Wear Behaviour Of Sintered Titanium-Diboride Reinforced Graphite Aluminium Composites.

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***Abstract*-The study of frictional forces of interacting surfaces, known as tribology, plays a vital role in friction and lubrication-dependent machining processes, but in any process where two surfaces come in contact. Using Graphite reinforcement in aluminium matrix composites has been reported to be beneficial in reducing wear due to its solid lubricant property, but results in reduction of strength. Adding Titanium diboride to aluminium matrix composites reinforced with graphite will improve both mechanical strength and wear resistance of composite and resulting in a hybrid composite. This work aims at the study of wear characteristics of Aluminium/Titanium -diboride/Graphite hybrid composites fabricated using powder metallurgy technique. Sintered Aluminium matrix composites with Titanium diboride were developed for wear applications. Composites with base material of commercial aluminium of 98% purity and 5wt% Graphite, containing various levels of Titanium diboride (5 to 20 wt%) were developed from elemental powders. Frictional wear tests were conducted using pin specimens against an EN steel disk using a pin–on–disk wear testing apparatus. For the sake of comparison, experiments were also conducted on three different samples such as pure Aluminium, Aluminium with 5%Gr, and Aluminium with 5%TiB_2. Increasing the percentage addition of Titanium -diboride by sintering reduces the ductility of the composites gradually. The wear loss and frictional force of the Aluminium/ Titanium -diboride /Graphite was reduced by adding 5 wt% Titanium -diboride and 5 wt% Graphite**

Key Words: Hybrid composite, sintering process, wear rate.

I. INTRODUCTION

The widely applied methods for the production of composite materials are based on casting techniques such as the squeeze casting of porous ceramic preforms with liquid metal alloys and powder metallurgy methods. The machining difficulties and processing costs related to particle reinforced aluminium matrix composites have limited the application range of these advanced materials. The volatile material properties of aluminium based particle reinforced composites are increased stiffness, wear resistance, specific strength and vibration damping, and decreased coefficient of thermal expansion compared with conventional aluminium alloys. [1]

We tend to think of the latter half of the twentieth century as the "Composite" age. In some ways this is realistic and gives us a feeling of continuity from former "material-based" ages such as the Stone, Bronze and Iron ages. Certainly the last 50 years have been associated with some remarkable developments in composite materials; some of which will be alluded to in various degrees of detail below.

A composite material is a material composed of two or more constituents. The constituents are combined at a microscopic level and are not soluble in each other. The material holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material. The most primitive man-made composite materials are straw and mud combined to form bricks for building construction. In recent times there has been a remarkable growth in the large scale production of fiber and fiber reinforced epoxy matrix composites because of their remarkable properties. [2, 3]

Metal Matrix Composites (MMCs) have recently evoked a keen interest for their potential applications in cylinder liners, brake drums, crankshafts, and the aerospace and automotive industries because of their greater strength to weight ratios and high temperature resistances. At the present time, aluminium metal matrix composites (AMMCs) have been well recognized and steadily improved because of their advanced engineering properties, such as their improved wear resistance, low density, specific strength and stiffness [8,9]

At present, the main industrial processing routes available for the production of aluminium based particle reinforced composites consist of casting, thixoforming, spray deposition and powder metallurgical processing. Powder metallurgy methods are based on the classical blending of matrix powders and reinforcing elements (dispersion powders, platelets and ceramic fibers) and further cold pressing and sintering followed by plastic working (forging, extrusion). In normal instances, in order to increase the strength and ductility, fine reinforcements and a relatively large volume fraction are preferred. However, it is difficult to take advantage of both these requirements because they are prone to cause an inhomogeneous distribution. Poor distribution of reinforcement degrades the composites in terms of its physical and mechanical properties and negates the attractiveness of reinforcement additions. [3, 4]

The powder metallurgy route to manufacturing metal matrix composites offers advantages compared with ingot metallurgy, stir-casting, and squeeze casting because of its low manufacturing temperature, which avoids strong interfacial reactions, minimizing undesired reactions between the matrix and the reinforcement. An additional advantage of powder metallurgy is the uniformity in the reinforcement distribution. This uniformity improves not only the structural properties but also the mechanical strength as well as imparts high wear resistance. Based on literature sources, studies on the tribological behaviour of hybrid composite are very limited. However, most of the reported research focuses on the effect of either one or two factors on the dry sliding wear behaviour of hybrid composites. [8] The conventional powder metallurgy route for making MMCs includes:

1. Mixing and blending
2. Consolidation, e.g. hot pressing
3. Secondary processing e.g. extrusion, rolling

Wear resistant materials must possess high strength with an adequate toughness and ductility at room and high temperatures. Such properties can be achieved through incorporation of hard dispersed particles into a ductile matrix. The two common approaches for wear resistance characterization are the determining of material weight loss and coefficient of friction. The weight loss was measured under different applied loads at constant sliding distance and sliding velocities. However, reported studies have indicated that efforts are scarce on parametric studies on the tribological behaviour of aluminium matrix hybrid composites. Consequently, an attempt is made here to study the influence of % reinforcement (TiB_2 particulates) and load, on constant sliding speed and sliding distance on the tribological behaviour of Al–TiB_2–Gr hybrid composites.

II. EXPERIMENTAL DETAILS

A. MATERIALS

Al-Gr-TiB_2 composites required for investigation was prepared from the elemental powder materials using conventional powder processing techniques.

Table 2.1 Chemical Composition of the Matrix Al

Element	Al	Fe	Mn	Ti	N	Cu	Si
Content%	98	0.1	0.02	0.03	0.001	0.02	0.1

Table 2.1 gives the chemical composition of the base material Al matrix used. The base materials Aluminium and graphite are mixed with TiB_2 in grain size of 50 µm.

B. FABRICATION PROCESS

The fabrication process is done by mixing the pre weighted powders of aluminium graphite and titanium–diboride. Four different samples of composites were produced by keeping the graphite wt% as a constant value of 5%[8,9,25] and varying the wt% of TiB_2 from 5 wt% to 20 wt%. In addition to pure aluminium as a matrix material which was produced by the same powder metallurgy technique. Also two more samples formed reinforcing 5 wt% of Gr with aluminium and 5 wt% TiB_2 with aluminium separately.

Table 2.3 Details of Prepared Composite

Composition	**Wear**		
	2N	**4N**	**6N**
Al	74	91	96
Al+5%TiB_2	67	77	79
Al+5%Gr	65	79	81
Al+5%TiB_2+5%Gr	56	60	67
Al+10%TiB_2+5%Gr	64	66	83
Al+15%TiB_2+5%Gr	67	70	87

The pre weighted elemental powders are mixed and then poured into a die of 50.8mm diameter for compaction.

Fig. 2.1 Pellets Formed From Elemental Powders

The compaction process was done with help of a universal testing machine by applying a load of 200kN gradually on the punch of the die set assembly containing powder. The powder mixtures were compacted to pellets as shown in Fig. 2.1 of 50.8mm diameter and 15mm thickness. The pellets are then sintered to a temperature of 550^{0}C gradually and hold on that temperature of 550^{0}C for 1hour in muffle furnace. Then the sintered composite pellets were taken out from the furnace on the next day, dimensional changes were observed. Then the pellets are again cold pressed for 250kN with the same punch – die set [23, 24]. After second pressing the pellet was fine hybrid composite metal of 50.8mm diameter and 12mm thickness. These pellets were then machined to respective specimens for wear testing by the help of a lathe machine tool. Under normal feed rate, 0.5 mm depth of cut and a spindle speed of 800rpm the pellets were reduced to pin specimens.

C. WEAR TEST

Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other. Wear is defined as the progressive loss of material from contacting surfaces in relative motion. The wear test (dry sliding wear test) performed on the fabricated composite is a type of adhesive wear. This type of wear is caused between two metallic components which are sliding each other under an applied load and in an environment where no abrasive are present. The apparatus is shown in Fig. 2.2 Dry sliding wear involves sliding of one surface over other under the application of a load normal to the plane of motion. Dry wear test will be carried out on the pin-on-disc apparatus. The wear test specimens will be studied under dry condition using pin-on-disc apparatus. The test will be carried out under varying loads. The wear test specimen will be prepared with diameter of 10 mm x 30 mm length. The test will be carried out under varying loads. A pin-on-disc wear test apparatus was used for the dry sliding wear experiments (as per ASTM G-99 standard).

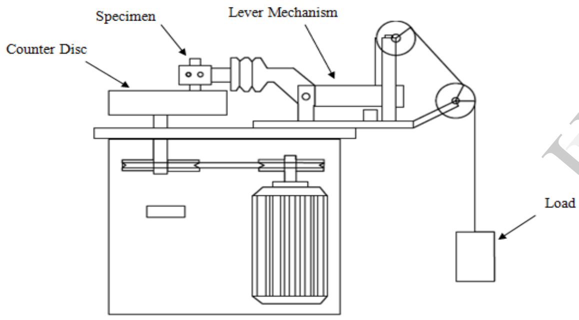

Fig.2.2 Schematic of Pin-on-disk Wear testing apparatus

A specimen in the form of a pin was held against a rotating disc made of EN25 steel with 165 mm diameter and 10 mm thickness and heat treated to a hardness of 32 H_B. The test was conducted for a specified test duration, sliding velocity and varying load of 2N, 4N, 5N. The surface of the specimen was perpendicular to the contact surface, prior to testing. The initial and final weight of the specimen was measured by using an electronic digital balance. The difference between the initial and final weight is the measure of weight loss. The weight loss was then converted into the wear volume using the density data. The specific wear rate (Ws) parameter provides a more comprehensive measure of the wear loss characteristics of the materials.

D. BRINELL HARDNESS

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex.

Hardness is an important characteristic which affects the wear behavior of the bearing material. Hardness is measured using Brinell hardness testing machine. Hardness depends on ductility, elastic stiffness and viscoelasticity. The specimen is prepared as per ASTM D 785 – 08 standards and size of the specimen is 12 mm x12 mm. An appropriate B scale is chosen to be used. The indenter moves down into position on the part surface. A minor load is applied and a zero reference position is established. The major load is applied for a specified time period (dwell time) beyond zero. The major load is released leaving the minor load applied. Then the reading from the B scale is marked as RHN (Brinell hardness number) value. For each specimen three hardness values were taken by applying the load in different spots. Then an average of three values was taken as the RHN. The indenter used for hardness testing is 1/16” Indenter of 0.58mm dia.

III. RESULTS AND DISCUSSIONS

In the present work, the friction and dry sliding wear behavior of Al hybrid composites without addition and with addition of TiB_2 particulates. The TiB_2 particulates are added from 5% to 20%. The composite samples have been studied in terms of the co-efficient of friction and specific wear rate. The hardness is also having been studied for the samples. The composite with 20 wt% TiB_2 failed to be machined due to brittleness. The sample can’t even withstand even 0.2mm depth of cut.

A. CO-EFFICIENT OF FRICTION

Applied load was the most significant factor influencing the Co-efficient of Friction of the composite, while the sliding speed and percentage reinforcement had only slight effects. However, the co –efficient of friction remained almost invariant with sliding distance for all composites. The increase in the applied load significantly increased the Co-efficient of Friction of the composites because at lower loads, the graphite film was found to be more stable than at higher loads, as the film was destroyed with an increase in the load. The co-efficient of friction for different samples is shown in table 3.1. The experimental data under a constant sliding distance of 1000m as a function of sliding velocity and normal loads are summarized.

Table 3.1 Co-efficient of friction

Composition	**Co-efficient of friction**		
	2N	**4N**	**6N**
Al	0.012	0.013	0.015
Al+5%TiB_2	0.006	0.007	0.008
Al+5%Gr	0.007	0.008	0.009
Al+5%TiB_2+5%Gr	0.005	0.006	0.007
Al+10%TiB_2+5%Gr	0.009	0.011	0.012
Al+15%TiB_2+5%Gr	0.01	0.012	0.014

The experimental results show that the co-efficient of friction increases with increase in applied loads. The sliding velocity is kept constant 2m/s. The tests were carried out for six samples as shown in table 3.1. For all composites the co-efficient of friction decreases with increase in TiB_2 particulates on Al - Gr composite. The friction force was maximum in the case of composite without addition of TiB_2 particulates and minimum for the composite with5% TiB_2 and 5% Gr.

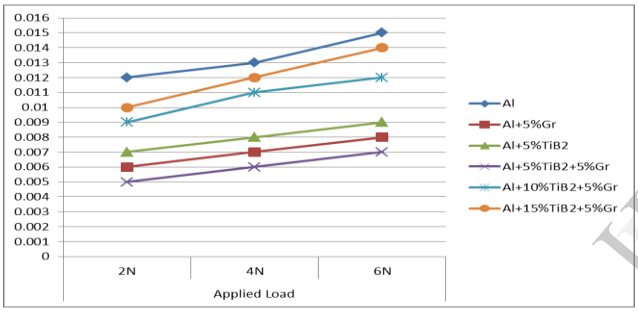

Fig. 3.1 Co-efficient of friction

B. EFFECTS OF LOADS ON SPECIFIC WEAR RATE

The sliding wear rate data of all composites are shown in fig. 3.2. The result reveals that the wear loss increases with increase in load employed for all composites. By increasing the wt% of TiB_2 wear rate of the composites are also increasing. The best wear results were obtained in composites with 5% TiB_2 and 5% Gr hybrid composite.

By comparing the specific wear rates of pure Al sample at various loads with other composites, the one with Al and 5% TiB_2 gives a little bit better wear results and by further addition of the self-Lubricating material graphite by 5wt %, we got the comparable better wear rates for various loads.

Table 3.2 Specific Wear Rate

Composition	**Wear rate at ($x10^{-9}$ mm^3/N-m)**		
	2N	**4N**	**6N**
Al	9.68	10.08	12.05
Al+5%TiB_2	8.56	9.78	10.89
Al+5%Gr	7.89	8.69	9.77
Al+5%TiB_2+5%Gr	2.05	2.65	3.6
Al+10%TiB_2+5%Gr	2.25	3.47	4.28
Al+15%TiB_2+5%Gr	4.96	5.79	5.97

The percentage addition of the reinforcement TiB_2 had the major influence on Wear of the composites. The Wear shows that Wear starts gradually increasing in the Fig for the addition of TiB_2 more than 5%. Thus it is clear from the Fig 3.2 that Wear increases by increasing the wt% of graphite.

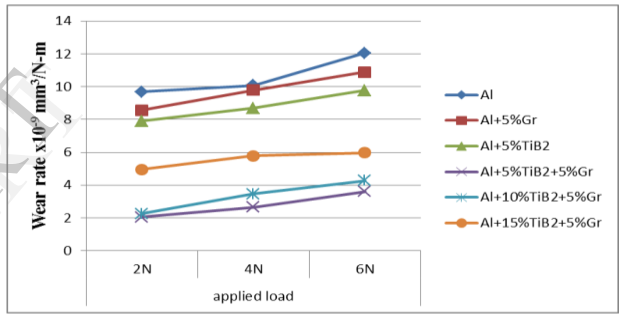

Fig. 3.2 Specific Wear Rates

IV. HARDNESS

The fabricated composite is subjected to hardness test. The hardness test was carried out using the Brinell hardness testing machine on all the samples prepared. The obtained result is hereafter discussed and analyzed experimental data is reported and compared in the following Fig. 3.3. It is seen that with the increase of filler content in the composite, the hardness value is decreased. The result shows that hardness of the composite is decreased in more percentage of filler content, since there occurred brittle transition from ductility due to high porosity developed by sintering process.

From the Fig 4.8, it is clear that the hardness increases for the addition of reinforcement up to 5 wt%, ahter there is an increasing face which gradually increases with proportion to the % reinforcement of TiB_2.

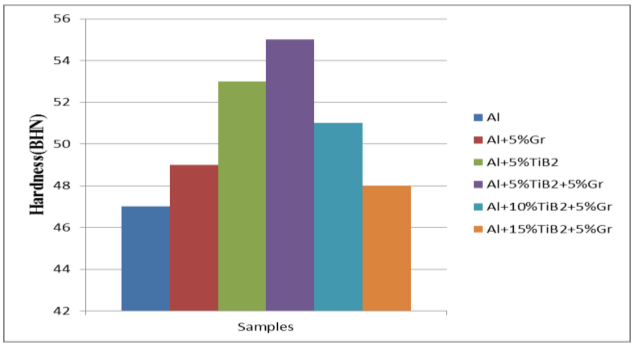

Fig. 3.3 Hardness BHN

V. CONCLUSIONS

Based on the experimental observations, the following conclusions can be drawn.

1. Among those hybrid composites fabricated, the one with Al+5 wt %TiB$_2$ and 5% Gr only exhibits better wear characteristics with hardness and CO-EFFICIENT OF FRICTION.
2. Increasing the wt % of TiB$_2$ more than 5% reduces the wear resistance of the composites slowly (i.e.) the specific wear rate is high for composites with more than 5 wt% of TiB$_2$.
3. Increasing the load influences the specific wear rate on the composites, but the brittleness of the composites affects the study on load for a constant sliding speed and distance.
4. Fabricating the composites reinforced with TiB2 by sintering process decreases the properties due to unavoidable porosity and void content.
5. Titanium-diboride is facing less reactivity with materials at sintering temperatures; it gives best results at less wt % of its addition to Aluminium matrix composites.

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