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A study on wear behaviour of Al/6101/graphite composites

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ABSTRACT

The current research work scrutinizes aluminium alloy 6101-graphite composites for their mechanical and tribological behaviour in dry sliding environments. The orthodox liquid casting technique had been used for the manufacturing of composite materials and imperilled to T6 heat treatment. The content of reinforcement particles was taken as 0, 4, 8, 12 and 16 wt.% of graphite to ascertain it is prospective as self-lubricating reinforcement in sliding wear environments. Hardness, tensile strength and flexural strength of cast Al6101 metal matrix and manufactured composites were evaluated. Hardness, tensile strength and flexural strength decreases with increasing volume fraction of graphite reinforcement as compared to cast Al6101 metal matrix. Wear tests were performed on pin on disc apparatus to assess the tribological behaviour of composites and to determine the optimum volume fraction of graphite for its minimum wear rate. Wear rate reduces with increase in graphite volume fraction and minimum wear rate was attained at 4 wt.% graphite. The wear was found to decrease with increase in sliding distance. The average co-efficient of friction also reduces with graphite addition and its minimum value was found to be at 4 wt.% graphite. The worn surfaces of wear specimens were studied through scanning electron microscopy. The occurrence of 4 wt.% of graphite reinforcement in the composites can reveal loftier wear possessions as compared to cast Al6101 metal matrix.

1. Introduction

Conventional aluminium metal matrix and its alloy show a receptacle protagonist in various technological areas such as aerospace, marine, nuclear, structures and automobile due to its low weight to strength ratio and excellent mechanical properties. Nevertheless, the punitive situation of aluminium alloy is that, they possess low resistance to abrasive wear in discrepancy lubricating environments and spartan preservation of lubricating film over the sliding surface, which turn out to be vain to tribological applications. To increase their tribological properties, aluminium alloy reinforced with graphite particulate composites had been explored. These Al/Graphite (self-lubricating) composites had been emphasized because of their anti-seizure influence [1–4], high damping absorption capacity, low coefficient of thermal expansion [5,6], low wear and coefficient of friction [7–11] and decreased temperature rise at wearing interaction surface [12]. Previous investigators had conveyed that in dry sliding environments Al/Graphite composites resulted in to development of an incessant film of solid lubricant [13–20] which had been formed on tribo-surfaces. This phenomenon happens as a consequence of cutting of graphite reinforcement particles which are situated underneath the sliding surface of composite, which assist in decreasing the extent of shear stress, which assuages the plastic deformation in the subsurface area, obstructs metal-to metal interaction and performs as solid lubricant between two sliding surfaces therefore decreasing wear, coefficient of friction and seizure resistance of the composites [18].

Hence development and preservation of this tribo-layer on the sliding surfaces, gearstick the wear behaviour of the composites by its features like; area of fracture, composition, thickness and hardness. Tribo-layer formation depends upon the nature of sliding surfaces, content of graphite and environment (dry/lubricated) in the composite. It had been explored that increasing the content of graphite reinforcement in Al/Graphite composites, wear rate of composite lowered [11,17,18]. Besides this, wear rate also simultaneously increased with increase in the volume fraction of graphite

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Table 1
Chemical composition of base metal AA6101.

Constituent	Al	Si	Mg	Cu	Mn	Cr	Fe	Zn
Content (wt.%)	97.6	0.30–0.70	0.35	0.10	0.03	0.03	0.50	0.10

Fig. 1. Casting facility used to prepare Al6101/Graphite AMCs.

reinforcement because of decrease in hardness and toughness of Al/Graphite composites [11,18–24]. In various conditions, transition of wear rate from mild to severe range takes place as a result of effect of graphite content in Al/Graphite composites. Therefore this research work aims to assess the influence of graphite on the tribological behaviour of Al6101/Graphite composites, in terms of rate of wear and coefficient of friction in dry sliding environments; and to estimate the optimum volume fraction of graphite addition in Al6101.

2. Experimental procedure

Aluminium Al6101 of commercial grade was used as the matrix material and graphite particles with size varying from 26 to 30 μm was used as the reinforcement material. Table 1 displays the chemical composition of Al6101 used in this research work. An orthodox casting technique was used for the manufacturing of composites. Set-up for stir casting technique is displayed in Fig. 1. The proper amount of Al6101 was heated in a graphite crucible placed in an electric furnace. The graphite was also preheated to 720 °C with the help of a separate electric furnace. After melting the Al6101 in the electric furnace, graphite reinforcement particles (preheated) were added and mixed molten mixture was stirred at 550 rpm for 10 min by using an electric motor which is fitted with a mechanical stirrer. The temperature was kept constant (800 °C) during whole stirring. The molten aluminium alloy split into droplets because of shear force imparted by the stirrer at the presence of graphite [18]. Now the molten mixture was exiled from the graphite crucible into a permanent preheated (500 °C) steel mould. The molten mixture was allowed to solidify in steel mould. The casted composite was

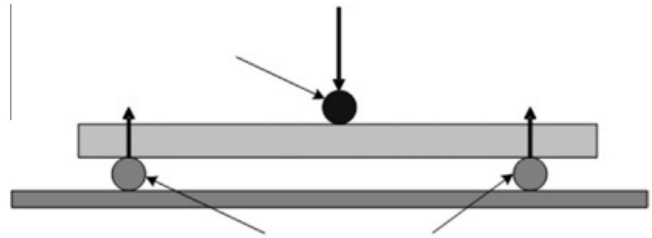

Fig. 3. The line layout of three point bending test.

subjected to T6 heat treatment. Heat treated composite was tested for various tests. The same procedure was followed to manufacture all other composition. The composites were manufactured at 0, 4, 8, 12 and 16 wt.% of graphite reinforcement particles.

Hardness measurement was carried out on a Vickers hardness testing machine with a load of 500 g and mean values of atleast five measurement from different areas on specimen were taken. The specimen for tensile test was made in accordance with ASTM E08 standard [25]. A distinctive tensile specimen is displayed in Fig. 2. The ultimate tensile strength was evaluated on computerized universal testing machine (HITECH TUE- C-1000, India) [26]. The flexural strength was assessed with the help of three point bending test (Fig. 3), to know the extreme load which the composite can withstand. Wear samples were prepared according to ASTM G99-95 standards, the wear tests were conducted using Pin-on-disc apparatus (Fig. 4) at room temperature (35 °C) and humidity 55–65%.

The wear tests were conducted at 0.4, 0.8, and 1.2 m/s sliding speed and 15, 30, and 45 N applied loads and with 1200 m as the sliding distance for 300 m as regular intervals. Wear samples (pins) with 50 mm height and 6 mm diameter were used for the wear test. The end surface of the wear test pins was properly cleaned and polished with abrasive papers of grades 400, 600, 800, 1000, and 1200 respectively. The wear rate was measured by weight loss method. The weight of the each wear sample was measured using an electronic weighing balance with resolution of ±0.1 mg. Scanning Electron Microscopy (Surpa 40 VP Bruker System, Germany) was used for examining the morphology of the worn surfaces of the wear specimens.

3. Results and discussion

Fig. 5 displays a reduction in hardness with increase in volume fraction of graphite reinforcement particles in Al6101. This decrease in hardness may be due to low hardness of graphite of 25.49 VHN as compared to 47.9 VHN of aluminium. Further the brittle nature of graphite due to increased content causes the composites to deform plastically. This behaviour is in good agreement with the results of previous researchers [9,18,19,27–30].

The ultimate tensile strength (UTS) decreased from 164 MPa to 147 MPa (Fig. 6) with a linear increase in graphite content in Al6101.

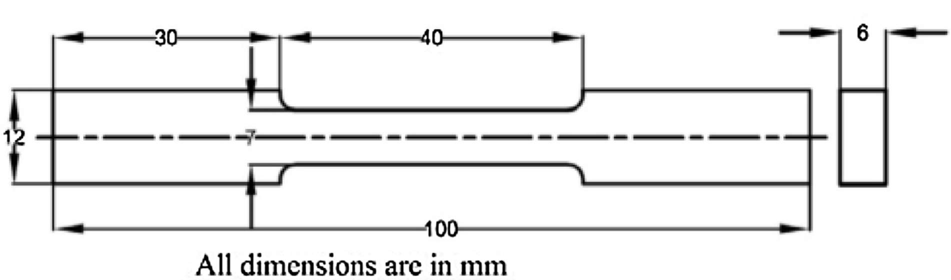

Fig. 2. Typical tensile test specimen.

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