"A Review on effect of grain refinement and modification on the dry sliding wear behaviour of eutectic Al– Si alloys"

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ABSTRACT

The effect of grain refiner and modifier on the wear behaviour of Al–Si alloys has been investigated using a Pin-On-Disc machine. Various parameters such as alloy composition, normal pressure, sliding speed and sliding distance were studied on Al–Si alloys. The cast master alloys (Al–Ti–B and Al–Sr) were then characterized by optical microscopic analysis. The results suggest that the wear resistance of Al–Si alloys increase with the addition of grain refiner and modifier as compared to the absence of grain refiner and or modifier. The present results also reveal an improvement in tribological properties, obtained due to the change in microstructure from coarse columnar dendrites to fine equiaxed dendrites and plate like eutectic Si to fine particles due to the addition of Al-Ti–B grain refiner and modifier (Sr), respectively. we are prepared samples for using both gravity-die and sand casting and also determine wear resistance for this sample and wear results compare with each other.

Keywords: Al–Si alloys, Al–Ti–B grain refiners, Al–Sr modifier, Sliding wear

I. Introduction

Wear is one of the most commonly encountered industrial problems leading to the replacement of components and assemblies in engineering [1]. Therefore, many efforts have been made to produce more durable materials and techniques to reduce the wear of tools and engineering components. These include modification of bulk properties of the materials, surface treatments and application of coating, etc. Over the last few years, many efforts have been made to understand the wear behaviour of the surfaces in sliding contact and the mechanism, which leads to wear [2]. The applications of aluminium and its alloys for the machine parts are increasing day to day in the industry. However, little has been reported on the wear behaviour of aluminium and its alloys with the addition of grain refiner and modifier [3]. Amongst the commercial aluminium casting alloys perhaps Al–Si alloys are the most common, particularly due to some very attractive characteristics such as high strength to weight ratio, excellent castability and pressure tightness, low coefficient of thermal expansion, good thermal conductivity, good mechanical properties and corrosion resistance [4]. Al–Si alloys find wide range of applications in marine castings, motor cars and lorry fittings/pistons and engine parts, cylinder blocks and heads, cylinder liners, axles and wheels, rocker arms, automotive transmission casings, water cooled manifolds and jackets, piston for internal combustion engines, pump parts, high speed rotating parts and impellers, etc. [5]. The in-service performance of the Al–Si alloy castings primarily depends on their microstructures. Basically, the microstructure consists of the primary phase α-Al in hypoeutectic, primary Si in hypereutectic alloy and Al–Si eutectic constituent. It is essential that these alloys solidify with fine equiaxed α-Al in hypoeutectic/fine primary Si particles in hypereutectic and fine eutectic Si. While the former can be achieved by suitable grain refinement treatment/ solidification processing and later the can be achieved by modification [6]. A fine grain size ensures improved mechanical properties, improved feeding during solidification, reduced and more evenly distributed shrinkage porosity, good tribological properties, uniform distribution of second phase particles on a fine scale and good surface finish resulting in improved machinability [7–8]. The wear resistance of these alloys may depend on the hardness of the matrix and the dispersed second phase Si particles/plates in the Al–Si alloys. The distribution state of the Si particles in the Al–Si alloys can be changed by modification [9]. Therefore, Al–Si alloys are suitable for studying the effect of second phase particle on the tribological and mechanical properties of the alloys.

The present investigation is an attempt to investigate the possibility of improving the tribological properties of Al-Si alloy through melt treatment.Al-Si alloy was refined with Al-Ti-B and modified by Al-Sr. Influence of melt treatment on dry sliding wear has been studied.

II. EXPERIMENTAL PROCEDURE

T.M. Chandrashekharaiah, S.A. Kori investigated on dry sliding wear behaviour of grain refined and/ or modified eutectic (Al–12Si) Al–Si alloy by using a Pin-On-Disc machine. The indigenously developed Al–1Ti–3B and Al -10Sr master alloys were used as grain refiner and modifier for the grain refinement of α-Al dendrites and modification of eutectic Si, respectively. Various parameters have been studied such as alloy composition, sliding speed, sliding distance and normal pressure. The cast alloys, master alloys and worn surfaces were characterized by SEM/EDX microanalysis. They performed an experiment on Al–12Si alloy was prepared using the commercial-purity Al and Al–20% Si master alloy. Commercially available LM-6 (12.5%Si) alloy was used for comparison study. Melting of Al–12Si and or LM-6 alloy was carried out in a resistance furnace under a cover flux (45%NaCl+45%KCl+10%NaF) and the melt was held at 720 °C. After degassing with solid hexachloroethane (C2Cl6), master alloy chips (Al–1Ti–3B and Al–10Sr) were added to the melt for grain refinement and/or modification. The wear tests were carried out under varying normal pressures (0.195, 0.390, 0.584, 0.780, 0.975 and 1.170 N/mm^2), different sliding speeds (0.942, 1.884 and 2.827 m/s) and with different sliding distances (282.743, 565.486, 848.230, 1130.970, 1413.710, and 1696.460 metre). Wear loss was measured with a linear variable differential transformer (LVDT) and was monitored by the loss of length of the specimen of the fixed diameter due to wear and wear loss was measured in microns. They concluded that Wear rate of Al–12Si and LM-6 alloys increases with increase in normal pressure and sliding distance and decreases with increase in sliding speed and also less wear rate (volume loss) was observed in case of the alloys containing grain refiner, modifier and combined addition of both as compared to the untreated alloys, due to the change in microstructure and leads to improvement in wear behaviour of the alloys [10].

S.A. Kori, T.M. Chandrashekharaiah worked on effect of grain refiner and/ or modifier on the wear behaviour of hypoeutectic (Al–0.2, 2, 3, 4, 5 and 7Si) and eutectic (Al–12Si) alloys have been investigated using a Pin-On-Disc machine. Various parameters such as alloy composition, normal pressure, sliding speed and sliding distance were studied on the hypoeutectic and eutectic Al–Si alloys. The cast master alloys (Al–5Ti–1B, Al–1Ti–3B and Al–10Sr) and worn surfaces were characterized by SEM/EDX microanalysis. The results suggest that the wear resistance of hypoeutectic and eutectic Al–Si alloys increase with the addition of grain refiner and or modifier as compared to the absence of grain refiner and or modifier. They performed an experimental on Al–Si alloys (0.2, 2, 3, 4, 5, 7 and 12 wt% Si) were prepared by using a commercial purity aluminium (99.7%) and Al–20 wt% Si master alloy. Melting of the alloy was carried out in a resistance furnace under a cover flux (45%NaCl + 45%KCl + 10%NaF) and the melt was held at 720 ◦C. After degassing with solid hexachloroethane (C_2Cl_6), master alloy chips (Al–Ti–B) duly packed in an aluminium foil were added to the melt for grain refinement. For modification, Al–10%Sr master alloy was used. The wear tests were carried out under varying Normal pressure (0.195, 0.390, 0.584, 0.780, 0.975 and 1.170 N/mm^2), different sliding speeds (0.942, 1.884 and 2.827 and 3.768 m/sec), and different sliding distances (282.743, 565.486, 848.230, 1130.970, 1413.710, and 1696.460 metre). The wear loss measured in microns was continuously monitored by the loss of the length of the specimen of the fixed diameter using a linear variable differential transformer (LVDT). They concluded that Specific wear rate decreases with increase in normal pressure and sliding speed due to the addition of Si as shown in fig 1 and wear rate increase with increase in sliding distance as shown in fig 2. Improved wear resistance can be achieved by the addition of grain refiner and or modifier (as the case may be) to Al–Si alloys [11].

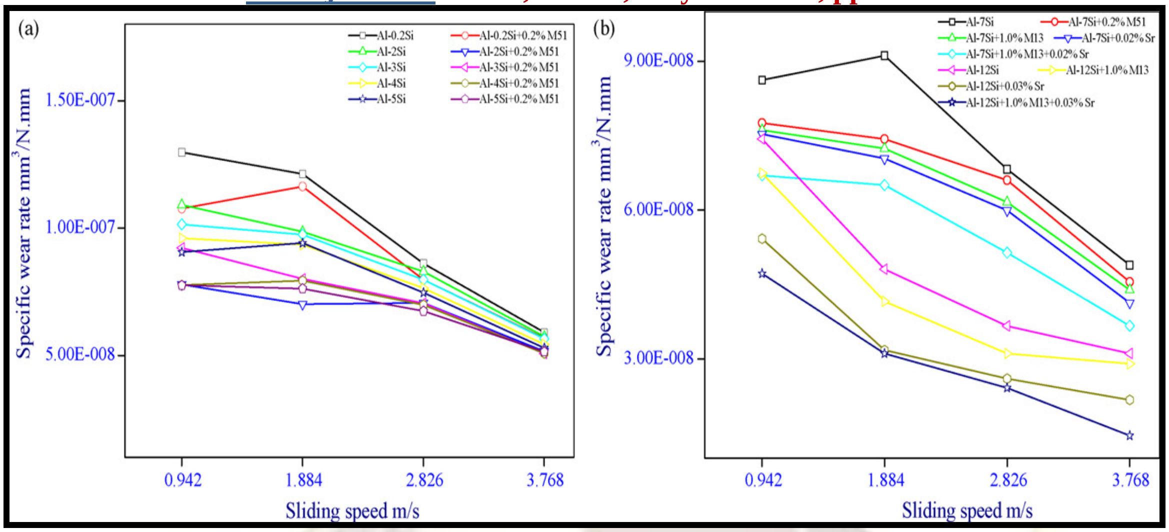

Fig.1. Shows the effect of sliding speed on specific wear rate: (a) Al–0.2 to 5Si alloys, (b) 7 and 12Si alloys.

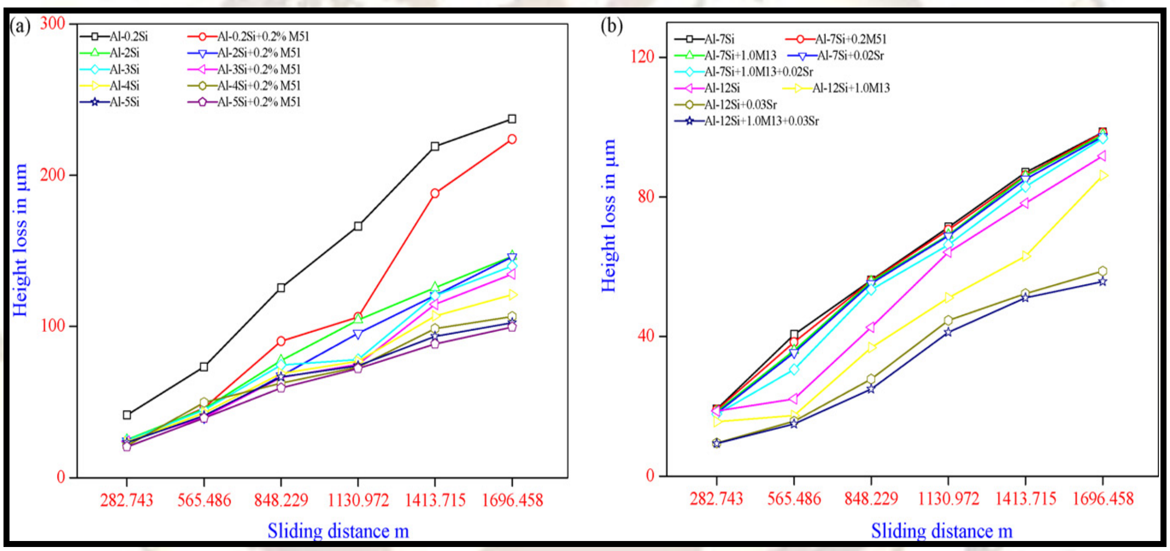

Fig.2. Shows the effect of sliding distance on wear (height loss in _m): (a) Al–0.2 to 5Si alloys, (b) 7 and 12Si alloys.

A.K. Prasada Rao, K. Das, B.S. Murty, M. Chakraborty worked on microstructure and wear behavior of grain refined and modified Al–7Si–0.3Mg (LM25) alloy. Combined grain refinement and modification is achieved by inoculating LM25 melt with various inoculation levels (0.2, 0.5 and 1.0 wt %) of a novel Al base master alloy containing Ti, C and Sr at 720 ◦C. They performed an experimental on Initially, LM25 alloy was taken and melted in a graphite crucible in a pit-type resistance furnace at 720 ◦C. The melt was degassed with commercially available degasser, hexachloroethane. In the next step, the calculated amount of Al–5Ti–2C–15Sr master alloy chips was added to LM25 alloy melt and stirred gently for about 30 s. Microstructure was characterized by using Leica Optical Microscope attached with an image analyzer system. Porosity of the castings was measured by using Archimedes Principle. The wear tests were conducted at sliding velocity of 1m/s, load of 50 N, and for a sliding distance of 1800 m and Track diameter of 100 mm was selected for the experiments. They concluded that grain refining and modifying efficiency of the master alloy developed is effective at shorter holding time (5 min), and its efficiency drops on longer holding (120 min) of the melt due to fading (for 0.2 and 0.5 wt% addition of the master alloy). However, grain refinement can be retained even for long holding at higher addition level of 1.0 wt%, although there is some fading of modification [12].

A.K. Prasada Rao, B.S. Murty, M. Chakraborty worked on Dry sliding wear and tensile studies have been conducted on Al–7Si alloy after various melt treatments like grain refinement and/or modification. Combined grain refinement and modification not only increases the tensile strength and wear resistance but also significantly enhances the load bearing capacity of the alloy during dry sliding wear. They performed an experimental on Al–7Si alloy was prepared by melting commercial pure aluminium (99.7% pure) with the Al–20Si master alloy in a graphite crucible in a pit-type resistance furnace at 720 ◦C. Melt was degassed with 1% hexachloroethane before the addition of grain refiner/modifier. Grain refinement of the Al–7Si alloy is done in the present study using 1% of Al–1Ti-3B master alloy. Modification was carried out by the addition of 0.02% Sr in the form of Al–5Sr master alloy. The wear test carried out on a pin-on-disc type machine. The wear tests were conducted at 1m/s sliding velocity and at various normal loads ranging from 50 to 200 N for 30 min and a sliding distance of 1800 m and Track diameter of 100 mm were selected for the experiments. They concluded that the grain refinement and/or modification improve wear resistance and the load bearing capacity during dry sliding of cast Al–7Si alloy and also improve ultimate tensile strength [13].

A.K. Prasada Rao, Karabi Das, B.S. Murty, M. Chakraborty investigated on effect of grain size of Al and dendritic arm spacing (DAS) of α-Al in Al–7Si alloy on wear behaviour of Al and Al–7Si alloy. Wear characteristics of the grain refined Al and Al–7Si alloy were studied by using a pin-on-disc wear-testing machine. The results show that the wear rate decreases with the decrease in the grain size and DAS of Al and Al–7Si alloy, respectively, at a load of 50 N, sliding distance of 1800 metre and sliding velocity of 1 m/s under dry sliding condition. Al–7Si alloy was grain refined using various grain refiners such as Al–1Ti–3B, Al–3Ti and Al–3B while Al was grain refined with Al–5Ti–1B.They concluded that wear rate is higher when the DAS is higher and lower at smaller DAS and also observed wear volume of Al–7Si alloy with and without grain refinement increases with an increase in the normal load and sliding distance. Grain refinement improves the load bearing capacity of Al–7Si alloy [14].

H.R. Lashgari , A.R. Sufizadeh, M. Emamy investigated the effect of strontium (0.5%) as a modifier on the microstructure and dry sliding wear behavior of A356–10%B4C particulate metal matrix composite (PMMC). The A356 monolithic alloy and A356–10%B4C (in unmodified and modified condition) were tested at a rotational speed of 247 rpm, corresponding to a speed of 0.5 m/s, under nominal loads of 20, 40, 60 N for a sliding distance of 1000 m using pin-on-disc machine. The weight of the specimens was measured before and after the wear test using an electronic balance (GR200-AND) with an accuracy of 0.1 mg. The worn surfaces were examined SEM.They concluded that wear rate of modified composite is lower than unmodified one in all applied loads and also observed the addition of strontium to Al–B4C cast composite contributes to a higher wear resistance due to silicon particle modification. They concluded that Specific wear rate increase with increase in normal pressure and sliding distance [15].

Gang Liu, Guodong Li, Anhui Cai, Zhaoke Chen worked on the modification response of Al–20 wt% Si alloys was studied with different Sr addition levels. Wear tests were carried out using a UMT-3 flat sliding wear machine and the tests were performed on the condition of the normal loads of 2, 5, 8 N, stroke length of 5.0 mm, frequency of oscillation of 10 Hz and test duration of 3600 s at ambient temperature. The worn morphologies of the wear surface were examined by scanning electron microscopy (SEM).They concluded that The frictional coefficients of the modified Al–20 wt% Si alloys are lower than that of the unmodified alloys for all the loads. The frictional coefficients of the unmodified alloys decrease with increasing of the load, but those of the modified alloys increase when Sr exceeds 0.04 wt%. Adhesive wear is the main mechanism for the unmodified alloys, while abrasion wear takes place for the modified alloys [16].

III. Conclusions

1) Addition of Al-Ti-B grain refiner to Al-Si alloy significantly refines coarse columnar α-aluminum dendrites to fine equiaxed α-aluminum dendrites.
2) Grain refinement reduces inter-dendrite arm spacing of α-aluminum dendrites.
3) Modification refines the primary and eutectic silicon crystals and changes the morphology of these crystals.
4) Wear rate of eutectic Al–Si alloys increases with increase in time duration and decreases with increase in sliding speed.

5) The wear rate increase in case of sand casting as compared to the in case of gravity-die casting.

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V.References

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