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Wear behaviour of A356/25SiC$_p$ aluminium matrix composites sliding against automobile friction material

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Abstract

In the present paper, the wear behaviour of aluminium metal matrix composite (Al MMC) sliding against automobile friction material has been compared 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 A356/25SiC$_p$ Al MMC and grey cast iron materials. Pins of 10 mm diameter have been machined from a brake shoe lining of a commercial passenger car. The grey cast iron disc has been machined from a brake drum of a commercial passenger car. The Al MMC disc has been manufactured by stir casting technique using A356 aluminium alloy and 25% silicon carbide particles and machined to the required size. The friction and the wear behaviour of Al MMC, grey cast iron and the semi-metallic brake shoe lining have been investigated at different sliding velocities, loads and sliding distances. The worn surfaces and sub-surface regions of MMC, the cast iron and the lining have been analysed using optical micrographs. The present investigation 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. The wear grooves formed on the lining material while sliding against MMC and cast iron have been analysed using optical micrographs.

Keywords: Wear behaviour; Metal matrix composites; Semi-metallic friction material; Stir casting; Wear properties; Optical micrograph

1. Introduction

The ever-increasing demand for light weight, fuel efficiency and comfort in automobile industries has lead to the development of advanced materials along with optimized design. MMCs are widely used in industries, as they have excellent mechanical properties and wear resistance. Particulate-reinforced composites cost less than fiber-reinforced composites owing to the lower cost of fibers and manufacturing cost. In addition to improved physical and mechanical properties, particulate-reinforced composites are generally isotropic and they can be processed through conventional methods used for metals. Thus, the silicon carbide-reinforced aluminium composites are increasingly used as substitute materials for cylinder heads, liners, pistons, brake rotors and calibers [1,2] in automobile industry. The addition of low volume fraction of SiC particle (up to 8%) to Al–Si alloys significantly reduced the wear rate and the wear resistance has been found to increase with percentage of reinforcement [3]. The investigation carried out by Kwok and Lim [4,5] on pin on disc machine using aluminium alloy has shown that the wear rate has been increased with applied load and sliding velocity. Sahin [6] used statistical approach to investigate the wear of aluminium and its composites using factorial approach and formulated the wear rate as a function of applied load and abrasive particles. Semi-metallic (SM) friction material is a composite material consisting of metal powders like iron, copper and zinc which enhance the friction coefficient. The wear and frictional behavior of brake drum and semi-metallic (SM) friction material is very complex and is characterized by non-steady state, high temperature and high pressure process. Yang [7] has proposed a wear coefficient equation based on exponential transient wear volume equation and Archard equation. Moreover some

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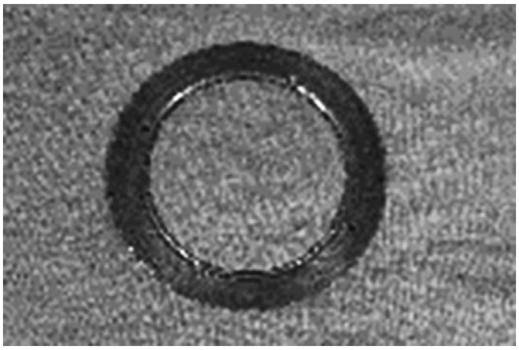

Fig. 1. Cast iron disc.

Table 1
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 2
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

investigators have studied the wear properties at elevated temperatures. Martin et al. [8] have investigated that the wear of SiC-reinforced Al alloys in the temperature range of 20–200 °C increased with temperature. All the above tests have been conducted by having MMC specimen as pin and hard steel disc as counter face. The above tests may not reflect the real wear behaviour in case of MMCs used for brake rotor applications. In these applications, the rotor material slides against automotive friction material and the friction coefficient are also high. Under these circumstances, a real study is needed to study the actual wear behaviour of these MMCs sliding against automotive friction lining. The friction and the wear of few MMCs and the automobile brakes are available in literature [9,10]. Ludema [11] has presented the sliding and adhesive wear mechanisms and proposed that the adhesive wear can be avoided by selecting dissimilar metal pairs for tribological applications. A comparative study on wear resistance MMC and white cast iron has been carried out by Berns [12] and concluded that the MMCs are better alternative materials for white cast iron normally found in wear applications. The wear resistance of cast irons commercially used for brake rotor applications has been investigated by Cueva et al. [13]. They have observed that the wear rate varies for different grades of cast iron and compact graphite iron is found to have more wear resistance. Zaidi and Senouci [14] investigated the real contact temperature and the friction coefficient of sliding surfaces. Czichos [15] suggested methods for presenting friction and wear data. Kennedy et al. [16] have investigated the tribological characteristics of several Cu based silicon carbide-reinforced MMCs synthesised from copper-coated SiC particles. They have observed that the Cu/SiCP MMC material sliding against friction material has worn less than cast iron. The tribological contact surfaces of organic brake pad have been presented by Eriksson and Jacobson [17]. Their investigation has shown that the increase in contact area results in an increased friction coefficient. Howell and Ball [18] have investigated the dry sliding wear of particulate-reinforced aluminium alloys against automotive friction materials. They have found that the specific wear resistance of MMC is higher than aluminium alloy and cast iron. The influence of load and temperature on the dry sliding wear of Al based composites against friction material has been investigated by Straffelini et al. [19]. They have found that wear resistance of Al MMC brake rotors are superior to those of cast iron rotor if the structure and the composition of lining material are correctly modified. But in all these investigations the real contact nature of rotor and lining material has not been used. Shorowordi et al. [20] investigated the effect of velocity on wear, friction of aluminium MMC sliding against phenolic brake pad. The investigation conducted by Celik et al. [21] has shown

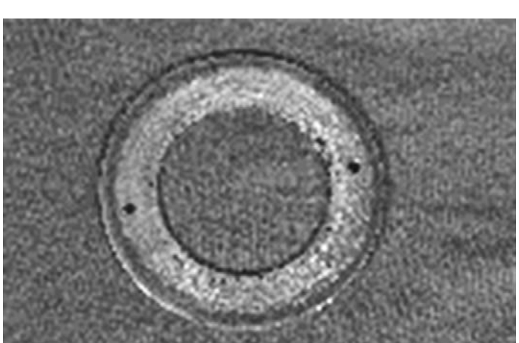

Fig. 2. MMC disc.

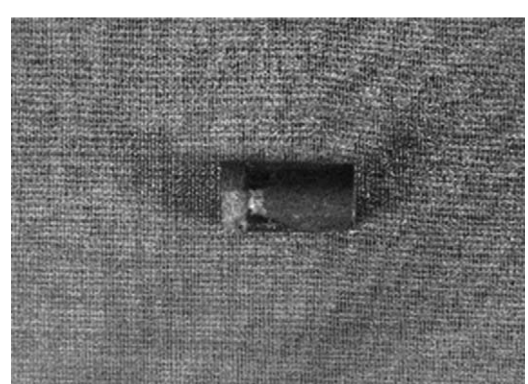

Fig. 3. Pin.