Characterization of Mechanical Properties and Wear behaviour of Aluminium-Silicon Piston Alloy

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Abstract

Al-Si alloys as a tribological component has been expanding widely in automobile, marine castings, cylinder block, piston for IC engine, etc. The composition of the Al-Si cast alloy assessed using spectro analysis. It is conformed as LM2 grade. After the conformation of Al-Si cast material are melted, and then cleaned and cast to make small size ingots. The mechanical properties and wear properties of these Al-Si alloys are vary on the heat treatment process. The hardness varies from 55.60HR15T to 60.40HR15T of before and after heat treatment respectively. The heat treatment process is also improving the tensile strength and wear resistance properties.

Keywords: *Al-Si alloys; piston materials; heat treatment; mechanical properties; wear resistance*

I. INTRODUCTION

Engine pistons are one of the most complex components among all the automotive industry. The piston can be called the heart of a engine. There are lots of research works proposing for engine pistons, materials and manufacturing techniques, and revolution under goes with a continuous improvement[1].The piston is one of the most stressed components of an entire vehicle. Damages may have different origins, mechanical stresses; thermal stresses; wear mechanism; temperature degradation; oxidation; etc. in this work only mechanical damages will be assessed. Al-Si alloys are widely used as a piston material. It has excellent castability and wear resistance[2].

Wear is a major problem in industry and its direct cost is estimated above four percent of gross national product. There are much efforts have been made to produce more durable materials and techniques to reduce the wear of tools and engineering components. Al-Si alloys have the potential for excellent castability, good weldability, good thermal conductivity, high strength and excellent corrosion resistance. They are well suited for aerospace, automobile industry, military application,etc[3]. The general aim of the present work is to improve the mechanical properties and wear properties of the Al-Si alloys in the as-cast and heat treated conditions so that specific recommendation can be put forward towards the tribological use of this alloy for local automobile spare parts manufactures.

II. EXPERIMENTAL PROCEDURE

A) Chemical analysis

The composition of the Al-Si cast alloy assessed using spectrographic analysis [4]. The results obtain from the chemical analysis, Al-87.96, Si-9.33, Fe-0.57, Cu-0.858, Ni-0.394, Mn-0.011, Mg-0.023, and Zn-0.958. It is conformed as LM2 grade. After the conformation of Al-Si cast material are melted, and then cleaned and cast to make small size ingots[5-6].

B) Heat treatment

The heat treatment is carried out at a temperature of 560° C for 3h and then the specimens are quenched in hot water at 50°C. After 10 min, they are removed and then after drying, they were kept in a freezer at -15°C for overnight. The ageing process is carried out at 160°C for 16 h and then the test bars are removed from the furnace[7].

C) Tensile and hardness tests

Tensile tests are performed on round specimen with universal testing machine[8]. The results of the tensile tests are averaged from two determinations. Rockwell hardness testing is conducted using 150 kg load and 1.5 mm diameter indenter. The loading time is about 15 sec.

D) Wear testing

Cylindrical pins of 10 mm diameter and 50 mm length from as-cast and heat treated specimens are prepared and used as wear test samples. Experiments are conducted in a (pin-on-disc) wear test machine under dry sliding conditions[9]. The apparatus consists of a abrasive disc having 80 mm diameter and 10 mm thickness.

This is fixed on the rotating shaft and the pin is fixed on a lever through a sample holder, which is used to apply a normal load. The rotating shaft is connected to a constant speed a.c. motor through a pulley and belt system. In this work, the loads of 0.5, 1,1.5 and 2 kg are used. The rotation of the shaft is continued for a period of 450 sec. The relative sliding speed of the pin and disc is adjusted by regulating speed of the motor to about 400 rpm. At the end of the experiment, the motor is stopped and the test pin was removed carefully from the sample holder. After testing, the worn surface of the pin is examined by optical microscopy.

III. RESULTS AND DISCUSSION

A) *Mechanical Properties of Al–Si piston Alloy*

Fig.1,2 and 3 show the properties of aluminum–silicon piston alloy for both as-cast and heat treated specimens. It can be seen that the strength and hardness have increased in the heat treated alloy at the expense of ductility. When the alloy is heat treated, it forms a homogeneous single phase, followed by quenching to retain the solute component in unstable state.

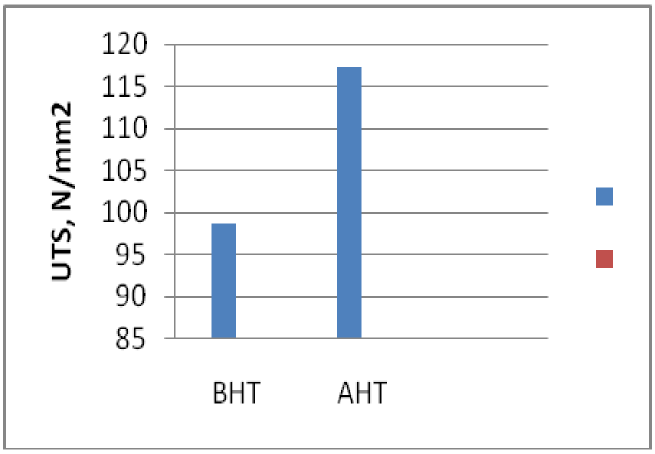

Fig.1 UTS

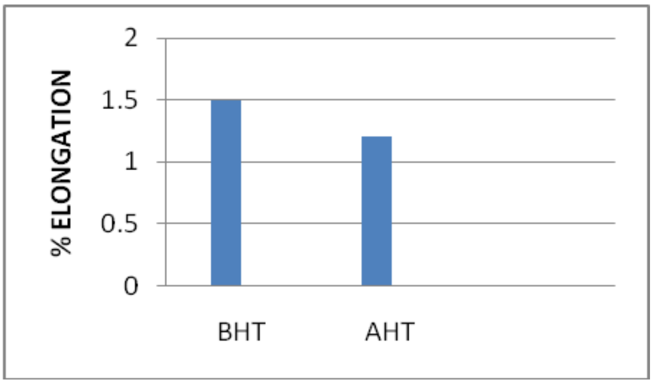

Fig.1 % Elongation

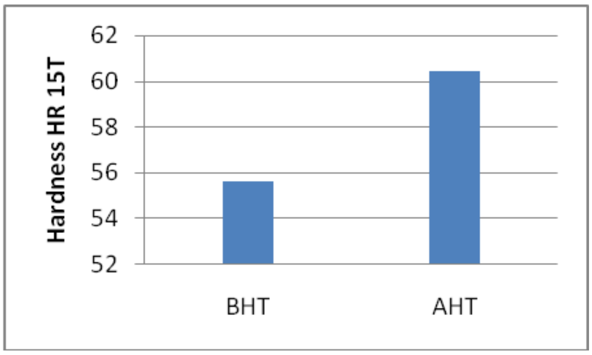

Fig.3 Hardness for Both As-Cast And Heat Treated Conditions

On subsequent ageing and precipitation treatment in the range of 160°C, the solute atoms are rejected and form a cluster as a coherent or semi-coherent precipitate. The strained field around a coherent or semi-coherent precipitate inhibits the movement of dislocations with increase in strength and hardness but decrease in ductility.

The piston alloy under investigation contains numerous alloying and impurity elements each of which have some effects on the mechanical properties of this alloys. The presence of nickel in the range 0.1–2.5% increased hardness of the Al–Si piston alloy. This is attributed to the dispersed component in the structure. Again, silicon of the alloy combines chemically with magnesium to form magnesium silicide along the direction of the aluminum matrix. This compound when finely dispersed by controlled precipitation during heat treatment is responsible for strengthening the alloy. It also observes that most of the heat treatable aluminum alloys produce higher strength and lower elongation when ageing is done after quenching.

B) *Wear properties of Al–Si piston Alloy*

Fig. 4 and 5 show the worn surfaces of the specimens studied in this work. Fig. 4shows the wear surface of as cast specimen,

Fig. 4 Worm Surface of Cast

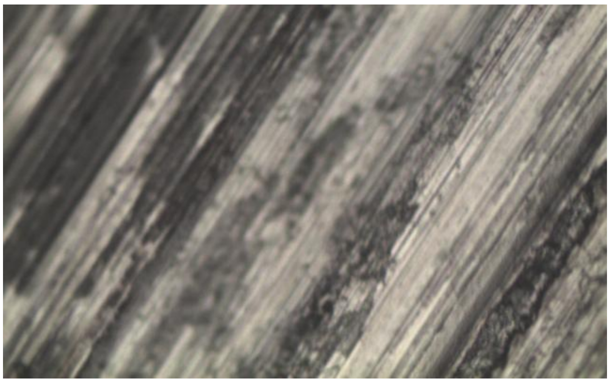

Fig.5 Worm Surfaces of Heat Treated Specimen

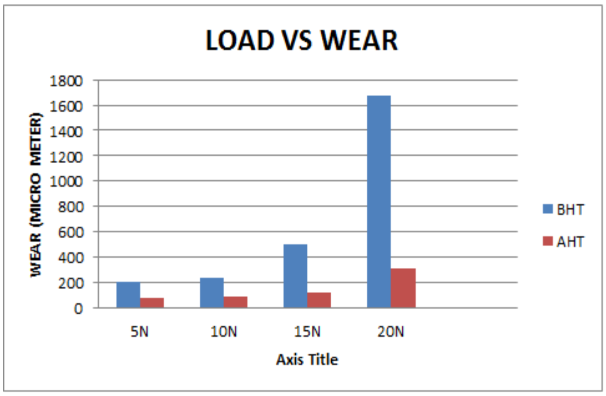

Fig.6 Wear Loss

This clearly indicates the mark of an adhesive wear with plastic deformation[10]. The wear surface of heat treated specimen in Fig. 5 shows abrasive type of wear due to micro cutting or ploughing of solid bodies with no plastic deformation. For material with higher hardness, abrasive wear tends to take place, while for material with lower hardness, adhesive wear is encountered. In the present study, for heat treated alloy with HR15T value 60.40, abrasive wear has been found to be the main mechanism, while for as-cast alloy with HR15Tvalue 55.60, adhesive wear has taken place. Thus, it can be said that the wear mechanism may also depend upon the hardness of the material.

As-cast specimen shows the greater rate of increase, while the heat treated specimens show decrease in wear rate with sliding distance (time). On the other hand, when load is increased, the as-cast sample shows greater rate of increase in wear but the heat treated cast sample shows decrease in wear.

IV. CONCLUSION

1. When compared to cast aluminum the heat treated specimen wear is reduced with various loads.
2. Mechanical properties like hardness and tensile properties are higher than the cast specimen.
3. The overall study shows that the heat treated Al-Si piston alloy has higher strength, hardness and wear resistance properties.

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