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EFFECT OF TI ADDITION ON THE TRIBOLOGICAL WEAR BEHAVIOR OF HYPEREUTECTIC AL-SI ALLOYS AT ELEVATED TEMPERATURES

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ABSTRACT

Effect of titanium addition on the dry sliding wear behaviour of hypereutectic Al-Si alloys are investigated at elevated temperatures. Wear tests are conducted for varying normal pressure from 0.20 N/mm^2 to 0.98 N/mm^2, for varying sliding velocity from 0.94m/s to 3.77 m/s and varying sliding distance from 282.74 m to 1696.46 m. In this present investigation, hyper eutectic aluminium based alloys containing 13% and 20% weight of silicon; with addition of titanium is synthesized using casting method. Wear behaviour is studied by using computerized pin on disc wear testing machine. Worn surfaces were examined and analysed by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). The wear results show that the wear rate increases with increase in normal pressure (0.20 N/mm^2 to 0.98 N/mm^2) and sliding distance (282.74 m to 1696.46 m), but wear rate decreases with increase in sliding velocity from (0.94 m/s to 3.77 m/s). The addition of titanium to Al-Si alloys increases the wear resistance at elevated temperatures.

KEYWORDS: Al-Si alloys, wear, titanium, Elevated Temperature.

INTRODUCTION

In recent years aluminium alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. The wide popularity of Al–Si alloys in the automobile industry stems from their high strength to weight ratio, excellent casting characteristics, good mechanical properties, low coefficient of thermal expansion, high thermal conductivity and high corrosion resistance, high wear resistance, high strength-to-weight ratio, excellent castability, hot tearing resistance, good weld ability etc. which makes them attractive candidate material in many Tribological applications, aerospace and other engineering sectors where they can successfully replace ferrous components in heavy wear applications. These applications demand the study of techniques to improve the wear properties of these alloys. For this purpose, many researches had been done to enhance their wear properties. Most common applications of aluminium silicon alloys are components like connecting rods, pistons, air conditioner compressors, engine blocks, cylinder liners, brake drums etc. The improvement in the Tribological properties depends on number of material-related properties like shape, size and size distribution of the second-phase particles in the matrix and microstructures in addition to the operating conditions such as sliding speed, sliding distance, temperature, load etc. With the development of automobile industry, the need of hypereutectic Al-Si alloys is increasing greatly.

Phase Diagram- Aluminium-Silicon system is a simple binary eutectic with limited solubility of aluminium in silicon and limited solubility of silicon in aluminium. There is only one invariant reaction in this diagram, namely $L \rightarrow \alpha + \beta$ (eutectic) L is the liquid phase, α is predominantly aluminium, and α is predominantly silicon. It is now widely accepted that the eutectic reaction takes place at 577°C and at a silicon level of 12.6%. Aluminium-Silicon (Al-Si) casting alloys are the most useful of all common foundry cast alloys in the fabrication of pistons for automotive engines. Depending on the Si concentration in weight percentage, the Al-Si alloy systems are divided into three major categories:

a) Hypoeutectic (<12 wt % Si)
b) Eutectic (12-13 wt % Si)
c) Hypereutectic (14-25 wt % Si)

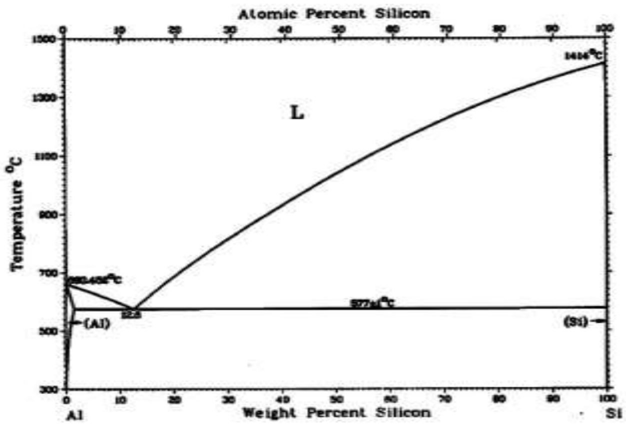

Fig.1.Phase Diagram

EXPERIMENTAL METHODOLOGY

Experimental details- Aluminium-silicon alloys were prepared with different weight percentage of silicon by stir casting in an induction heating furnace. Samples of different dimensions were cut for different tests. By using optical emission spectrometer their composition was analysed. Wear behaviour of different composition samples were studied by conducting several wear tests on computerized DUCOM wear and friction monitor TR-20LE-PHM-600 pin on-disc wear test machine.

Preparations of Alloys- Al-Si alloys are prepared via foundry technique. Calculated quantities of commercial purity aluminium (99.7 Wt% purity) and Al-20 Wt % Si master alloy are melted in a resistance furnace with addition of a cover flux (45% NaCl+45% KCl+10% NaF). A master alloy containing titanium is added to the resistance furnace and the melt is held at 720℃ ±5℃. After degassing the melt with solid hexachloroethane (C2Cl6) the melt is poured into cylindrical graphite mould (25 mm diameter and 100 mm height) surrounded by fire clay brick with its top open for pouring (for preparing the specimen for macro and micro structural studies) and also the melt is poured into the graphite split mould (12.5 mm diameter and 125mm height- for preparing the specimen for wear pins).

Melts were poured after holding for about 30 minutes into cylindrical graphite mould (25mm diameter and 100 mm height) surrounded by fire clay brick with its top open for pouring and also the melt is poured into graphite split mould.

Fig.2.Preparation of Al-Si Alloys (a) Graphite mould, (b) Alloys after casting, (c) Specimens used for wear test

Wear tests were conducted using pin on disc wear testing machine (TR-20LE-PHM-600, DUCOM, and PINON- DISC MACHINE).The disc is made of low carbon alloy steel (EN-32 Steel, 160 mm diameter and 8 mm thickness) having hardness value of about 62RC. Losses of wear were recorded. Wear losses were measured with a linear variable differential transformer (LVDT) and it was monitored by the loss of length due to wear of the specimen of the fixed diameter. The wear loss was measured in microns (µm). Weight loss method is followed to get the more accurate results. In this method weight of the wear pin before and after conducting the wear test is recorded using an electronic weighing machine. Difference between the initial and final weight of the specimen gives the weight loss due to wear.

Three sets of wear testing experiments are conducted to study the Tribological wear behaviour of all these alloys. Three sets of experiments are:
a) Normal pressure dependent experiments.
b) Sliding distance dependent experiments.
c) Sliding speed dependent experiments.

RESULTS AND DISCUSSION

Dry sliding wear test

The wear tests of Al-Si alloys were carried out with varying applied load, sliding speed and sliding distance. The experiments are carried at elevated temperatures. In the present study, hypereutectic aluminium based alloys containing 13% and 20% weight of silicon with and without addition of titanium. The results are obtained from the series of tests which is done by keeping two parameters out of the three (sliding distance, sliding speed and load) constant against wear. The normal pressure is obtained by varying the Normal Pressure from 0.2 N/mm^2 to 0.98 N/mm^2; Sliding Velocity is varied from 0.94 m/sec to 3.77m/sec and Sliding Distance is obtained by varying from 282.74 m to 1696.46 m. At each condition, the weight loss from the specimens was determined, and converted into volume loss using the measured density of the materials. The volume loss is obtained by using the density value 2.7g/cm^3. Wear behaviour is studied by using computerized pin on disc wear testing machine.
1. Normal pressure Vs volume loss.
2. Sliding distance Vs volume loss.
3. Sliding velocity Vs volume loss.

Normal pressure Vs volume loss-The volume loss versus normal pressure of Al-Si alloys with and without addition of titanium at elevated temperature of 60℃ , 120℃ and 180℃ are shown inFig.3 and Fig.4. The normal pressure is obtained by varying the pressure from 0.2 N/mm^2 to 0.98 N/mm^2 at constant sliding velocity of 1.88 m/sec for a constant sliding distance of 565.49 m. The graph is obtained for hyper eutectic Al-Si alloys such as Al-13%Si and Al-20%Si with and without the addition of titanium. It is observed that volume loss increases with increase in normal pressure.In dry sliding wear contact load is main variable as it controls the degree of adhesion, sub-surface damage on the sliding surface.

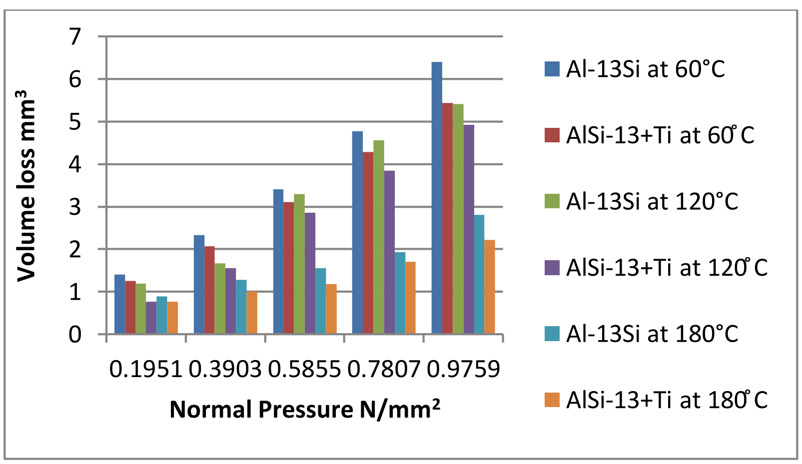

Fig.3.volume loss v/s normal pressure of Al-13Si alloys with and without addition of titanium at elevated temperature

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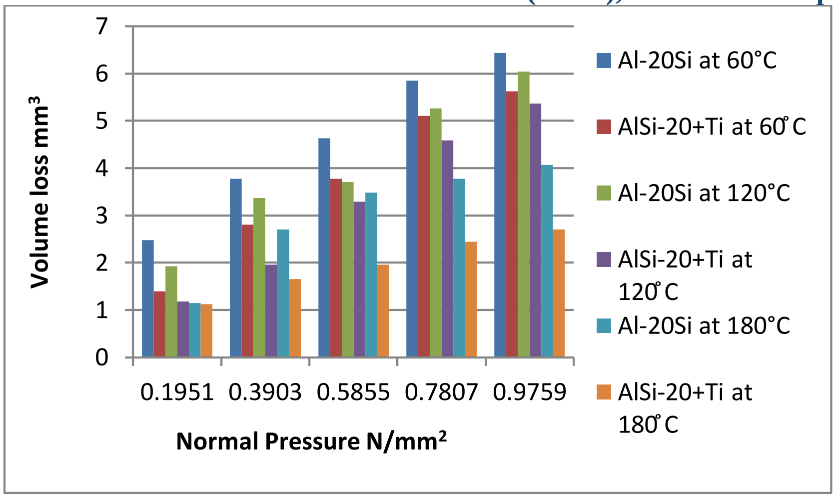

Fig.4.volume loss v/s normal pressure of Al-20Si alloys with and without addition of titanium at elevated temperature

Sliding distance Vs volume loss- The volume loss versus sliding velocity of Al-Si alloys with and without addition of titanium at elevated temperature of 60℃ , 120℃ and 180℃ are shown in Fig.5 and Fig.6. The sliding velocity is obtained by varying the speeds from 200 rpm to 800 rpm at a constant normal pressure of 0.975 N/mm^2 for a constant sliding distance of 565.49 m. At each speed, the weight loss from the specimens was determined and then converted into volume loss using the measured density of the materials. The volume loss is obtained by using the density value 2.7 g/cm^3. The graph is obtained for hypereutectic Al-Si alloys such as Al-13%Si and Al-20%Si with and without addition of titanium at elevated temperature of 60℃ , 120℃ and 180℃. It is observed that the volume loss are minimum at high sliding velocity 3.77 m/sec and maximum at low sliding velocity 0.94 m/sec. Volume loss decreases with increase in sliding speed from 0.94 m/sec to 3.77 m/sec and the interface temperature increase with increase in the sliding speed.

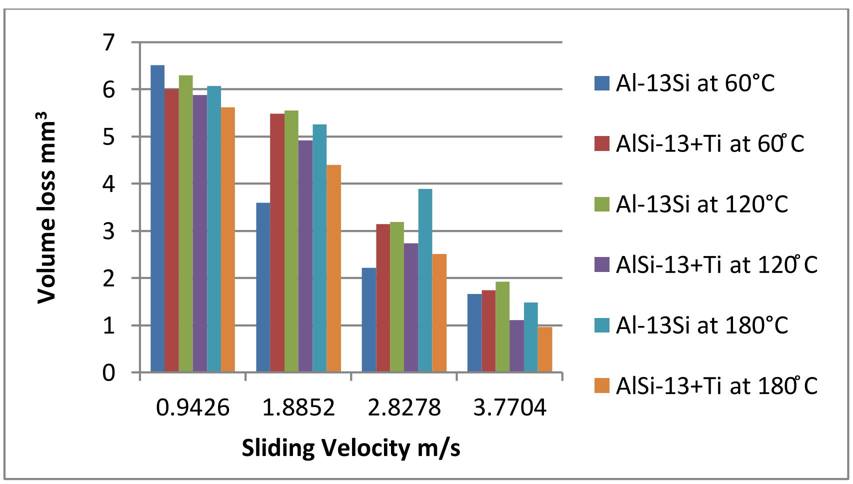

Fig.5.Volume loss v/s Sliding Velocity of Al-13Si alloys with and without addition of titanium at elevated temperature.

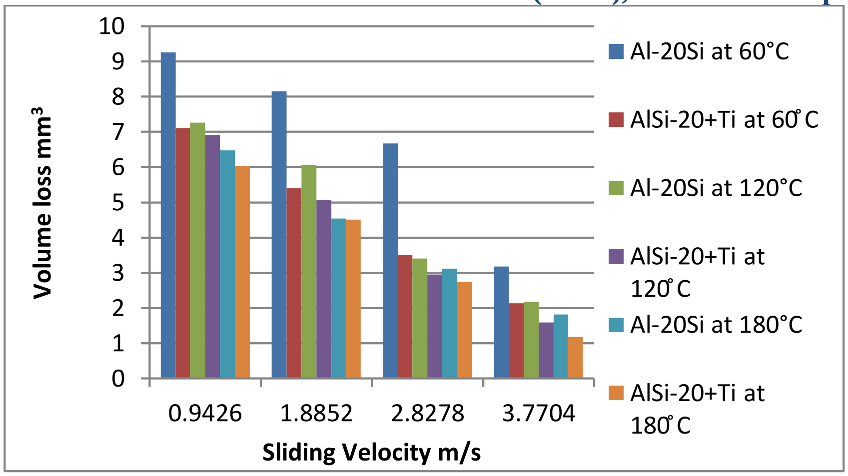

Fig.6.Volume loss v/s Sliding Velocity of Al-20Si alloys with and without addition of titanium at elevated temperature.

Sliding distance Vs volume loss- The volume loss versus sliding distance of Al-Si alloys with and without the addition of titanium at elevated temperatures of 60°C , 120°C and 180°C are shown in Fig.7 and Fig.8. The graph is obtained for hyper eutectic Al-Si alloys such as Al-13%Si and Al-20%Si with and without the addition of titanium. It is observed that volume loss increases with increase in sliding distance.

In dry sliding wear the sliding distance is main variable as it controls the degree of adhesion, sub-surface damage effects on the sliding surface due to frictional heat and tendency to form and break the oxide film. Increase in the silicon content of material decreases the wear resistance. In the aluminium matrix the presence of silicon leads to wear resistance in Al-Si alloys. In eutectic Al-Si alloys decreases the wear resistance with increasing the silicon content.

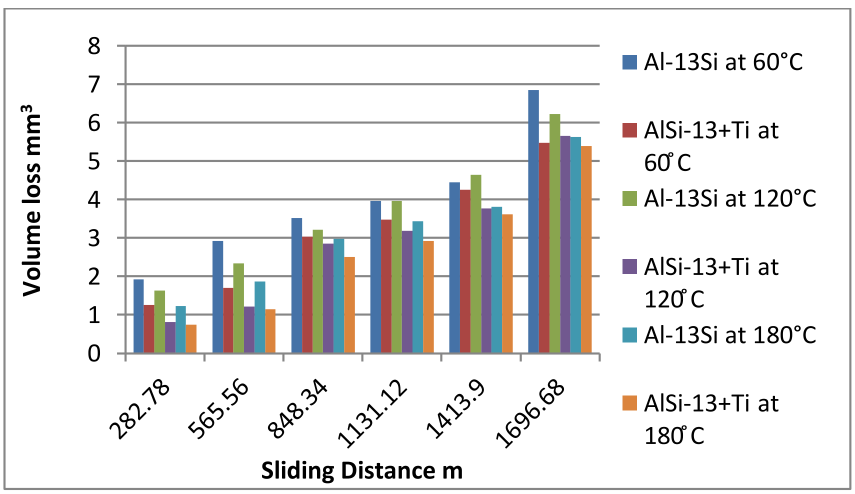

Fig.7.Variation of volume loss of Al-13Si alloys with and without the addition of titanium for sliding distance at elevated temperature.

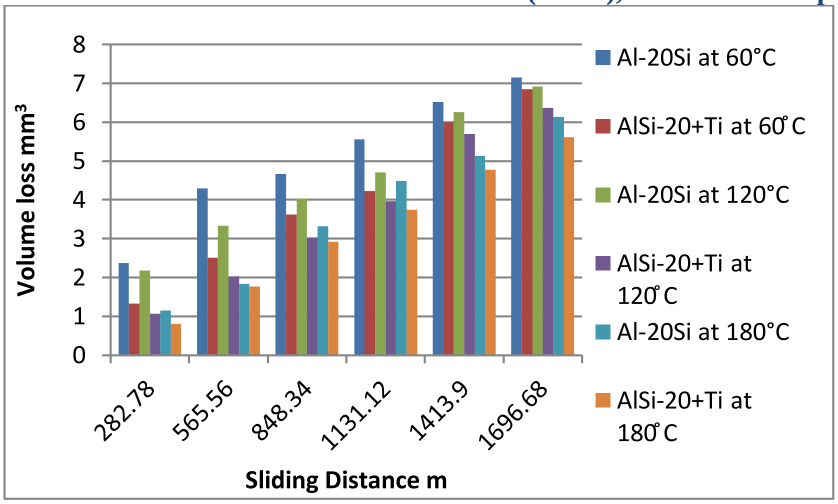

Fig.8.Variation of volume loss of Al-20Si alloys with and without the addition of titanium for sliding distance at elevated temperature

Topography- In SEM, the worn surfaces were studied and observed that, under the load and speed conditions severe wear was caused. The topographical features do not change significantly with increasing silicon content from 13% to 20%. The distinct topographical features indicate that the surface is subjected more than one mode of material removal. Most of the worn surface consists of smooth strips with fine scoring marks. Scoring may be due to abrasion by entrapped debris, work hardened deposits or hard asperities on hardened steel. This mode does not constitute a major wear mechanism as the amount of material removed is very small. As the temperature is increased we can see the increase in oxygen content and the formation of oxide layer due to which the wear is reduced.

CONCLUSION

The dry sliding wear behaviour of Al–13Si, 20Si and Al-13Si+Ti, 20Si+Ti alloys was studied and compared at elevated temperatures and the following conclusions were drawn.

1. The wear rate of the Al-Si alloys increases as the normal pressure and sliding distance is increased whereas the wear rate is decreases with increase in sliding velocity.
2. Wear rate increases with increase in silicon content for hyper eutectic Al-Si alloys.
3. The wear rate of the Al-Si alloys decreases with an increase in temperature. This effect is due to the oxide film formation on sliding components, which is more rapid at high operating temperatures. These later prevent the direct metal-to-metal contact of sliding surfaces during sliding.
4. The addition of titanium in the aluminium silicon alloys reduces the wear rate.

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