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Short communication

Wear behaviour of cast hypereutectic aluminium silicon alloys

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Abstract

In the present paper, influence of alloying elements on wear behaviour of binary (Al–17%Si) and multi-component (Al–17Si–0.8Ni–0.6Mg–1.2Cu–0.6Fe) cast hypereutectic aluminium alloys has been reported. Experimental alloys were prepared via foundry technique. Wear behaviour of Al–17Si and Al–17Si–X {X = Ni, Cu, Mg, Fe} alloys was studied using pin on disc (ASTM: G99) type of friction and wear testing machine. Dry sliding wear tests were performed at various sliding speeds (0.2–4.0 m/s) and contact loads (10–30 N) against hardened ground steel disc (hardness 60 HRC). It was observed that the addition of alloying element not only reduces the wear rate in mild oxidative wear condition but also increases the transition load. Temperature of wear pin near the sliding surface was measured and it was related to wear and friction behaviour of experimental alloys. Increase in hardness was also noticed due to alloying. SEM study of wear surface and wear debris was conducted to analyse the mode of wear and wear mechanism.

Keywords: Cast Al–Si alloy; Alloying elements; Dry sliding wear; Transition load; Mild oxidative and severe metallic wear; Sliding speed; Interface temperature

1. Introduction

Use of cast Al–Si alloys as a tribological component in recent years has been expanding widely in military, automobile and general engineering industry [1–6]. The wear behaviour of these alloys depends on a number of material related parameters, i.e., shape, size, composition and distribution of micro constituents in addition to the service conditions such as load, sliding speed, temperature, environment and counter surface [5–9]. The presence of silicon as alloying elements in these alloys improves wear resistance significantly [7,9,10]. However, Bai et al [10] concluded that there is no systematic trend in wear of Al–Si alloys with respect to silicon content. Wear resistance in mild (oxidative) wear situations has been found maximum at about eutectic composition [11,12]. Seizure resistance improves with the silicon addition beyond the eutectic composition in aluminium alloys [13]. Addition of modifiers (such as sodium, antimony, strontium and phosphorous) and refiners (such as Al–Ti–1B and Al–Ti–C) is not yet very clear for their affect on wear resistance [14,15]. Transition-load at which the mode of wear changes (oxidative to metallic) and wear resistance increases by the presence of alloying elements, particularly Cu, Ni and Mg [16]. The effect of alloying elements on transition load and seizure resistance has not been reported in light of frictional heating over a wide range of speed, i.e., 0.2–4.0 m/s. To increase the understanding further in this area, wear studies were carried out on binary Al–17Si alloy and Al–17Si-0.8Ni–0.6Mg–1.2Cu–alloy.

2. Experimental procedure

2.1. Material

Experimental alloys were prepared by controlled melting of high purity aluminium, Al–28%Si and

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Al–10%Mg, Al–30%Cu, Al–10%Fe and Al–10%Ni master alloys in appropriate proportions in a graphite crucible using a muffle furnace at 850 ± 5 °C. Molten metal was poured in metallic mould of size $25 \times 25 \times 150$ mm. Alloys were refined by adding 0.01% P in the form of red phosphorous. Wear test pins (cylindrical) of diameter 6 mm and length of 20 mm were prepared by turning and one end of the pin was polished.

2.2. Friction and wear behaviour

A pin on disc type wear monitor (DUCOM, TL-20, Bangalore) with data acquisition system was used to evaluate the wear friction behaviour of aluminium alloys against hardened ground steel disc having hardness of RC60 and surface roughness (R_a) of 0.5 μm. Principle diagram is shown in Fig. 1. Load was applied on pin by dead weight through pulley string arrangement. The system had maximum loading capacity of 200 N. Disc was rotated by D.C. motor, having a speed range of 0–2000 rev min^{-1} to yield sliding speed of 0–10 m/s. Weight loss was used as a measure of wear. Counter surface was abraded against carbide polishing papers and cleaned with acetone and dried before each sliding test in order to maintain the identical sliding conditions. Temperature and wear were acquired at a rate of five samples per second during the 60 min of sliding at various velocities, 0.2, 1.0, 2.0, 3.0, 4.0 and 5 m/sec constant normal load in the range of 10–40 N. Variation in disc revolution per minute (at 80 mm track diameter) was used to regulate the sliding speed. Sliding conditions have been considered as seizure like conditions when a lot of vibration, noise and gross metal transfer takes place . The friction force was recorded during the experiment by using a load cell (accuracy 0.1 N and capacity 200 N).

2.3. Temperature measurement

Temperature measurements of wear pin during the sliding were carried out using three chromel–alumel thermocouples. These thermocouples were inserted into three holes each of 1 mm diameter at 1.5, 3.0 and 4.5 mm away from sliding surface drilled up at axis of cylindrical pin. To find out the temperature exactly at the sliding surface, extrapolation method was used. This sliding surface temperature has been referred to as interface temperature in the forgoing section. Temperatures were noted with the help of digital temperature indicators after 2000 m of sliding distance. Temperature at sliding surface can be important in explaining the friction and wear because mechanical properties of material and surface oxidation are affected by temperature.

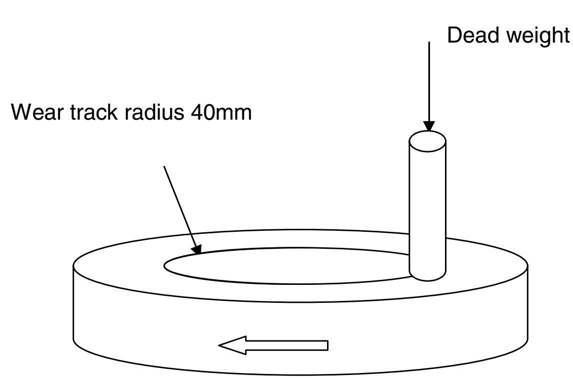

Fig. 1. Principle diagram of pin on disc wear monitor.

2.4. Mechanical test

Hounsfield computerised tensile testing machine was used to carry out tensile test at 1 mm/min strain rate for tensile strength and ductility by using a diameter of 6.2 mm and gauge length of 23.2 mm as tensile sample. Vickers hardness test was performed at 5 kg load to study the effect of alloying on hardness and to relate it with wear friction behaviour.

3. Results

3.1. Wear behaviour

Wear (weight loss) of binary Al–17Si alloy and Al–17Si–0.8Ni–0.6Mg–1.2Cu–0.6Fe alloy, as a function of sliding time at constant speed of 4 m/sec and various

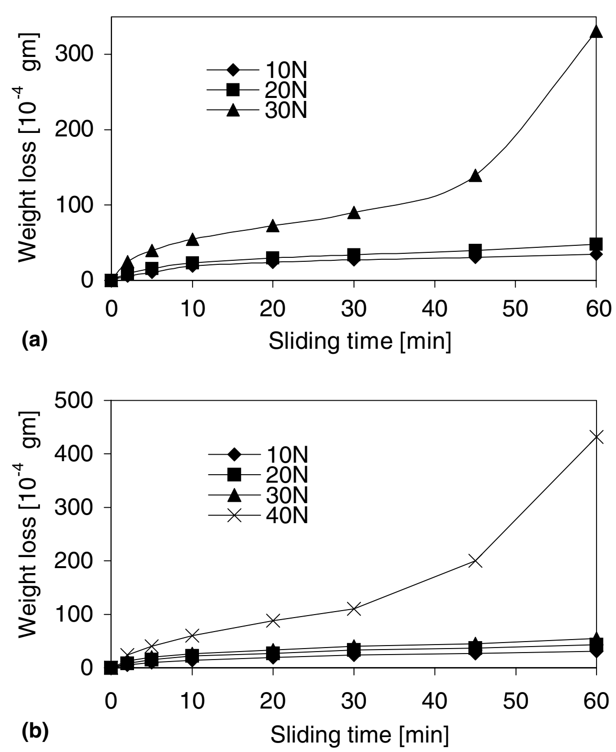

Fig. 2. Weight loss-sliding time relation for (a) binary (b) multi-component alloy at constant 4.0 m/sec sliding speed and various contact loads.