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Scrutinization of A356/25sicp AMC and Gray Cast Iron as Brake Rotor Material

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***Abstract*— T**he current paper is in concern with the wear behaviour of aluminum metal matrix composite (Al MMC) sliding against automobile friction material and comparison with the conventional grey cast iron. The wear tests are under consideration on a pin on disc machine, using pin as brake shoe lining material and discs as A356/20SiCp Al MMC and grey cast iron materials. The friction and the wear behaviour of Al MMC, grey cast iron and the semi-metallic brake shoe lining at different sliding velocities, loads is studied and registered. The case study based on parametric comparison by and is focused on parameters like I) Wear in Al MMC and cast iron material with conventional brake pad material. II) Wear in brake pad material sliding against cast iron and Al MMC. III) Variation of frictional force and friction coefficient with applied load. The investigation is in regard shows that the MMCs have considerable higher wear resistance than conventional grey cast iron while sliding against automobile friction material under identical conditions. A gradual reduction of friction coefficient with increase of applied load is observed for both cast iron and Al MMC materials. However, in all the tests it is observed that the friction coefficient of Al MMC is 25% more than the cast iron while sliding under identical conditions. The wear of the lining material has been observed more when sliding against MMC disc because of the ploughing of the lining material by the silicon carbide particles.

I. Introduction

The ever-increasing response for light weight, fuel efficiency and luxury in automobile industries has lead to the development of advanced materials along with optimized design. The increased demand for light-weight materials with specific strength in the aerospace and automotive industry has spread the development and use of one group of composites: metal-matrix composites (MMCs). MMCs are widely used in industries, as they have excellent mechanical properties and wear resistance. MMCs have slowly replaced some of the conventional have excellent mechanical properties and wear resistance. MMCs have slowly replaced some of the conventional light-weight metallic alloys such as the various grades of aluminum alloys in applications where low weight and energy saving are important considerations and yet without sacrificing the strength of the components.

The investigations carried out by Kwok and Lim on pin on disc machine using aluminum alloy has shown that the wear has been increased with applied and sliding velocity.Sahin used statistical approach to investigate the wear of aluminum and its composites using factorial approach and formulated the wear rate as a function of applies load and abrasive particles. Under these circumstances a real study is needed to study the actual behavior of these MMC's sliding against automotive friction lining. The wear resistance of cast irons commercially used for brake rotor applications has been investigated by Cueva et al. They have observed that wear rate varies for different grades cast iron and compact graphite iron is found to have more wear resistance. Howell and Ball have investigated the dry sliding wear of particulate-reinforced aluminum alloys against automotive friction materials. They found that that wear resistance of MMC is higher than aluminum alloy and cast iron. A comparative study on wear resistance MMC and white cast iron has been carried out by Berns and concluded that MMCs are better alternative materials for white cast irons. Shorowordi et al. Investigated the effect of velocity on wear, friction of aluminum MMC sliding against phenolic brake pad. Hence in present paper cast iron and the MMC materials are used as disc and the commercial automobile brake lining is used as pin. The influence of load, speed and sliding distance on the tribology of cast iron and MMC sliding against lining pin material has been studied.

II. Experimental Methodology

In regard to parameters of Al MMC and gray cast iron, the experimentation is to investigate the effect of load on wear properties to register the validation of material for brake rotor. The effect of sliding velocity on wear of gray cast iron and Al MMC with brake pad material is required to determine the wear rate. The experimentation is also in regard to investigate the variation of frictional force and friction coefficient with applied load.

The wear behaviour of brake drum material and its counter face friction material are going to be determined in this paper. A semi-metallic brake lining and two brake drum materials are considered for the test. One is the commercially used gray cast iron and the other is the proposed MMC.

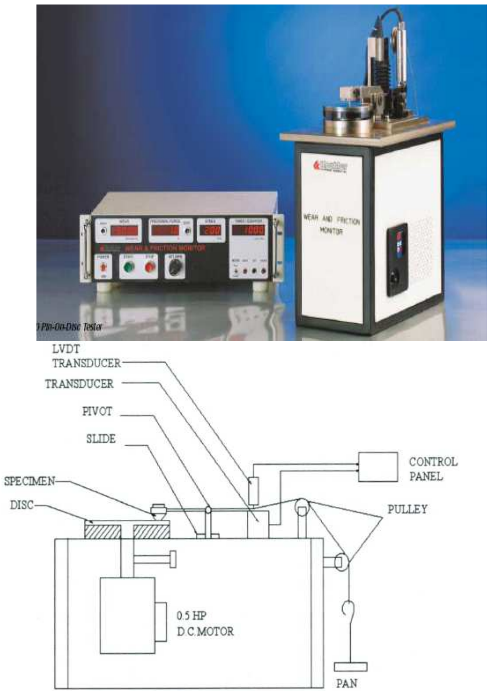

Fig. 1 Experimental setup of Pin on Disc Tribometer (TR-20LE)

Material for wear disc

The cast iron and the MMC disc are used for the test. The cast iron disc is going to be machined from a commercial passenger car brake rotor. The outer diameter and the thickness are 165 and 8 mm respectively. The surface is machined to an average roughness value of 1.5µm which is same as the roughness value of the sliding surface of the actual commercial brake rotor. The composition of the material is shown in Table I. The MMC was manufactured through the liquid metallurgy route (stir casting). A-356 aluminum alloy is used as matrix and silicon carbide particle of size 43µm as reinforcement. The alloy was melted in an electric furnace up to a temperature of 750ºC. When it reached the molten state a stirrer driven by a motor is introduced into the molten metal and a vortex was created on the top surface. The calculated (25% by weight) amount of preheated SiC particles is uniformly added and the stirring was continued. The composite slurry was then poured into a preheated cast iron mould. Then the solidified casting was removed and subjected to T6 heat treatment. The casting was then finished to a size of outer diameter and thickness as 165 and 8 mm respectively. The composition of the aluminum alloy is shown in Table II.

Materials for pin

To study the effect of candidate MMC material on the counter face friction material, a commercial semi-metallic brake shoe lining of a passenger car is going to be used as the pin for the wear test. The surface will be polished by using A320 emery paper. The surface will be cleaned and conditioned before starting of every experiment. The composition of the lining material is shown in Table III.

TABLE I
COMPOSITION OF GREY CAST IRON

Constituent	Percentage
Fe	93
C	3.2-3.5
Mn	0.6-0.9
P	0.12
S	0.15
Si	2.2

TABLE II
COMPOSITION OF A356 ALUMINIUM ALLOY

Constituent	Percentage
Al	90-93
Si	6-7.5
Mg	0.45
Cu	0.25
Mn	0.35
Fe	0.6
Ti	0.25
Zn	0.35

TABLE III
COMPOSITION OF AUTOMOBILE FRICTION MATERIAL

Constituent	Percentage
Phenolic resin	30
Asbestos fiber	45
Cu	4
Zn	3
Fe	4
Others	14

B. Experimental procedure

For tribotests Ducom pin on disc machine as shown in Fig.1 is used. The cast iron and the proposed MMC disc have been mounted on the machine. The lining material in the form of pin has been fixed on a holder, which has a provision for applying the load. A balance having an accuracy of 0.1 mg with a maximum weighing capacity of 200 g is used to find the mass of cast iron disc, MMC disc and SM lining material (pin). The machine is connected to a controller and a computer to control and measure sliding velocity, applied load, sliding time and frictional force. The disc and the SM lining have been weighed before and after the each test and the weight loss has been used as the measure of wear. The frictional forces are recorded in the computer. Although the frictional force varies with sliding time, an average value is considered for the analysis. The wear test is conducted by varying the load and keeping the speed and sliding distance as constant. Tests have been carried out for a sliding distance of 3000m and for each experimental point three tests have been conducted and the average value has been used. The above procedure is repeated for different speeds and sliding distances.

III. A CASE STUDY ON COMPARISON OF WEAR RESISTANT AL MMC AND GRAY CAST IRON

N. Natarajan et. al compared, the wear behaviour of aluminum metal matrix composite (Al MMC) sliding against automobile friction material with the conventional grey cast iron. The wear tests have been carried out on a pin on disc machine, using pin as brake shoe lining material and discs as A356/25SiCp Al MMC and grey cast iron materials. The friction and the wear behaviour of Al MMC, grey cast iron and the semi-metallic brake shoe lining have been studied at different sliding velocities, loads and sliding distances. Following are the results of investigation.

A. Wear Of Cast Iron Sliding Against Friction Material:

In the first phase, the wear of cast iron and the friction lining pin material have been determined from several tests conducted at different loads and speeds. The wear in terms of volume loss will be useful in order to determine the geometrical changes in the components. The variation of wear with load for cast iron disc sliding against friction lining is shown in Fig. 2(a). The wear is low at lower value of applied loads and increases with load at constant a ratio. At lower loads, the contact plateaus and temperature rise are low. So at lower loads, reduced wear is observed. As the applied load is increased, the wear loss is found to increase. Higher wear is observed for the maximum load. The same trend is also observed for the increased sliding velocity and is shown in Fig. 3(a).

B. Wear of MMC against friction material

The wear of MMC sliding against the friction material is determined for various loads and sliding velocities. The variation of wear with applied load is determined by keeping the load and the sliding velocity as constants. The same experiment is repeated for different sliding velocities. The wear is found to increase with applied load at a slower rate as shown in Fig. 2(b).For increase of sliding velocity, the wear is found to increase and it is shown in Fig. 3(b). In case of MMCs, it is observed that the surface film is formed on both the sliding surfaces but more at the MMC surface.

C. Wear comparison of cast iron and MMC

The comparison of wear of cast iron and the MMC sliding against the friction material under identical conditions are shown in Fig. 2. The wear is observed as 1.5 times high for cast iron. For MMCs, the wear is found to be low, because of the presence of the hard SiC particles present in the MMC which acts as the load bearing member and abrasive nature. The variation of wear with sliding velocity for cast iron and the MMC are shown in Fig. 3. In all these comparisons, the wear is found to be more for the cast iron material.

D. Wear of friction material against cast iron and the MMC

The wear of friction material is measured before and after every test and the results are analyzed. From Fig. 4(a) it is observed that the wear of lining material is found to increase with applied load and this increase is high for higher loads. At higher load the friction material is forced against the disc resulting in high temperature at

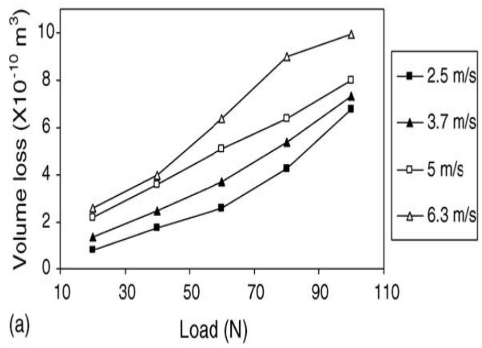

Fig.2 (a) Variation of wear in cast iron with applied load.

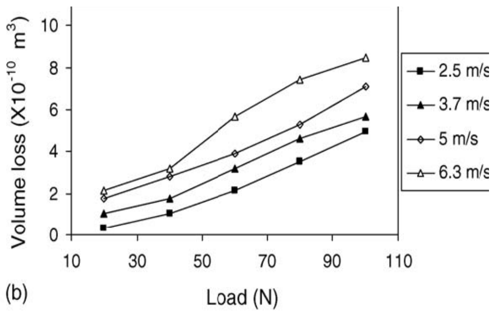

Fig.2(b) Variation of wear in MMC with applied load

the interface, thereby destroying the transfer film at a faster rate. So new transfer films are formed at faster rate enhancing the wear of the lining.

The variation of wear with sliding velocity is shown in Fig.5 (a). The variation of wear in lining material with applied load is shown in Fig. 4(b). The variation is more for the applied loads and very high at higher loads. The higher wear rate is because of the presence of the SiC particles in the counterface material. The protruding SiC particles from the counterface destroy the transfer film and plough the lining material. The variation of wear with sliding velocity is shown in Fig. 5(b).

E. Comparison of wear in friction material

The comparisons of wear in the friction material sliding against cast iron and the MMC under identical conditions are presented in Fig. 8. The comparisons of wear at different sliding velocities are shown in Fig. 9. It is observed that the variation of wear is less for lining material with sliding velocities. But in all the cases, it is observedthat the wear is more for SM friction lining while sliding against the MMC counterpart.

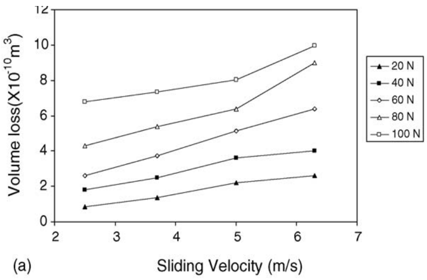

Fig.3(a) Variation of wear in cast iron and MMC with sliding velocity.(a)Cast iron

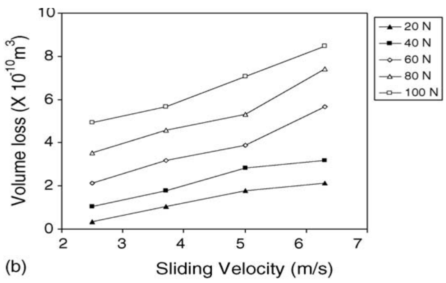

Fig.3 (b) Variation of wear in MMC with sliding velocity.

F. Frictional force:

The variation of frictional force with applied load for cast iron and friction material couple is shown in Fig. 6(a). More variations are observed with applied load than with the sliding velocity. At higher loads, the frictional force is higher because of more contact area at the friction material surface. The variation of frictional force while sliding against the MMC is shown in Fig. 6(b).

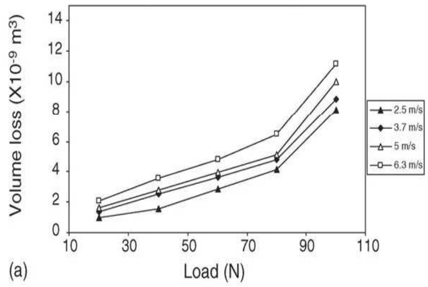

Fig.4(a) Variation of wear in semi-metallic lining material sliding against cast iron with applied load.

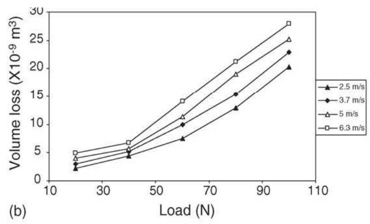

Fig.4(b) Variation of wear in semi-metallic lining material sliding against MMC with applied load.

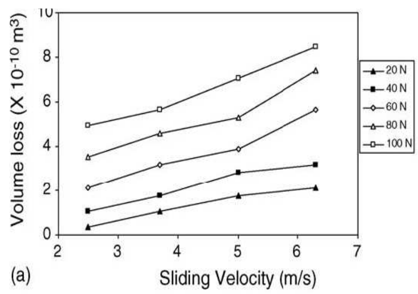

Fig.5(a) Variation of wear in semi-metallic lining material Sliding against cast iron.

Here, higher variations are observed for loads and lower variations for the variation of sliding velocities. The comparison of frictional force developed by these materials under identical conditions is presented in Fig. 6. In all these cases, the frictional force is observed as high for the MMC and the SM friction material sliding couple

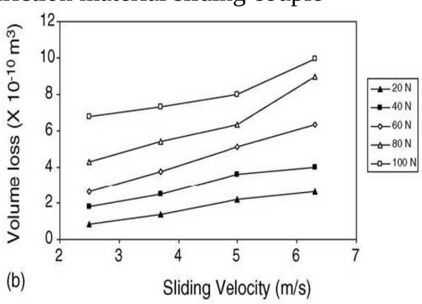

Fig.5 (b) Variation of wear in semi-metallic lining material sliding against MMC.

G. Friction coefficient:

There exists a definite ratio between the force developed and the applied force, called the friction coefficient. A stable and higher friction coefficient is essential for brake drum applications. The variation of friction coefficient for cast iron and lining material couple is shown in Fig. 7(a). The friction coefficient is observed high for lower loads and reduced for increase of applied loads. This is because at lower loads, the transfer film is found to be stable for more time and temperature rise is also low, whereas at higher loads the transfer film is destroyed at faster rate and the temperature rise is also high. The friction coefficient is also found to increase with sliding velocity as shown in Fig. 7(a).

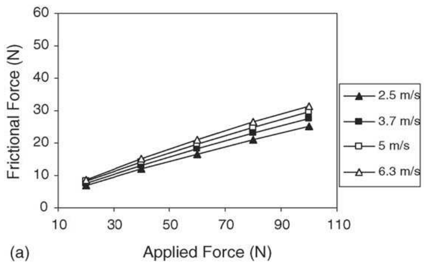

Fig.6 (a) Variation of frictional force with applied force sliding against cast iron.

For all loads, the friction coefficient is found to increase with increase of sliding velocity. The variation of friction coefficient for MMC and lining couple is shown in Fig. 7(b). In all observations it is found that the friction coefficient is slightly higher than the cast iron. The figure shows the uniform decrease in friction coefficient with applied load and uniform increase with sliding velocity.

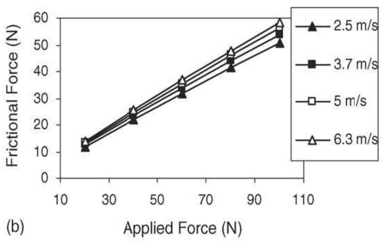

Fig.6 (b) Variation of frictional force with applied force sliding against MMC.

Similar variations are observed for the variations of applied load as mentioned above. The comparison of friction coefficient for cast iron and the MMC is shown in Fig. 7. The decrease in friction coefficient is found to be more for cast iron than MMC. At low applied load and sliding velocity the friction coefficient is observed less due to less formation of transfer film at the interface. At higher sliding velocities, the formation of transfer film is fast. Hence the friction coefficient is found to be slightly high. But at higher velocity and at higher loads, the formation and destruction of the transfer film is fast which results in reduced friction coefficient. However, in all these observations, the friction coefficient of MMC is found 1.25 times more than cast iron while sliding under identical conditions.

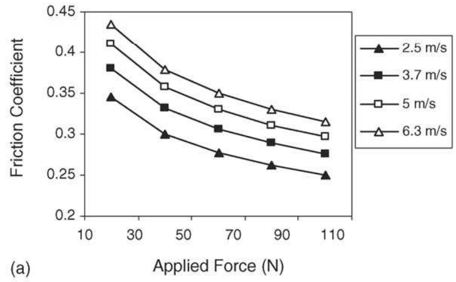

Fig.7 (a) Variation of friction coefficient with applied load sliding against cast iron.

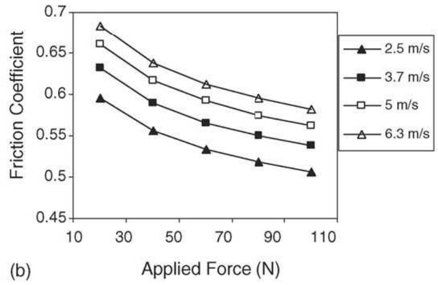

Fig.7 (b) Variation of friction coefficient with applied load sliding against MMC.

IV. CONCLUSION

The wear of Al MMC and cast iron with conventional brake pad material have been studied. In case study the tests on a pin on disc tribometer have been studied. After studying the case study following conclusions are registered:

(1) The wear of cast iron has been found to increase with applied load and sliding velocity. The friction coefficient was almost constant because of the formation of stable friction film at the interface. For the counter face friction material, the wear rate is slightly higher than the cast iron.

(2) The wear of MMC is lower than the cast iron. Since MMC has more wear resistance and stable friction coefficient, it can be a better candidate material for brake drum applications. The load and sliding velocity have less influence on the wear. However, for lining material the wear rate is very high because of the presence of the hard SiC particles in the disc.

(3) The wear of lining material sliding against cast iron is comparatively lower than the wear against the MMC. So there is the necessity of developing new friction material

which will have more wear resistance for using against the MMC materials.

(4) The frictional force variations with the applied force are determined at various speeds. It was found that the frictional force increased with applied load and sliding velocity. It can be also concluded that the frictional force in the MMC is 20% more than the cast iron sliding under identical conditions.

(5) The friction coefficient of the MMC is found to be 20% more than that of cast iron which will enhance the braking performance.

(6) The wear comparison study has shown that the MMC is more suitable candidate material for brake rotor applications, but a new friction material is to be developed.

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