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Mechanical and dry sliding wear behavior of cenosphere particulate reinforced Al-Si12 matrix alloy composites produced by squeeze casting

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ABSTRACT – In this study, the effects of weight fraction of cenosphere on dry sliding wear behavior of Al-Si12 matrix alloy particle reinforced composites, fabricated by squeeze casting technique was investigated. Wear tests were carried out on a pin-on-disc wear tester at 0.5235, 1.0472, 1.5708 and 2.0944 m/s sliding velocity under loads of 5, 10, 15 and 20 N against EN 31 steel disc. The results showed that the higher the load and the faster the sliding velocity are, the higher the wear rate is. The coefficient of friction of the matrix alloy and composites decreased with increase with the load.

1. INTRODUCTION

In the last few years, the metal matrix composites (MMCs) have emerged as the best material in the various industries due to its novel properties. Increasingly, MMCs are being used to replace the conventional materials in many applications, especially in the automobile industries [1]. Casting is one of the most economical methods for fabrication of MMCs [2]. However, there are many drawbacks in conventional castings, such as porosity, hot tears, A and V segregates [3]. To overcome all these drawbacks, new casting techniques have been introduced. Among other casting methods, squeeze casting has more potential to create less defective cast components [4].

Most of the investigations on squeeze casting were carried out in cast aluminum alloys such as Al6061, AA603, Al2024, Al-Si8Cu3Fe, Al-Si7Mg, A357, A535 and A7010. However, no studies have been reported on the Al-Si12 matrix alloy with cenosphere by squeeze casting process. The present investigation is based on the dry sliding wear behavior of both the Al-Si12 matrix alloy and Al-Si12/cenosphere composites.

2. METHODOLOGY

The chemical composition of the Al-Si12 matrix alloy used in the present investigation is given in Table 1. The cenosphere is used as reinforcement in the present study, ordered from National Power Engineers, Kolkata, India. The size of the cenosphere particles are in the range of 30-200 μm, and the density is 0.6 g/cm^3.

Table 1 Chemical compositions of Al-Si12 alloy.

Elements	Percentage (%)
Cu	0.1
Mg	0.1
Si	10.0-13.0
Fe	0.6
Mn	0.5
Ni	0.1
Zn	0.1
Pb	0.1
Ti	0.2
Sb	0.05
Al	remainder

The calculated matrix alloy was melted at 800-900 °C in clay graphite crucible using an electric resistance melting furnace for 2-3 hours. The matrix alloy has been reinforced with 5, 7.5, 10, and 12.5 wt. % of cenosphere particles. The cenosphere particles were preheated at 40-50 °C in a separate muffle furnace for 2-3 hours to remove moisture and other gasses. The preheated cenosphere particles were then added to the melt, and the melt was stirred at 100-150 rpm by a mechanical stirring system. A 100-ton hydraulic press with close control on the rate of application of pressure, dwell time and ejection facilities was used for squeeze casting. The hot pressing die of H13 steel had a mould cavity with a dimension of 130 mm x 50 mm x 50 mm. The initial die temperature was maintained at about 100-120 °C by controlled electrical resistance heating. The composite melt was poured into the preheated die cavity before the application of pressure. The pouring temperature of the composite melt was kept constant at 720 °C. The squeeze pressure was maintained at a level of 50 Mpa within a dwell period of 2 min, and then the solidified casting was ejected. After cooling the solidified casting was subjected to machining and samples of suitable size for different experimentation were obtained. Samples of the unreinforced matrix alloy were squeeze cast in a similar manner under the same conditions.

The dry sliding wear tests were carried out on a pin-on-disc wear testing machine designed as per ASTM G-99 standard, supplied by Magnum Engineers, Bangalore, India. The tests were performed under a dry condition at room temperature.

3. RESULTS AND DISCUSSIONS

Fig. 1 shows the variation of the coefficient of friction of the Al-Si12 matrix alloy and composites with load at 0.5235 m/s sliding velocity. It can be seen that the coefficient of friction of the matrix alloy and composites decreased with increasing load. The friction coefficient decreases with increase in the wt. % c/s. There are two reasons for decrease in coefficient of friction with increase in load-

1. Due to increase in load the temperature of the contact surface increases and softens the surface of the pin. So, friction coefficient decreases.
2. When the load increases more wear of pin surface occurs, and the wear debris stuck in between pin and counter surface and acts as roller ball. Therefore, the coefficient of friction decreases.

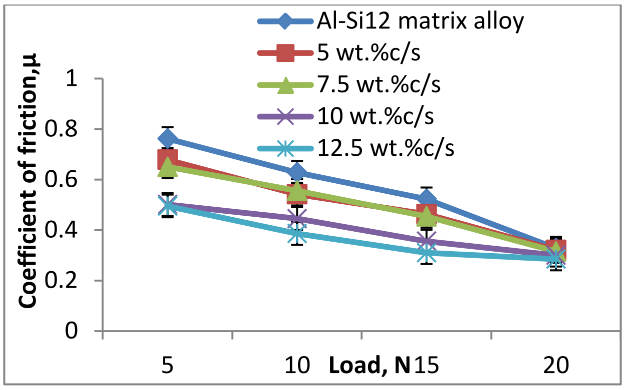

Figure 1 Variations in coefficient of friction with loads

Fig. 2 presents the variation of wear rate of matrix alloy and composites with load at 1.0472 m/s sliding velocity. The wear rate increased with the increase in the load. This can be attributed due to following reasons-first one- At low load, mild wear was examined, but as the load increased beyond 10 N, the severe wear occurred. The second one- During the initial stage of abrasion, abrasive is in contact with the matrix, has less hardness as compared to angular silica sand (abrasive) particles. At that particular instance, the ratio Ha (hardness of the abrasive particle)/Hs (hardness of the surface) is much more than unity, resulting in severe matrix damage and the rate of material removal is very high. Thus, the specific wear rate is more. When the load increases, cenosphere particles get in contact with abrasive particles, Ha/Hs ratio is a little more than unity; as a result, cenosphere particles provide better resistance to the process of abrasion and reduce the wear rate.

Fig. 3 represents the variation of SWR of matrix alloy and composites with sliding velocity. The SWR first decreased with increasing sliding speed up to 1.5708 m/s and then increased with further increasing sliding velocity. This is because, at slow sliding velocity, the sliding surface was covered with oxide like mechanically mixed layer (MML) formed at the sliding interface and minimized direct metallic contacts. This resulted in lower wear rate. At very high-velocity thermal softening of the matrix and localized melting on the interface, surfaces were reported. This causes the breakdown of the MML and allows more direct metallic contact during sliding, and cenosphere particles became dislodged, and suddenly huge wear resulted.

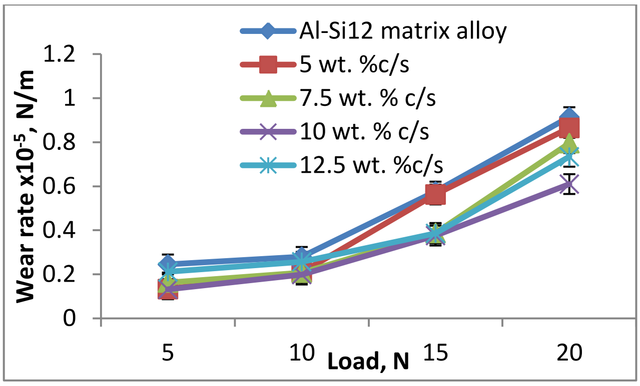

Figure 2 Variations in wear rate with loads

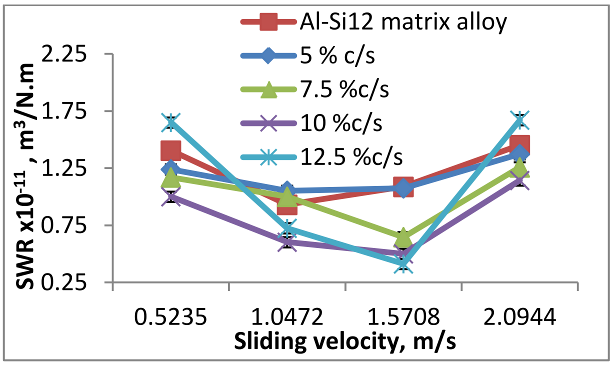

Figure. 3 Variation in SWR as a function of sliding velocity

4. CONCLUSIONS

1. The coefficient of friction of the matrix alloy and composites decrease with increasing load.
2. The wear rate increases with increase in the load.
3. The SWR increases with increase in the sliding velocity.

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