among these particulates, TiC has emerged as an outstanding reinforcement. This is due to the fact that TiC is stiff, hard and more importantly, does not react with aluminium to form any reaction product at the interface between the reinforcement and matrix. Madhusudhan *et al.* [1] studied the mechanical characterization of Al7068-ZrO_2 reinforced Metal Matrix Composites were significant improvement in Hardness and Tensile strength was found with increase in Zirconium dioxide particles in weight percentage of composites. As expected, the percentage elongation diminished with increased weight percentage of reinforcement in the aluminium matrix. Sartaj *et al*.[2] studied the mechanical, tribological property and wear behaviour of Al7068 alloy/alumina composite with various weight fractions (3%, 5%, 7%) were prepared by stir casting method and result of tribological properties showed that the load increases the wear rate increases. Veeravalli Ramakoteswara Rao *et al.* [3] studied the sliding friction and wear behaviour of aluminium matrix composites (AA7075–TiC) have been investigated under dry sliding wear conditions. AMMCs studied are contained 2–10 wt. % of TiC particles in both as cast and heat treated (T6) conditions. The wear tests were carried out at a sliding velocity of 2 m/s, sliding distance 2 km and at normal load of 20 N. The wear resistance of the composites increased with increasing weight percentage of TiC particles. S. Gopalakrishnan *et al.* [4] studied the wear characterisation of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method and resulted as numerical analogy of mathematical model that the wear loss increased linearly with the normal load. But, the wear rate increased marginally with increased TiC addition. Rajnesh Tyagi [5] studied the effect of TiC content on friction and wear behaviour of al-TiC composites The Al-TiC composites containing three different volume fractions 0.07, 0.12 and 0.18 of TiC have been fabricated and wear characteristics of Al-TiC composites have been investigated under dry sliding. Dry sliding wear tests have been carried out using a pin-on-disk wear tester at normal loads of 9.8, 14.7, 19.6 and 24.5 N and at a constant sliding velocity of 1.0 m/s. The wear rate is significantly lower in composites as compared to that in base material. Basavarajappa *et al* [6] in his research work, synthesis and characterization of in-situ Al-TiC composites was carried out. In-situ Al-TiC with 3%, 6% and 8% composite were produced by introducing carbon bearing activated charcoal in to an Al-Ti melt, thereby forming TiC particles in the melt. Dry siding wear tests have been carried out using pin-on-disk wear tester at constant sliding velocity and constant load and are observed from the tests that increase in the percentage of TiC decreases the wear rate.

A. Problem Statement & Objective

In literature survey A lot of research has been carried out to enhance the properties of AMCs using various methods and different reinforcements like Al_2O_3, B_4C, TiC, CNT, SiO_2, Fly Ash, TiO_2, Graphite, SiC etc., The literature on reinforcement Titanium Carbide (TiC) is less and can be much interest due to excellent strength, hardness, and wear and corrosion resistance and it was revealed that wear tests have been conducted extensively for different composites made by different processing methods and not reported on Al-7068 with TiC reinforced particles hence the present work was attempted to study the dry sliding wear behaviour of Al-7068 alloy reinforced with TiC particles at different loads, sliding velocity and different wt% reinforcement and its hardness.

II. METHODOLOGY

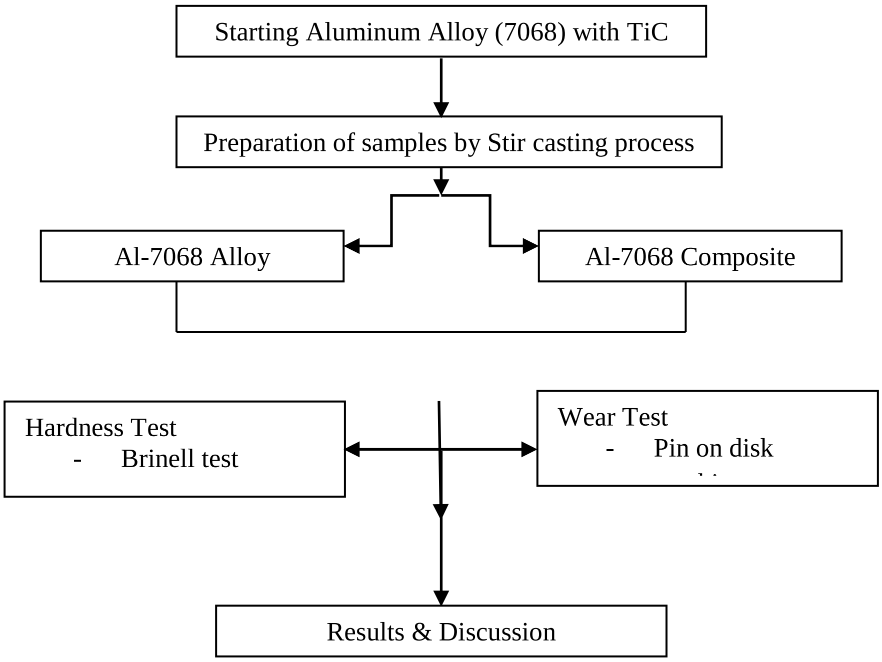

Fig 2.1 Methodology

A. Preparation of samples by stir casting

A stir casting setup as shown in fig consisted of an induction furnace and a stirrer assembly was used to synthesize the composite. The stirrer assembly consisted of a graphite stirrer, which was connected to a variable speed vertical drilling machine with range of 80 to 890 RPM by means of a steel shaft. The stirrer was made by cutting and shaping a graphite block to desired shape and size manually. The stirrer consisted of three blades at an angle of 120^0 apart. Approximately 1.5 Kg of Aluminium 7075 in solid from was melted at 8000°C in the induction furnace, and then preparing the alloyAluminium7068 by adding zinc metals in weight percentage. Preheating of reinforcement Titanium Carbide was done for one hour to remove moisture and gases from the surface of the particulates. The stirrer was them lowered vertically up to 3cm from the bottom of the crucible (total height of the melt was 9cm). The speed of the stirrer was gradually raised to 800 RPM and the preheated reinforced particles with 3% TiC (~45 grams) at first were added with a spoon at the rate of 10-20g/min into the melt. The speed controller maintained a constant speed of the stirrer, as the stirrer speed got reduced by 50-60 RPM due to increase in viscosity of the melt when particulates were added into the melt. After the addition of reinforcement, stirring was continued for 5-8 minutes for proper mixing of prepared particles in the matrix. The melt was kept in the crucible for approximate half minute in static condition and then it was poured in the mould. And after completion with 3% TiC casting, the next 3% of TiC were added in order to make the remaining alloy (~1.2 kg) with 6% of TiC (~37grams) and the steps are repeated in order to make 9% and 12% of TiC reinforcement. The following fig 2.2 and 2.4 shows the die moulds and round cylinder castings

TABLE I
CHEMICAL COMPOSITION OF AL-7068 ALLOY (WEIGHT PERCENTAGE)

Weight (%)	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Zr**	**others**
MIN	-	-	1.6	-	2.2	-	7.3	-	0.05	-
MAX	0.12	0.15	2.4	0.10	3.0	0.05	8.3	0.10	0.15	0.05

Fig 2.2: Die moulds

Fig 2.3 Preparation of TiC reinforcements by weight

Fig 2.4 Casted cylinders with different weight (3%, 6%, 9%, 12%) of Reinforcements

B. Wear Testing Machine

Dry sliding wear tests for different number of specimens was conducted by using a pin-on-disc machine (Model: Wear & Friction Monitor TR-201 CL DST- FIRST). The pin was held against the counterforce of a rotating disc with wear track diameter 60 mm & the pin was loaded against the disc through a dead weight loading system. For each type of material, test were conducted at 60mm track diameter and load of (2kg and 3kg) and the sliding speed of (200,400, 600) RPM. The surfaces of the pin samples was slides using emery paper (80 grit size) prior to each test in ordered to ensure effective contact of fresh and flat surface with the steel disc.

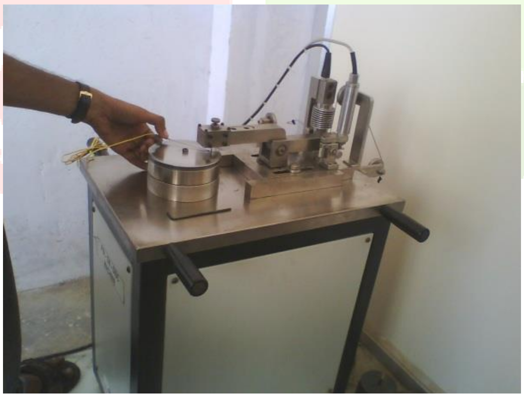

Fig. 2.5 (a) Pin on disc wear testing machine *(b) Display unit*

Fig 2.6 Wear test samples with different reinforcements

Basic specification

Track diameter: 60mm

Specimen size: Φ8mmx32mm
Timer: 5 minutes

C. Hardness Test

Hardness is the resistance of a material to localized deformation. A hard material surface resists indentation or scratching and has the ability to indent or cut other materials. Hardness of the four stir casted samples was tested on Brinell Hardness Tester. In the Brinell hardness test, a hardened steel ball is pressed into the flat surface of a test piece using a specified force. The ball is then removed and the diameter of the resulting indentation is measured using a microscope. The Specimen used is of IS 1500-2005 standard. Readings on 2 locations were taken and average reading of each sample was considered.
Brinell hardness number is given by

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where,
P-------load in Kg
D------diameter of indenter in mm
d-------diameter of indentation in mm

- Indenter diameter: 5mm
- Load applied : 250 Kg's

Fig 2.7: Brinell hardness tester

Fig 2.8 Hardness Samples With Different Reinforcements

III. Result & Discussion

A. Tribological Properties (Wear Test)

The tests were carried out in order to find the wear behaviour of composites over weight percentage of reinforcements and the variation over speed and load in a way to find the least and optimum wear condition. The test samples are made with 0%, 3%, 6%, 9%%, & 12% of TiC particulates as reinforcements in Al-7068 Alloy. The parameters were chosen as speed variation over loads. The speed variation of 200 RPM, 400 RPM, 600 RPM on load of 2Kg & 3Kg were taken as condition to study the tribological properties. The comparison graphs are made in order to study the wear behaviours on reinforcements.

Fig 3.1 shows the comparison graph of reinforcements such as 3, 6, 9 & 12% of TiC at 200 RPM at 2 Kg load and Fig 3.2 shows the comparison graph of reinforcements such as 0, 3, 9 & 12% of TiC. When we see the graph of fig 3.1 it is cleared that as the wear rate marginally increases as the % addition of TiC addition increases and found to be high wear at 9% of TiC of about 148 microns of wear and when compared with the Pure Al-7068 alloy (fig 3.2) the wear of 150 microns has found to be marginally decreased and found to minimum wear at 3 % of TiC of 48 microns of wear. And wear has found to decrease at 12% of TiC which indicates the properties of TiC as surfaces Hardening, wear resistance and lower temperature. Similarly when compared with 3 Kg of load, the effects of reinforcements is similar and has found high wear 240 microns of wear at 9% of TiC and low wear at 3% of TiC of about 56 microns which is shown in the graphs of fig 3.3 and fig 3.4. Similarly the same condition or wear behaviour result were found in the 400 RPM & 600 RPM (fig 3.5 to fig 3.12) and on analysis with different type of test with variable conditions and considering all parameters it is found that 12% TiC has found to optimum and minimum wear rate at different load with different speed.

When the effect of speed is considered the speed variations of 200RPM, 400RPM & 600RPM on load of 2 kg from the graph it is cleared that wear is found to be minimum at 200 RPM at about 48 microns wear but when we compared to other speed at 400 RPM has found increase wear to 270 microns of wear. It is quite obvious that speed increases, coefficient of friction also increase and also wear increases due higher friction but when we see 600 RPM the wear has found to be decrease to 100 micros of wear this is due to rare cases like at low speed, grease on the surface of the friction pair is not easy to form homogeneous lubricating film, in the early wear and tear, the oxide film on the surface of the block and makes high coefficient of friction and wear rate is also increased. And under high speed, while friction coefficient is higher, but due to high temperature and hardening effect, higher surface hardness so lower wear rate. As test continues the lubrication film of surface of track will form homogeneous & when comparison graph of Al-7068 composite with 3% of TiC as reinforcement which consist of 200 RPM, 400 RPM & 600RPM at 3 kg load which shows the wear behaviour at different speed and found to high wear at 600 RPM due to high friction and high load and most of the cases the effect on wear behaviour was almost same result and found to be that at high speed the great wear resistance and have great life value of material over a period of time.

While studying the effect of load the wear properties of Al-7068 alloy reinforced with TiC, the load of 2 kg (19.62N) and 3 kg (29.43N) are considered in order to know the effect of load on the composites & the comparison result graph of the test sample of PURE Al-7068 alloy and 3% of TiC reinforcement with specification of 2kg and 3kg at a speed of 200 RPM. It is cleared from the comparison graph that the wear increases as the load increases. As comparing with pure AL-7068 alloy and 3% of TiC, the wear rate was found to be decreased. And found to be minimum wear at 3% TiC at 200 RPM at 2 kg load. The wear rate increases steeply with the addition of normal force. As the normal load increases, the coefficient of friction also increased which led to more wear rate. This is quiet a common phenomenon in most of the material. Further, the size of the wear debris increased with increasing loads and thereby, resulting in large wear loss at higher loads. Out of three parameters such as percentage of TiC, sliding velocity and normal load, the sliding velocity has relatively little effect on the sliding wear rate where as normal load has the highest effect on the sliding wear rate.

Fig 3.1: Comparison Of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 3, 6, 9 & 12% Tic Particles With Speed Of 200 Rpm At 2 Kg Load

Fig 3.2: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 0, 3, 9 & 12% Tic Particles With Speed Of 200 Rpm At 2 Kg Load

Fig 3.3: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 3, 6, 9 & 12% Tic Particles With Speed Of 200 Rpm At 3 Kg Load

Fig 3.4: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 0, 3, 9 & 12% Tic Particles With Speed Of 200 Rpm At 3 Kg Load

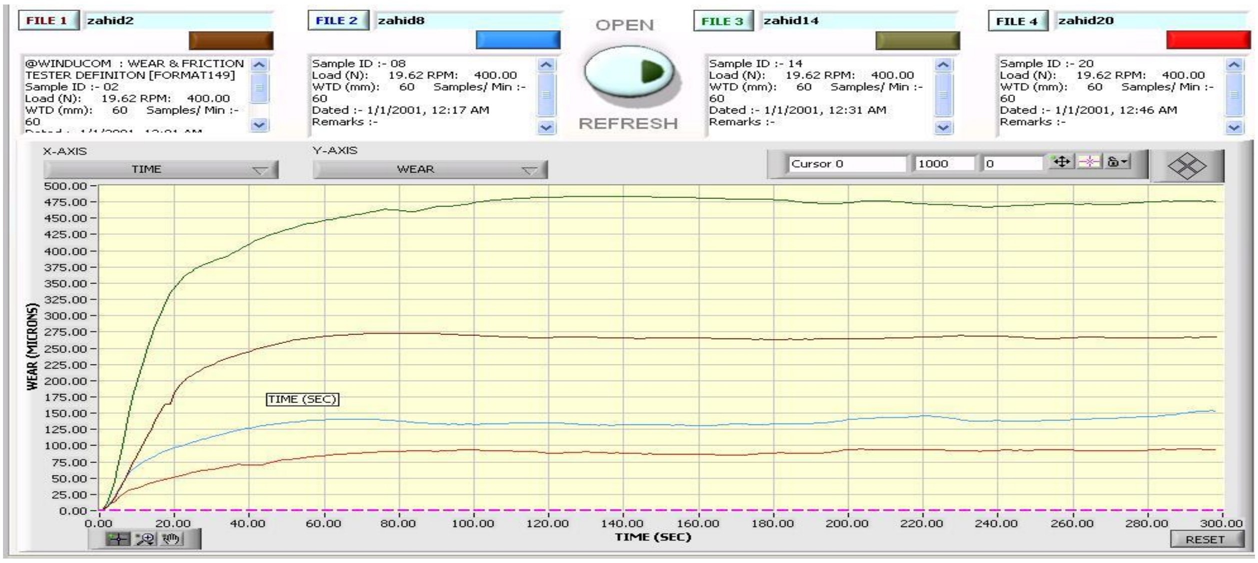

Fig 3.5: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 3, 6, 9 & 12% Tic Particles With Speed Of 400 Rpm At 2 Kg Load

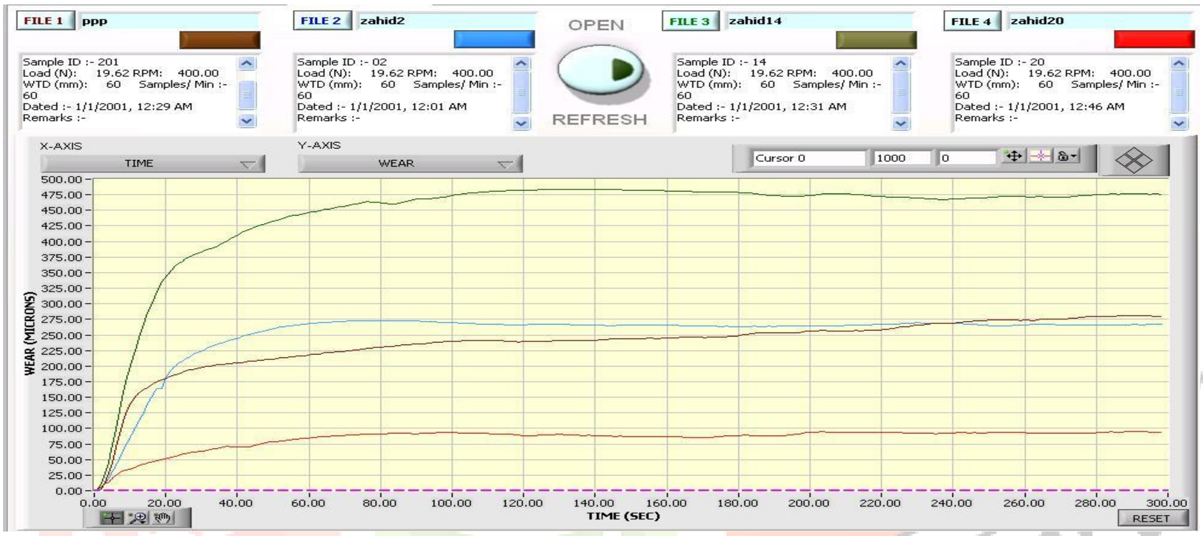

Fig 3.6: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 0, 3, 9 & 12% Tic Particles With Speed Of 400 Rpm At 2 Kg Load

Fig 3.7: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 3, 6, 9 & 12% Tic Particles With Speed Of 400 Rpm At 3 Kg Load

Fig 3.8: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 0, 3, 9 & 12% Tic Particles With Speed Of 400 Rpm At 3 Kg Load

Fig 3.9: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 3, 6, 9 & 12% Tic Particles With Speed Of 600 Rpm At 2 Kg Load

Fig 3.10: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 0, 3, 9 & 12% Tic Particles With Speed Of 600 Rpm At 2 Kg Load

Fig 3.11: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 3, 6, 9 & 12% Tic Particles With Speed Of 600 Rpm At 3 Kg Load

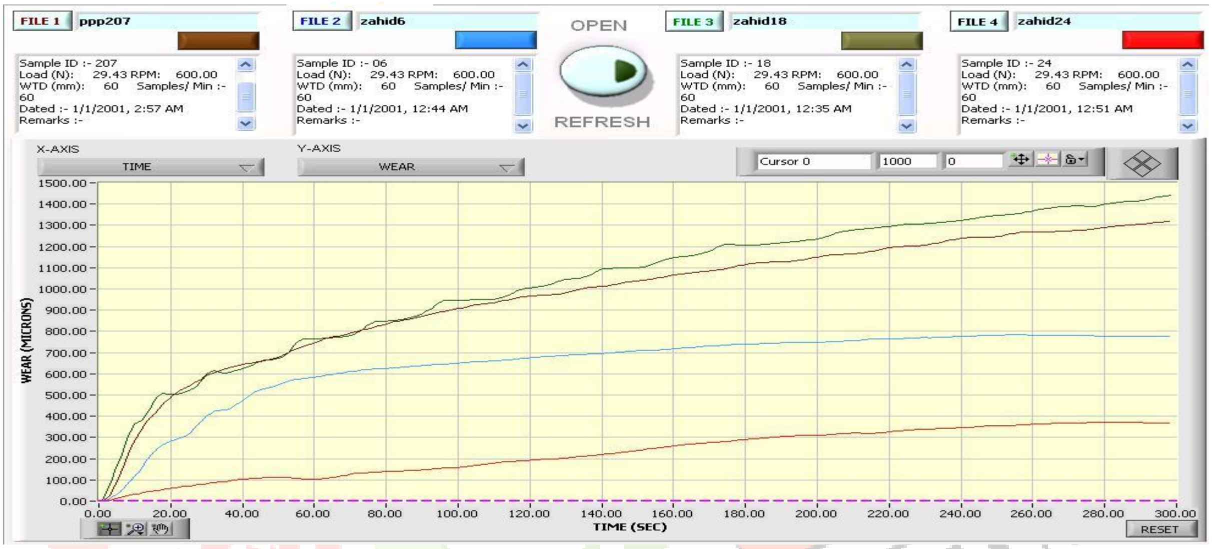

Fig 3.12: Comparison of Wear Behaviour Graph Of Al-7068 Composite Reinforced With 0, 3, 9 & 12% TiC Particles With Speed Of 600 Rpm At 3 Kg Load

B. *Hardness Test of Al-TiC Composite*

The variation of hardness the composite is shown in Fig 3.13. The hardness of the MMC's increased more or less linearly with the weight fraction of the particles in the alloy matrix due to the increasing ceramic phase of the matrix alloy. From fig 3.13, it is found that hardness increases with increasing TiC content in the material. A significant increase in hardness was found in 12% of TiC into Al-7068 Alloy composite. As compared to pure Al-7068 alloy, 3% of Tic increases the hardness of 21.62% and for 6% and 9% was found to be increased the hardness of 36.48% and 43.24% respectively. And the high hardness of 114 BHN (54.05% compared to pure cast alloy) was found in the 12% of TiC reinforcement. It is believed that improvement in hardness in casted components may be attributed to uniform distribution of reinforcements in the composites.

TABLE II
HARDNESS OF AL-7068 ALLOY AND ITS COMPOSITES

S/N0	Alloy/Composite Designation	Trail-1 Hardness BHN	Trail-2 Hardness BHN	AVERAGE BHN	%Increase in Hardness
1	PURE AL-7068	76	72	74	--------------
2	AL-7068+3% TiC	95	85	90	21.62%
3	AL-7068+6% TiC	95	107	101	36.48%
4	AL-7068+9% TiC	117	95	106	43.24%
5	AL-7068+12% TiC	121	107	114	54.05%

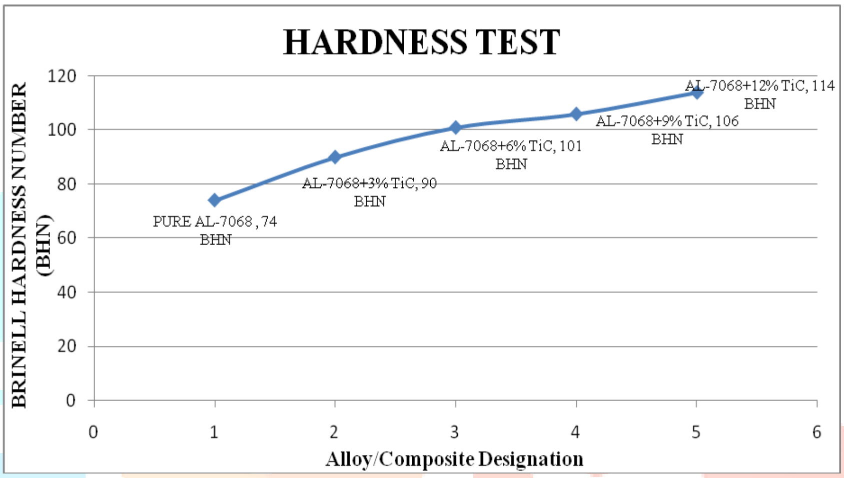

Fig 3.13 Hardness of Al-7068 Alloy and Its Composites

IV. Conclusions

Dry sliding wear tests using a pin-on-disc were conducted on Al-7068 with TiC particulates composites. The effect of reinforcement's content and the different load with different speed on the Tribological properties and the hardness of the different composition were studied and the following conclusions were drawn from the study.

1. The synthesis of composite Al-7068 with TiC particulates with different weight fraction were successfully fabricated using stir casting method.
2. The effect of load indicates that as load increases the wear increases and found to be highest effect on wear rate.
3. The effect of speed indicates that as speed increases the wear increases due to higher friction but in some cases the wear found to be minimum at higher speed due the properties of Titanium carbide such as toughness and hardness.
4. The effect of reinforcements was found to be different for initial wear and steady state wear.
5. On analysis with different type of test with variable conditions and considering all parameters it is found that 12% TiC has found to optimum and minimum wear rate at different load with different speed.
6. The wear resistance of Al-7068 alloy is improved by addition of TiC particulates.
7. Hardness of the Aluminum alloy improved significantly by adding up of TiC particles into Al-7068 Alloy and it almost vary linearly with the weight fraction off particles and found to higher at 12% of TiC particulates of average 114 BHN.

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