Effect of heat treatment on tribiological properties of Al-Sn alloy

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***Abstract*: The present study aims to investigate the effect of heat treatment on wear property of Al-15Sn alloy. The cylindrical shaped Al-Sn alloy was isothermally held in the tubular furnace at temperature of 150˚C for about 30 minutes and cooled in air as well as in furnace. Cooled specimens were subjected to wear testing using pin on disc wear apparatus at a speed of 1000RPM (4kg load) and results were compared. Micro structural study was conducted to understand the effect of surface wear for the specimens cooled under different media.**

***Keywords*: Al-15Sn alloy, Heat treatment, Wear property, Micro structure**

1. Introduction

Lead (Pb) containing alloys such as white metals and Cu-Pb-Sn (lining) with Pb-based overlay plating have been extensively used as materials for internal combustion engine bearings during the last decades [1-2]. However, owing to environmental and health concerns, the use of Pb containing materials are restricted in engineering applications. In view of this, attempts are under way to develop and replace Pb-containing materials with Pb–free bearing materials [3-4].

The most common Pb-free bearing material is Al-Sn based bearing alloy. The Al–Sn based alloys, known as "soft tribological alloys", are widely used in automotive industry as sliding bearing materials for supporting the reciprocating rotation of the crankshaft in internal combustion engines owning to its excellent friction and wear properties [5-7]. A great efforts are attempting to promote the properties of Al–Sn based bearing alloys to satisfy the application requirement towards higher load and speed together with eliminating of toxic Pb [8-9].

Excellent tribological properties can be achieved in Al-Sn alloys when the soft Sn-rich phase is dispersed homogeneously into the Al matrix .However due to the low density of the aluminum alloys, in engineering applications especially where it has to perform in friction environment it is necessary to improve its mechanical and tribological properties to support different loads and provide expected performance to the alloys [8]. As is evident that only very few studies pertaining to heat treatment of Al-15Sn have been conducted so far. This work focuses on investigation of tribological properties of Al-15Sn by modifying grains through heat treatment of alloy and using different cooling media.

2. Experimental

Al-15Sn alloy ingot was purchased in the dimensions of 350mm in length and 40mm of height as shown in Figure 1. The ingot was sectioned into as per the standard specimen of wear testing using the electron discharge machine (EDM) by adopting wire radian cutting method at Bengaluru. The standard dimension is 10mm in diameter and length of 50mm as shown in Figure 2.

Rapid quenching experimental setup (tubular furnace) was used for heat treatment of samples. The set up consists of a vertical furnace for heating a standard specimen with a specimen holder and a temperature controller. The furnace is cylindrical in shape with small through hole which runs through the length of the furnace to hold the specimen from above and sudden quench from below. The dimension of the hole is 50mm in diameter and 200mm in height, the setup of tubular furnace is shown in Figure 3.

The specimens were heated to a temperature of 150°C for duration of 30mins. Two heat treated specimens were cooled in different media under two different conditions. Firstly specimens was cooled in atmospheric air and secondly cooled within the furnace. Further results are compared with as-received cylindrical specimen.

Figure 1: As-received Al-15Sn Ingot

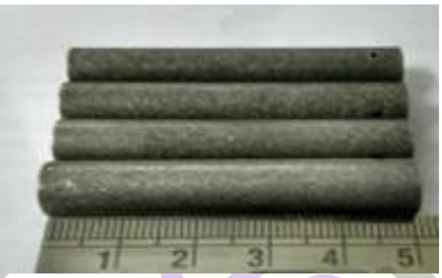

Figure 2. Wear Standard Specimen

Figure 3. Tubular Furnace

Both the heat treated specimens were subjected to wear testing and results are compared with as-received specimen. Wear testing was carried out using Pin on disc wear test machine (Contech Micro System, Bangalore) to find the wear property for the specimens. The wear test was conducted by applying a load of 4kg at a disc speed of 1000rpm having radius of 50mm for time period of 30 minutes. The specimen subjected for wear testing is shown in Figure 4. After wear testing all the specimens were mirror polished and observed under the metallurgical microscope by etching, to investigate the effect of heat treatment on grain structures.

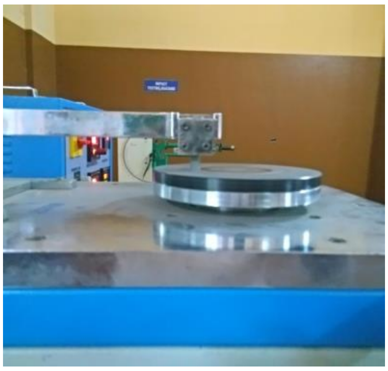

Figure 4. Specimen under Wear Test

3. Results and Discussion

Plot of wear vs time for worn specimens cooled in different media is shown in Figure 4. Wear rate increased as the time increased. Specimen cooled in the furnace exhibited higher wear rate compared to as received specimen.

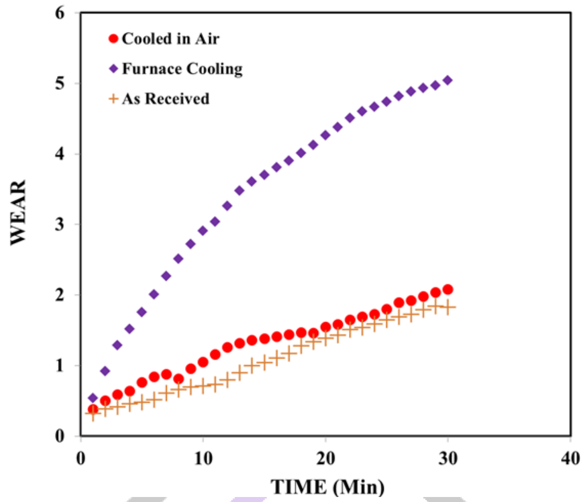

Figure 5: Wear vs time for worn specimens cooled in different media

Microstructure of worn surface of as received specimen is shown in Figure 6. Microstructures of worn surfaces of specimen cooled in furnace and air are shown in Figure 7 and 8.

Worn surfaces clearly revealed that, the wear rate increased with time. This is due to plastic deformation and increase of temperature at the interface between specimen and wear disc. The furnace cooled sample exhibited higher worn surface because of higher ductility than samples cooled in air and as received surface. The extruded quantity of Sn in as-received specimen rapidly enlarged to about 20 to 30% only. Therefore wear rate of as received samples showed decreasing trend.

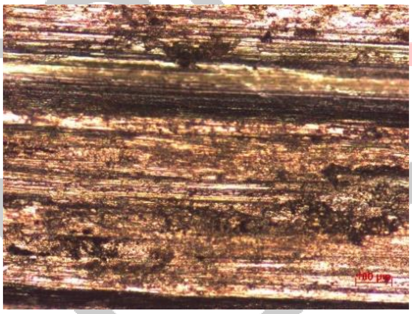

Fig 6 : Microstructure of worn surface of As-received specimen

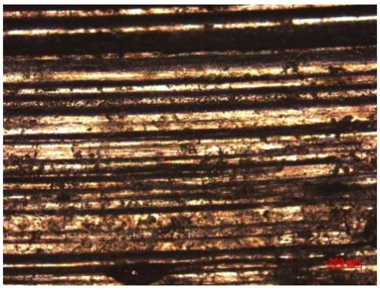

Fig 7 : Microstructure of worn surface of heat treated specimen cooled in Air

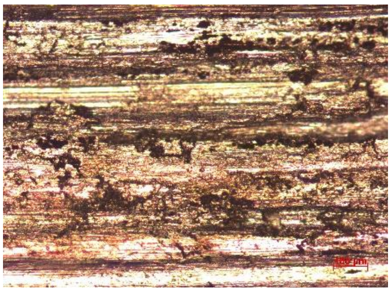

Fig 8 : Microstructure of worn surface of heat treated specimen cooled in furnace

Microstructures of as received specimen without heat treatment are shown in Figure 9. Microstructures of specimens after heat treatment are shown in Figures 10 and 11. The cooling media of alloy significantly affected the microstructure of the Al-Sn alloy. Microstructure of air cooled showed almost similar behavior (Fig 10) that of furnace cooled (Fig 11). For the specimen cooled in air, grain boundaries were clearly visible (Fig 10). This was due to the cooling of the heat treated specimen in the direct atmospheric air. Due to the slow solidification process in the furnace, the grains get formed freely without any obstruction from the surrounding. As a result the grains are partially visible. Hence there is no clear picture regarding the grain boundary formation. Similar behavior was observed by Prabhu et al [10]. However, due to extrusion and contraction of grains in the as-received specimen, microstructure did not exhibit the grain boundaries properly. The grains were compressed (Fig 9).

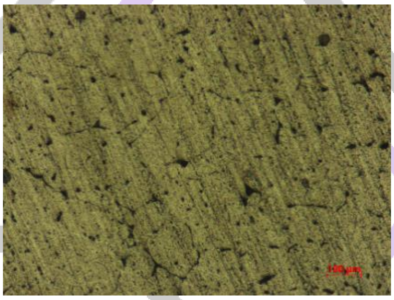

Fig 9 :Microstructure of as recived specimen As received

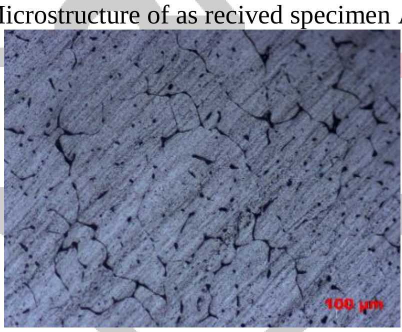

Fig 10 : Microstructure of specimen cooled in Air

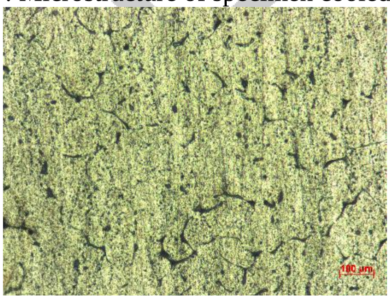

Fig 11 : Microstructure of specimen cooled Furnace

3. Conclusions

- Wear rate of specimen increased as the time increased.
- As received heat treated specimen exhibited less worn surface.
- Furnace cooled specimen exhibited more worn surface. Larger grains were observed for the specimen cooled in air and furnace.

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