SYNTHESIS AND STUDY ON EFFECT OF PARAMETERS ON DRY SLIDING WEAR CHARACTERISTICS OF ALUMINIUM ALLOYS

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Abstract - *The ever increasing demand from aerospace industries, automotive industries and marine industries to manufacture components which lighter and stronger than conventional steel has prompted the significant usage of aluminium alloys..The effect of parameters on dry sliding wear characteristics of Al-Si alloys was studied. Aluminium-silicon alloys containing 7%, 12% and 14% weight of silicon were synthesized using stir casting method. Dry sliding wear characteristics of samples were studied against a hardened carbon steel (Fe-2.3%Cr-0.9%C) using a pin-on-disc Wear Apparatus. The wear test carried out by varying one of the three parameters (Applied Load, Sliding Speed and Sliding Distance) and keeping other two constant at room temperature. Micro structural characterization was done using optical microscope (OM) and scanning electron microscope (SEM). Hardness and wear characteristics of different samples have shown near uniform behaviour. The wear rate decreased when the percentage of silicon increases. Wear was observed to increase at higher applied load, higher sliding speed and higher sliding distance. The wear characteristics of Al-14%Si was observed superior to those of Al-7%Si and Al-12%Si due to the degree of refinement of their eutectic silicon.*

Keywords: *Stir casting; Al-Si alloys; Wear Parameters; Microstructures; Vickers hardness.*

1. INTRODUCTION

1.1 Tribology of Materials

Tribology is defined as the science and technology of interacting surfaces in relative motion, having its origin in the Greek word Tribos meaning rubbing. It is a study of a Friction, Lubrication and Wear of engineering surfaces with a view to understanding surface interactions in detail and then prescribing improvements in given applications. The nature and the consequence of the interactions that take place at the inter face, control the friction and wear behaviour of the materials involved. During these interactions, forces are transmitted, energy is consumed, physical and chemical natures of the material are changed, the surface topography is altered and sometimes loose wear particles are generated Wear is a principal cause of material wastage; any reduction of wear can affect considerable savings. Friction is a serious cause of energy dissipation and considerable savings can be made by better control of friction. Lubrication is the most effective means of controlling wear and lowering friction. Thus the tribology plays a major role in material and energy conservation. The purpose of research in tribology is understandably the minimization and elimination of unnecessary wastes at all levels of technology where the rubbing of surfaces is involved.

There are three fundamental aspects to the science of Tribology that must understand to deal with the technology of the field.

- The effect of environment on surface characteristics through physico- chemical interactions
- The force generation and transmition between the surfaces in contact
- The behaviour of the material near the surface in response to the external forces acting at the contact of the surface

These three aspects of tribology are clearly interrelated and therefore must be understood to deal with totality of tribological problems. In simple terms, it seems that the core objective of tribology is to minimize the two main disadvantages of solid-to-solid contact; friction and wear but the same does not occur always. Minimizing friction and maximizing wear or minimizing wear and maximizing friction or maximizing both friction and wear are desirable in some situations. For example, reduction of wear but not friction is desirable in brakes and lubricated clutches, reduction of friction but not wear is desirable in pencils, increase in both friction and wear desirable in erasers.

1.2 Wear

Wear is defined as an unwanted process of gradual removal of materials which may result, when two surfaces in contact move relative to each other under pressure (ASTM standard G-44).The wear performance of a material is governed by its material characteristics such as composition, microstructure and mechanical properties. The test parameters which also influence wear performance of materials are sliding speed, applied pressure, type of sliding action and environments. Wear (material removal) is experienced in our everyday life regularly. There are many examples that can be put forthright from brushing of teeth (wherein both brush and teeth are rubbed against each other) to machining of components (leading to blunting of tool) and cutting of material to shape it into a definite form. However, the phenomenon of reduction in size of brush and blunting of tool is called wear because both are undesired. On the other hand, cleaning of teeth and component making cannot be categorized as wear simply because they are desired in industry, the wear occurs in the form of component failure leading to shut down of machine. Unserviceable components are to be replaced resulting in huge economic losses due to significant reduction in operating efficiency and increased power loses. Wear rate is expressed in terms of the loss of volume of material per unit time. As the sliding speed is frequently maintained constant, wear rate can be expressed as mass (grams / m) or volume loss of the material per unit sliding distance (m3/m).

2. EXPERIMENTAL

2.1 Material and Method

Aluminium (99.7%) and commercially pure Silicon (99.5%). The equipment used includes a coke fired graphite crucible furnace, a thermocouple, hexachloroethane, Al-Ti master alloy, optical emission spectrometer, optical microscope (OM), scanning electron microscope (SEM), electronic weighing machine, acetone, pin-on-disk machine and Vickers hardness machine.

2.2 Preparation of the Alloys

Al-Si alloys with varying silicon composition was prepared by melting commercially pure aluminium (99.7%) and commercially pure silicon (99.5%) in a coke fired graphite crucible furnace. The melt temperature was maintained at 10˚C above 710˚C pouring temperature. This was to attain homogeneous composition in the melt. Dissolved hydrogen reduction and microstructure modification was achieved by plunging 2% solid hexachloroethane and 0.1% Al-Ti master alloy into the melt. The weight of Si charged per 500gm of Al, for the preparation of Al-7% Si, Al-12%Si, and Al-14% Si alloys are 38.5, 62.2 and 73.4gm respectively. Each melt was stirred for 20s after degassing and modification held for 5 min and then poured into a 200˚C pre-heated metallic mould. The measuring of temperature was achieved using thermocouple that measure temperature up to 1000˚C. The cast samples were of 100 mm length and 12 mm diameter. The same size and shape was machined from the as cast Al-Si alloys to present uniformity in measurements.

2.3 Determination of Hardness Values

In determining the hardness of the sample, Vickers hardness testing machine was used. The applied load during the testing was 5 kgf with a dwell time of 20 seconds. Four indentations were made at random locations for all the samples. Two indentations were performed on the top face and two on the bottom and the average values of the lengths of diagonals of the impressions were used to calculate Vickers hardness number.

2.4 Determination of Wear Values

Wear test was carried out on pin-on-disc machine under dry sliding conditions at room temperature (25°C). The sample was mounted vertically on a still vice such that its face pressed against the rotating disc. The disc used was carbon steel (Fe-2.3%Cr-0.9%C) hardened to 65 HRC, 50mm track diameter and 8mm thick. Specimens of 10 mm diameter and 30mm length were prepared from the cast 12 mm diameter round bars. On completion of each sample testing the specimen was removed, cleaned with acetone, dried and weighed to determine the mass loss due to wear. The difference in the mass measured before and after the test gives the wear of the specimen. The mass loss of the pin (specimen) was measured in an electronic weighing machine with a least count of 0.001 g. The ratio of mass losses to sliding distance was defined as wear rate. The wear test was carried out by varying one of the three parameters (load, sliding speed, and sliding distance) and keeping other two constant. The constant values for load, sliding speed, sliding distance used were 10N, 200rpm and 1884m respectively.

Fig-1 Pin-on-Disc Wear Machine

3. RESULTS AND DISCUSSION

3.1 MICROSTRUCTURES

Microstructures obtained from optical microscope at 100x magnifications are shown in Figure -2 for Al-7% Si, Al-12% Si and Al-14% Si respectively. It was observed that with increase in silicon percentage in the alloy, the microstructure was different for Al-7%Si and Al-12%Si alloys compared with Al-14%Si alloy. It showed light areas with rounded particles (aluminium) are crystallized, which are surrounded by networked structure of dark fine areas (eutectic silicon). The micrograph of Al-12%Si alloy showed the refinement of the dark networked structure of eutectic silicon particles. The silicon has long rod like structure. It may be seen in Al-14%Si that the degree of refinement of the eutectic silicon increased as the silicon content of the alloy increased beyond the eutectic composition. Here the primary silicon appears as coarse polyhedral particles. Although the presence of primary silicon was also observed in the Al-12%Si, but its size and volume fraction was less compared to Al-14% Si alloys. The micrographs taken at low and high magnifications respectively for Al-7%, Al-12% and Al-14%Si alloys. The deep separated grooves of Al-7%Si alloy shown in figure - 3 was more compared to Al-12%Si in Figure -3 and was lowest in Al-14%Si shown in figure -3. It revealed wear was highest in Al-7%Si and lowest in Al-14%Si. The presence of deep separated grooves may be that the hard dispersed particles or fractured pieces are removed during abrasion by entrapped debris, hard asperities on the hardened steel counter face or work hardened deposits on the counter face. For Al-12%Si the deeper grooves was observed to be smooth in nature. This may be due to the fact that some wear debris of the material might have flown off. In Al-14%Si, shown in figure -3 as Si content increases hardness of the material also increases. Deeper grooves may be due to the abrasion of Si particles that have forced the silicon in platelet form, for which deeper grooves are produced. The worn surface of the alloys from the wear test observed under scanning electron microscope at magnification of x500 and x1500 are presented below.

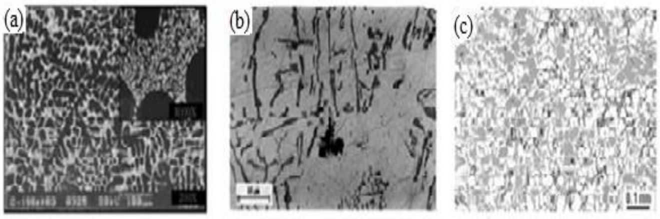

Figure:2. Microstructures of (a) Al-7%Si Alloy(b) Al-12%Si Alloy (c) Al-14%Si Alloy

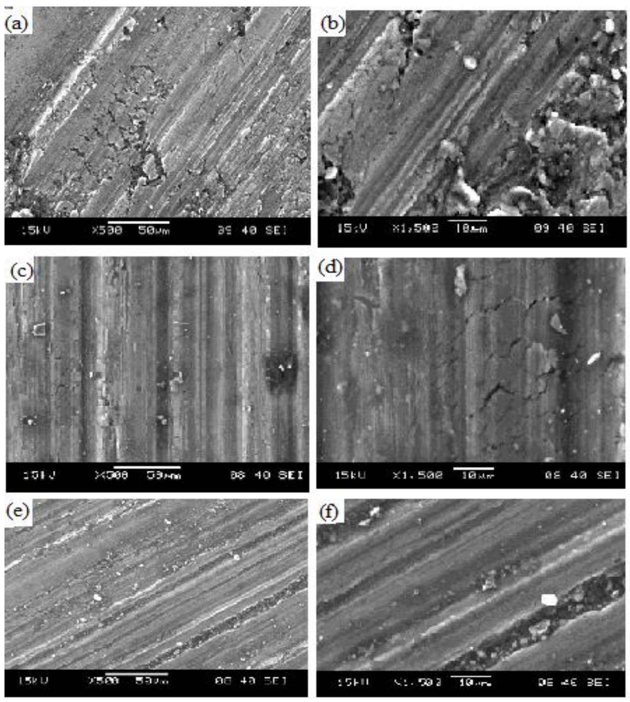

Figure-3SEM Micrograph of worn surface of alloys: Al-7%Si (a, b), Al-12%Si(c, d), Al-14 %(e, f)

3.2 Determination of Hardness Values

The following figure shows the Vickers hardness numbers for Al-7% Si, Al-12% Si and Al-14% Si are found to be 52.14, 65.5 and 69.12 respectively. This shows that hardness of the Al-Si alloy increases with the increase in the weight percentage of silicon. This may be due to the increment of silicon amount, which is harder. Figure 4 shows the hardness of Al-Si alloys.

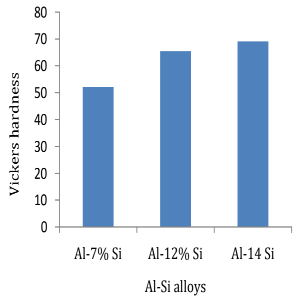

Figure-4 Variation of Hardness along with Their Standard Deviation

3.3 Effect of Wear Rate of Al - Si Alloys with Applied Load

The wear rate of Al-Si alloys are plotted as a function of applied load at different sliding speeds of 0.52 m /s, 1.05 m/s, 1.57 m /s and 2.09 m/s and is shown in Figure -1(b) , Figure- 1 (c) and Figure- 1(d). It is noted that the wear rate initially increases slowly with increase in applied load. It is further noted that at the later stage beyond certain applied load, the wear rate shoots of rapidly. It is evident from the Figure- 1 (b-d), the curves at the sliding speeds of 0.52 m/s, and 1.05 m/s shows the same trend as explained. But at higher speeds the trend is entirely different. From the Figure- 1 (b-d), it was noted that for higher speeds of 1.57 m/s, and 2.09 m/s, the wear rate shoots up rapidly and gets seized. At higher speeds, no stable zone was observed between transition pressure and seizure pressure. The pressure at which wear rate increases suddenly to a very high value is termed as transition pressure. The pressure at which materials get seized is termed as seizure pressure. In case of Al-7%Si alloy at lower speed the transition pressure and seizure pressure are different but at higher speed they are noted to be almost same. Figure- 1 (b-d) shows the wear test of Al-Si alloys at different operating parameters. The result of wear rate on all samples with varying loads with increasing silicon content is shown in Figure -1 (b-d). It may be noted that wear rate decreases when the percentage of silicon increases and the wear rate increases with increasing load. The increases in wear rate throughout the tests confirm that increasing load increases wear rate. For Al-7%Si alloy, the wear rate was 2.805x10-5g/m, whereas for Al-12%Si alloy, the wear rate decreased to 2.366x10-5g/m. and for Al-14%Si alloy, the wear rate was only 1.831x 10-5 g/m

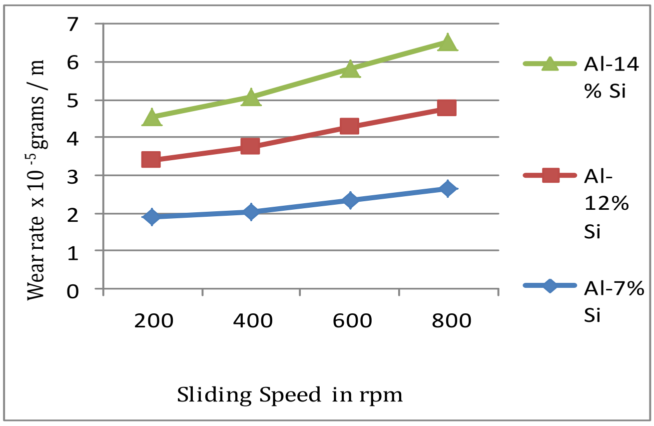

Figure -2 (a) Variation of Wear Rate of Al-Si Alloy with Sliding Speed

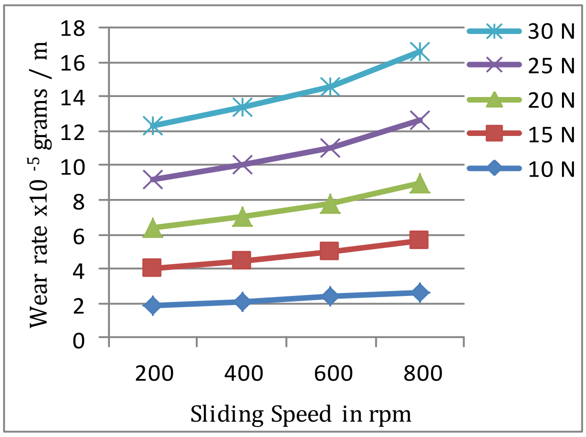

Figure -2 (b) Variation of Wear Rate of Al-7% Si with Sliding Speed

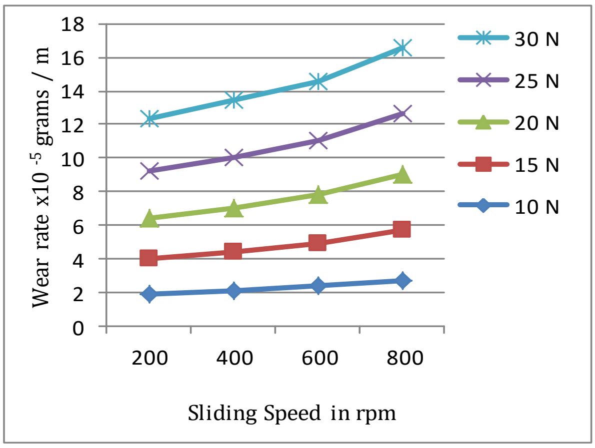

Figure-2 (c) Variation of Wear Rate of Al-12% Si with Sliding Speed

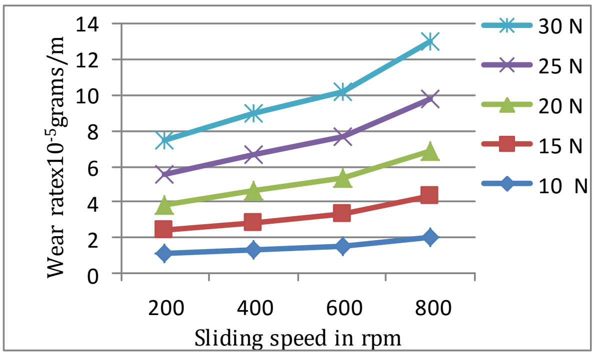

Figure: -2 (d) Variation of Wear Rate of Al-14% Si with Sliding Speed

3.5 Effect of Wear Rate of Al- Si Alloys with Sliding Distance

The wear rate of Al-Si alloys are plotted as function of sliding distance tested at four different speeds of 0.85 and 1.72 m/s and at five different applied loads. Figure -3(b-d) represents the variation of wear rate with the sliding distance at five different loads 10 N,15 N,20 N,25 N and 30 N. From the Figure -3, it was understood that the wear rate with sliding distance at the applied load 30 N is more than that observed at 10 N. In this it was noticed that the wear rate increases slightly from 1884m to 7536m sliding distance. This is primarily due to the occurrence of adhesion of brass material (pin) to the counter surface (disc). At this stage no attempt has been made to know the seizing point with the sliding distance. Figure -3(a) shows the wear test of Al-Si alloys at different applied loads. The result of wear rate on all samples with varying sliding distance with increasing silicon content is shown in Figure -3(b-d).The wear rate increased with increasing sliding distance for all condition. For Al-7% Si alloy, , the wear rate was 1.883 x 10-5 grams / m, for Al-12%Si alloy, the wear rate was 1.507 x 10-5 grams / m and for Al-14%Si alloy, the wear rate was 1.132 x 10-5 grams / m for 1884 m sliding distance which was due to the presence of hard silicon particles. The wear rate increase with increasing sliding distance is due to more amount of time in wearing for all conditions. These trends are also consistent with the results of the earlier research in the field.

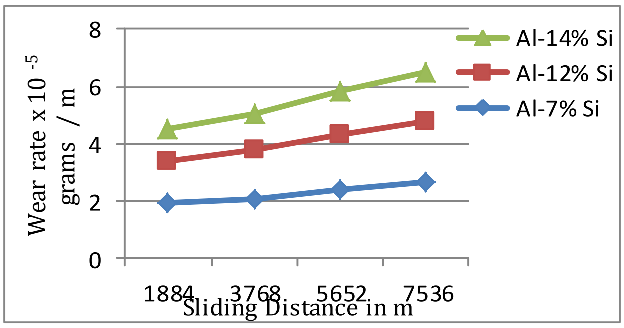

Figure -3 (a) Variation of Wear Rate of Al- Si Alloy with Sliding Distance

increasing the wear rate due to plastic deformation of the material.

- The wear rate increase with increasing sliding distance is due to more amount of time in wearing for all conditions.
- We found that wear rate of Al-Si alloy is directly proportional to applied load, sliding distance and sliding speed.
- We noticed that wear rate of Al-Si alloy is inversely proportional to increase the percentage of silicon in pure aluminium.

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