Micro-Structural and Tribological Behavior of AA6063/12sic-5Gr Hybrid Composites

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Abstract— In this paper the friction and wear behavior of aluminium matrix reinforced with silicon carbide and graphite is investigated. A pin on disc type apparatus is used to measure the sliding wear rate (WR), the frictional force (F) and the coefficient of friction (μ). Friction and wear behavior of the hybrid metal matrix composites (HMMC) have been investigated at various loads, sliding velocity and constant sliding distance. The applied loads are 20N, 40N, 60N and 80 N respectively, sliding speeds are 1.5 m/sec and 3 m/sec and the sliding distance is 1500 m. The aluminium based MMC has been produced by stir casting technique. AA6063 with 12SiC-5Gr composite is machined to the required size. Optical microscope is used for investigating the microstructure and surface properties of the specimen. The addition of graphite and silicon carbide reinforcement to AA 6063 alloy increases the wear resistance and hardness of the composites.

Key words: Hybrid Metal Matrix Composites, Stir casting, Optical microscope, Rockwell hardness, Wear rate

I. INTRODUCTION

Aluminium alloys are used in various applications like Automobile and Aerospace industries because of their high strength to weight ratio and excellent corrosive resistance. Aluminium alloys have poor Tribological properties and low wear resistance. Aluminium MMC is required for improved wear resistance and better Tribological properties. The addition of graphite and SiC reinforcement to aluminium alloy reduced the wear rate of the composites [1].

Fehmi Nair et al. have investigated AA6063 reinforced with SiC_p and the results indicate extrusion ratio is increased, the fiber alignment is improved, but fracture is more severe [2]. The investigation on machining of 0-8.2 wt. % for Al-Gr composites by Suresh et al. has indicated reduced wear rate with increase in particulate content [3]. Baki Karamis et al. have observed that the effect of fine particles on the die wear is more effective than those of coarser one [4]. Suresh et al. have discussed that the squeeze cast matrix is used to improve hardness and also minimize porosity and it have lower weight losses [5].

MMC has less wear rate and stable friction coefficient as noticed by Natarajan et al. [6]. The investigation carried out by Daud et al.[7] on pin on disc machine using aluminium alloy has shown that the wear rate has been increased with applied load and sliding velocity. Wang [8] used statistical approach to investigate that the coefficient of friction is decreased with increase of load.

II. EXPERIMENTAL PROCEDURE

A. Fabrication of Hybrid MMC

AA6063 aluminium alloy is used as a matrix material and 12% of SiC particles and 5% of graphite were used as reinforcement. The chemical composition of the AA6063 matrix is found by ARL. Spark Analyzer and is listed in the Table 1.

Element	Si	Fe	Mn	Mg	Ti	Al
Weight. in %	0.41	0.15	0.023	0.38	0.016	Bal

Table 1: Chemical Composition of Aa6063 Matrix Material (Wt. %)

The Al/SiC-Gr metal matrix composite is manufactured by stir casting process. First, the Al material is melted in resistance heated furnace in a graphite crucible and the liquid metal is heated to 800ºC. Next, SiC and graphite is pre-heated to 400°C are added into molten aluminium material by means of argon gas flow with the rate of 20 g/min. During the processes, the molten metal and SiC-Gr are stirred by a mixture with 750rev/min. When the temperature of the matrix material decreased to near the melting point, the stirring process makes the molten metal hard, the process is then stopped and further the matrix material is heated again up to 800°C to ensure the homogeneity of the mixture.

After completion of stirring process, the mixed material at 700-800°C is cast into a metallic mould and it is quenched in atmosphere air together with mould.

B. Microscopic Investigation and Hardness Test

After machining HMMC parts are cut with suitable dimensions by hack saw. A freshly mixed etchant consisting of 95 ml distilled water, 1.5 ml HCl, 1 ml HF and 2.5 ml HNO_3 are used to reveal the shape of deformation zone. The longitudinal section of the composite is polished on SiC paper (grit 80-1200), immersed at room temperature into etching solution for a few seconds. The particle orientation and deformation zone are investigated through optical microscope. The micro hardness test is evaluated using Rockwell hardness tester as per the IS: 1586-2000.

C. Wear Test

Wear experiments are carried out using pin-on-disc wear testing apparatus shown in Fig.1. The test parameters used for the present work are listed in Table 2.

Fig. 1: Pin on Disc Apparatus

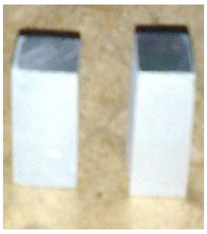

Fig. 2: MMC specimen for Wear Test

The measurement of wear of the pin is used to evaluate the volumetric loss, which in turn is used to compute the wear rate of the composites using the following formula [9]:

$$W_R = V/LP$$

Where, W_R is the wear rate in mm^3/N-m, V is the volumetric wear loss in mm^3, L is the sliding distance in m and P is the normal load in N.

Pin material	Al 6063/12SiC$_p$-5Gr
Disc material	EN 36 steel with a hardness of 65 HRC
Pin dimensions	Rectangle with length 10 mm, width 10 mm and height 30 mm
Sliding speed (m/sec)	1.5 &3
Sliding distance (m)	1500
Track diameter (mm)	100
Disc speed (rpm)	287 &573

Table 2: Details of Wear Testing Parameters

III. RESULTS AND DISCUSSION

A. *Micro-Structural Studies*

Fig.3. shows the microstructure of the hybrid MMC in Cast condition. The microstructure clearly indicates the particles distributed in the reinforcement and matrix alloys.

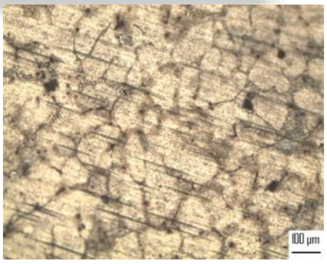

Fig. 3: Microstructure of Al6063 Cast Composites

B. *Hardness Test*

Micro hardness improvement is calculated using the equation given below. The effect of reinforcement was studied by comparing the hardness of stir casted composite material with the base material. The hardness value of composite material is taken from five different points because of the non-homogeneous property. The hardness of AA6063 and AA6063 SiC-Gr Hybrid composite at different points are shown in Fig.4.

$$\text{RH improvement } (\%) = \frac{\text{HRCc} - \text{HRCmx}}{\text{HRCmx}} \text{x100}$$

Where, HRCc and HRCmx are the Rockwell hardness of hybrid metal matrix composite and AA6063 material. The average hardness of metal hybrid metal matrix composite is 56HRC and hardness of AA6063 is 40 HRC.

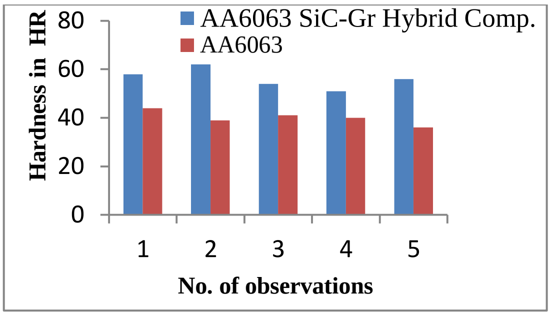

Fig. 4: Rockwell hardness of composite and AA6063

C. *Wear Study*

1) *Wear of HMMC*

The wear of composite pin material has been determined from several tests conducted at different loads and speeds. The wear in terms of volume losses will be useful in order to determine the geometrical changes in the components. The variation of wear with load for composite pin is shown in Fig. 5.

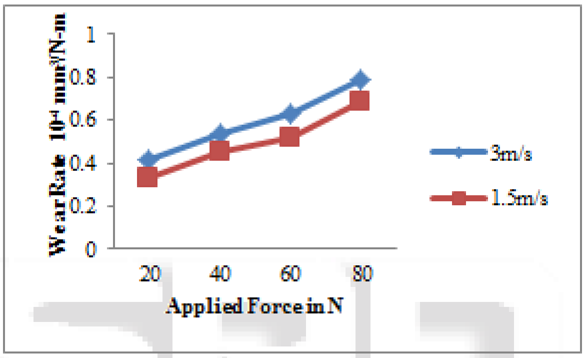

Fig. 5: Wear Rate of AA6063 SiC-Gr Hybrid composite at Different Velocity and Applied Load

The wear is low at lower value of applied loads. So at lower loads the reduced wear is observed. As the applied load is increased, the wear loss also increased. Higher wear is observed for maximum load.

2) *Frictional Force*

The variation of frictional force with applied load for composite material is shown in Fig.6. More variations are observed with applied load then with the sliding velocity. At higher loads, the frictional force is higher because of more contact area at the friction material surface. Here, higher variations are observed for the maximum load.

3) *Coefficient of Friction*

The coefficient of friction is a definite ratio between the developed and the applied force. The friction coefficient is observed high for lower loads and reduced for increase of loads is shown in Fig.7.

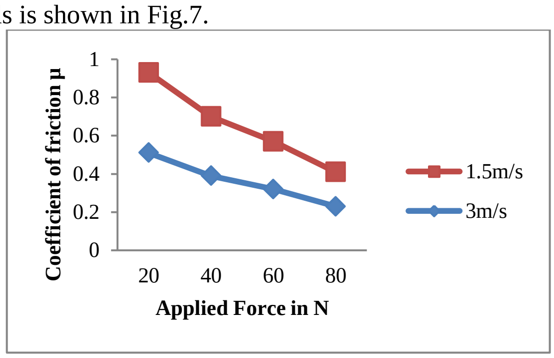

Fig.7: Coefficient Of Friction of AA6063 Sic-Gr Hybrid Composite at Different Velocity and Applied Load

IV. Conclusion

The hardness of AA6063 SiC-Gr Hybrid composite improved by 40% compared with the matrix material (AA6063).The wear of composites was found increased with increasing in load and sliding velocity. The friction coefficient is decreased with increase in load. AA6063 SiC-Gr Hybrid composite had more wear resistance and stable frictional coefficient. It can be a better material for brake drum applications. The frictional force and frictional coefficient of the hybrid composite was found to be varying with the applied force and at different speeds. It was found that the frictional force increased with applied load and sliding velocity. Thus the addition of graphite and silicon carbide particles reinforcement to AA 6063 alloy increases the wear resistance and hardness of the composites.

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