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Wear and mechanical characteristics of Al 7075/graphite composites

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ABSTRACT

This work investigates 7075 aluminium alloy–graphite composites for its tribological and mechanical behaviour under dry sliding conditions. The conventional liquid casting technique was used for the fabrication of composite material and subjected to T6 heat treatment. The reinforcement content was chosen as 5, 10, 15 and 20 wt.% of graphite to identify its potential for self-lubricating property under dry sliding conditions. Wear tests were conducted by using pin on disc apparatus to evaluate the tribological behaviour of the composite and to determine the optimum content of graphite for its minimum wear rate. The wear rate decreases with addition of graphite content and reaches its minimum at 5 wt.% graphite. The wear mass loss was found to decrease with increasing sliding distance. The average coefficient of friction decreases with addition of graphite content and was found to be minimum at 5 wt.% graphite. The mechanical properties of the composites and base alloy were tested. The mechanical properties decrease with increasing graphite content as compared to base alloy. The worn surfaces were examined through SEM. The presence of 5 wt.% graphite in the composites can exhibit superior wear property as compared to base alloy.

1. Introduction

Aluminium and its alloys play a crucial role in various technological fields such as automobile and aerospace sectors owing to their excellence in strength to weight ratio and other mechanical properties. However the adversity of aluminium alloys is that they exhibit low resistance to abrasive wear under deficit lubricating conditions and severe retention of lubricating film over the sliding surface which becomes abortive to tribological applications. To improve their tribological properties, aluminium alloy graphite particulate composites are being explored. These self-lubricating composites have accentuated due to their excellent anti-seizure effect [1–4], low thermal expansion, high damping capacity [5–6], low friction and wear [7–10] and reduced temperature rise [11] at the wearing contact surface.

Earlier researchers have reported that during dry sliding the metal/Graphite composites develop a continuous layer of solid lubricant [12–16] which is formed on the tribosurface. This phenomenon occurs as a result of the shearing of graphite particles which are located underneath the sliding surface of the composite which helps in reducing the magnitude of shear stress, alleviates the plastic deformation in the subsurface region, inhibits metal-to-metal contact and acts as solid lubricant between two sliding surfaces hence reducing friction, wear and improves seizure resistance of the composite. Therefore formation and retention of this tribolayer on the sliding surface controls the wear behaviour of the material by its characteristics such as area of fracture, thickness, hardness and its composition. It relies on the nature of sliding surface, environment and graphite content in the composite. It has been analysed that by means of increasing the graphite content [16] in Al/Graphite composites, the wear rate is lowered. It is some declarations that by increasing the graphite content, the wear rate also simultaneously increases due to the decrease in fracture toughness and hardness [17–20] of composites. In some cases during sliding, there occurs a transition of wear rate from mild to severe range due to the effect of graphite content in these composites. Hence this attempt aims to evaluate the effect of graphite on the tribological behaviour of Al 7075 composites which is made by liquid casting method, in terms of wear rate and friction coefficient under dry sliding conditions; and to evaluate the optimum amount of graphite addition in Al 7075.

2. Experimental procedure

Commercial grade aluminium Al 7075 was used as the matrix material and graphite particles with sizes ranging from 20 μm to 26 μm was used as the reinforcement material. The chemical composition of the Al 7075 is shown in Table 1. A conventional casting route was used for fabricating the composites. The appropriate weight of the aluminium was charged in a graphite crucible and was heated in an electrical furnace. The graphite particles were preheated at 750 °C in a separate furnace. After melting the charge in the furnace, the preheated graphite particles were added and the

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Table 1
Chemical composition of Al 7075.

Zn	Cu	Mn	Mg	Fe	Cr	Ti	Si	Al
5.4	1.42	0.12	2.42	0.42	0.21	0.11	0.13	89.77

mixed charge was stirred at 500 rpm for five minutes by using an electric motor during which the temperature was kept constant at 800 °C. Due to the stirring action, the melted aluminium alloy split into droplets due to the shear forces induced by the impeller at the presence of graphite. Now the charge was evacuated from the crucible into a steel mould and it was solidified. The casted composite materials were subjected to T6 heat treatment. These heat treated composite materials were used for various tests. The same procedure was repeated for all other compositions. The composites were fabricated at 5, 10, 15 and 20 wt.% of graphite.

Hardness measurements were carried out on a Rockwell hardness testing machine using a load of 100 kg and the mean values of at least four measurements from different areas on the sample were taken. And the flexural strength was measured using three point bending test (Fig. 1), to find the maximum load withstanding ability of the composites.

According to ASTM G99-95 standards, the wear tests were conducted using Pin-on-disc apparatus (Fig. 2) at room temperature (30 °C) and humidity 60–65%. The tests were conducted at 0.6, 0.8 and 1.0 m/s sliding speed and 10, 20 and 30 N applied loads and with 1000 m as the sliding distance for 250 m as regular intervals. Pins with 6 mm diameter and 50 mm height were used for the Wear test. The surface of the pin was polished and was rotated against an OHNS disc which was heat treated to a hardness of 62HRc. The wear tests were conducted after the initial run in period when the pin specimen was entirely in contact with the disc surface. The wear rate was calculated using weight loss method. The weight of the each specimen was measured using an electronic weighing balance with resolution of ±0.1 mg. Scanning Electron Microscopy (JOEL model 6390) was used for analysing the morphology of the worn surfaces of the pins.

3. Results and discussion

Fig. 3 shows a decrease in hardness with increasing graphite content in Al 7075. This is due to increasing brittle nature of graphite particles, which easily tends the composites to deform plastically. This behaviour is in good agreement with the results of Ted Guo and Tsao [9]. The flexural strength of the base alloy and composites are shown in Fig. 4. The flexural strength decreases with increasing graphite content and the addition of graphite causes an increase in the tendency of initiation of crack and propagation at the interface between graphite and matrix. This result is in good agreement with other studies in this field [2].

The wear rate of the base alloy and its composites with varying graphite content is shown in Fig. 5. The wear rate decreases with increasing graphite content and it was found to be minimum at

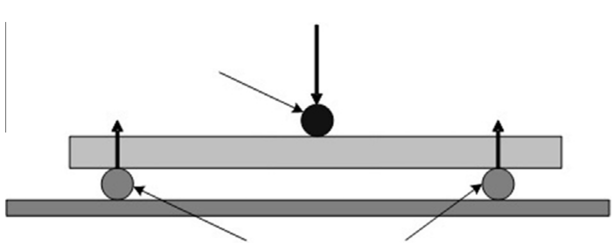

Fig. 1. The layout of three point bending test.

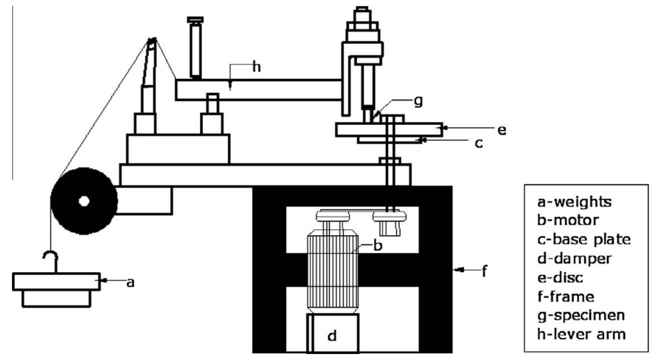

Fig. 2. A schematic diagram of pin on disc apparatus.

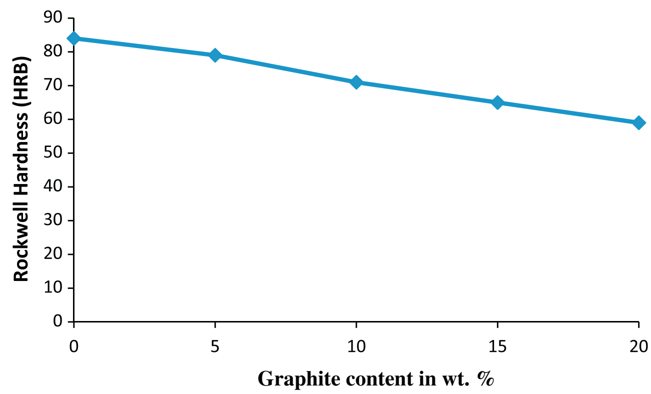

Fig. 3. Hardness with varying graphite content.

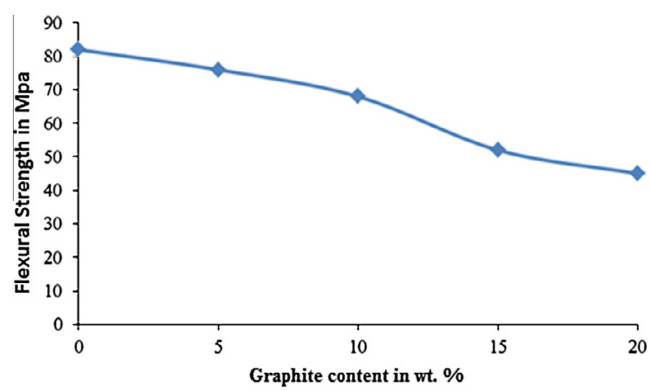

Fig. 4. Variation of flexural strength with varying graphite content.

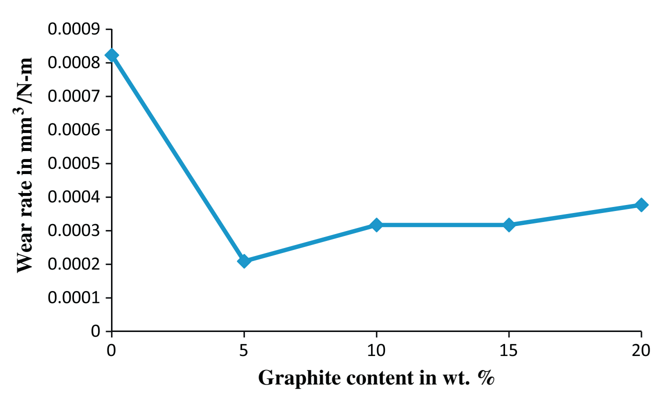

Fig. 5. Variation of wear rate with varying Graphite content.