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Investigation on the Microstructural, Mechanical, Tribological and Corrosive Behavior of Al6061 with Varying Proportion of Tin Inclusion

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Abstract: ***Aluminum alloys have high strength, durability, low density, cost and machinability. These properties make it a very attractive compared to other materials. Aluminum matrix composites are among the most promising materials for wear and structural applications due to their low cost, light weight and the ease of fabrication. In this research effect of tin on Aluminum 6061based on the various mechanical, tribological and corrosive behavior with tin additions as an alloying element in as cast condition is investigated. Varying weight percentage of tin (5%, 10% and 15 wt %) is effectively alloyed with Al-6061 aluminum alloy through stir casting technique. The casted Al-Sn alloy is machined by WEDM in accordance to the ASTM standards for micro structural, mechanical, tribological and corrosive characterization. The micro structural characterization has to be carried out which explains the grain refinement and modifications that takes place with the addition of tin elements. Mechanical characterization involves the micro hardness and mechanical strength which has to be carried out as per ASTM standards. Tribological behavior of the developed alloy and the influence of tin element with respect to its addition in wear rate and coefficient of friction are investigated employing pin-on-disc equipment. It has been studied based on literatures that tin element enhances the corrosion resistance of the developed alloy and the investigation of the same is carried out and the results obtained through an electrochemical workstation.***

Keywords: Aluminum alloys, composites, structural characterization

1. Introduction

Aluminum is one of the major elements on earth. It is an important material in our modern world after steel. Aluminum makes it possible for structures that would be too heavy to be use if made from other material like steel. Aluminum alloy is a precipitation hardening alloy. The major alloying elements are magnesium and silicon which has good mechanical properties and exhibits good weld ability. Aluminum alloys is one of the most common for general purpose application. Aluminium has less density when compared to steel and also has good corrosion resistance, mechanical properties. Aluminium and Alloys are used widely. For example Aluminium 6061 has high thermal conductivity, low density hence it has poor wear resistance. To overcome this ceramic materials are reinforced in it due to that its wear resistance and young's modulus values are increased.

Some ceramic materials are:

1.1 Aluminum – Tin Alloys

There should be a balance between softness and stiffness in bearing alloys. Aluminium-tin bearing has good surface properties and high fatigue strength such as seizure resistance, enbed ability, softness. This alloy has higher loading and when compared to lead or tin based alloys since they are employed in conjucation with ductile or hardened steel from crankshaft.

1.2 Aluminum – Silicon Alloys

3 to 25% of silica content is there in aluminum-silicon alloys. This alloy uses casting for primary use; they can also be used in powder metallurgy and rapid solidification process. Alloys used in powder metallurgy but not through casting may contain 50% of silicon. Silumin has a high resistance to corrosion, making it useful in humid environments.

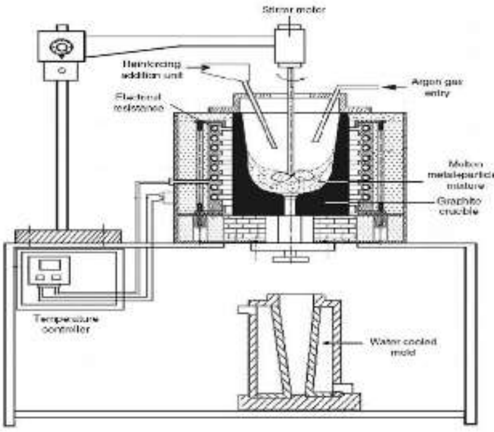
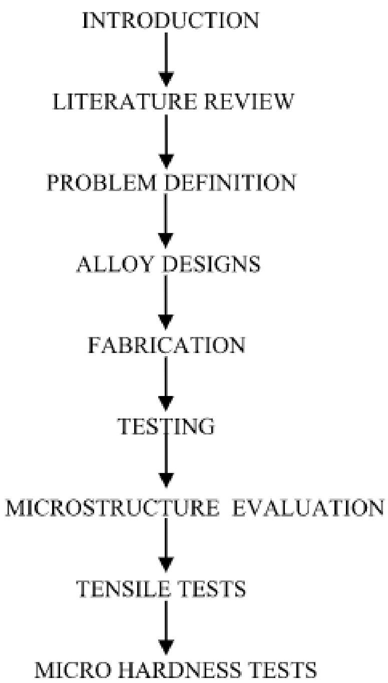


Figure 1.1: Stir casting experimental setup

2. Problem Definition

It is a known fact that the aluminum alloys has been extensively used in the various automotive and aerospace application in lieu of its enhanced strength to weight ratio. Based on the literature survey, it has been confirmed that the inclusion of alloying element tin in certain metals Mg and Iron has been proved that refinement of grain structure has been taken place and developed alloys. Literatures based on aluminum have been survived and it has been visualized that tin coatings has been provided to aluminum alloys to enhance the corrosive resistance of the particular alloy. On behalf of these studies, in this research tin element for varying weight percentages are included into al-6061 alloy a commonly used and available metal and the effect of tin addition was evaluated and analyzed. A detailed analysis of the micro structural characterization through optical microscope and SEM was studied. Again to this a detailed study on the mechanical strength of developed set of alloys has to be studied and their mechanism through fractography analysis has to be carried over.

2.1 Methodology



3. Fabrication

3.1 Experimental Procedure for Stir Casting

Here there is the experimental procedure for stir casting. About 2.5kg capacity of crucible can be carried in the electric furnace. 1000 ºC is the maximum operating temperature. The current rating of furnace is single phase 230V AC, 50Hz. The Al6061 is has been made into fine scrap using the shaping machine of about 2.25kg. All the metal scraps are poured into the furnace and heated to a temperature till it reaches the semi liquid form of around 600 ºC. The mixing of the alloy is done manually for uniformity. After that the reinforcement powder heated to 500 ºC is added to the furnace. Reheating of aluminum matrix is done till it reaches the complete liquid state, simultaneously argon gas is introduced into the furnace. There by stirring process is done using the stirrer having an 150rpm. The composite materials at 800 ºC reaches complete liquid state (aluminum melting point is 700 ºC). Hence the complete matrix component is poured in the permanent molds.

3.2 Stir Casting

In the present investigation Al6061alloy-tin composite is prepared by stir casting technique. The various proportions of tin like 5%, 10%, 15% volumes are tried and castings are prepared. Al6061alloy is melted in the furnace to a temperature of 7200C & then tin which is in the powdered form(1nm) is poured slowly, simultaneously stirrer is made to rotate at an optimum speed of 450 rpm for a period of 5-10 minutes, then the melt is degassed by passing Nitrogen gas. Finally, the molten metal is poured into the finger metal mould. The mould is coated with chalk powder to prevent sticking of the molten metal into the surface of the mould. The cast samples are then subjected to heat treatment and hot extrusion. The solidified metal is removed from the die & is subjected to heat treatment where solidification is done at 5900C for a period of10 hours and then it is immersed in hot water maintained at 1000C and allowed it to cool for 12hours. And finally ageing is done at 1750C for a period of 5 hours.

Figure 3.1: Stir Casted Al-Sn alloy

Figure 3.2: Specimen before tensile test

4. Results and Discussion

4.1 Optical Microscope

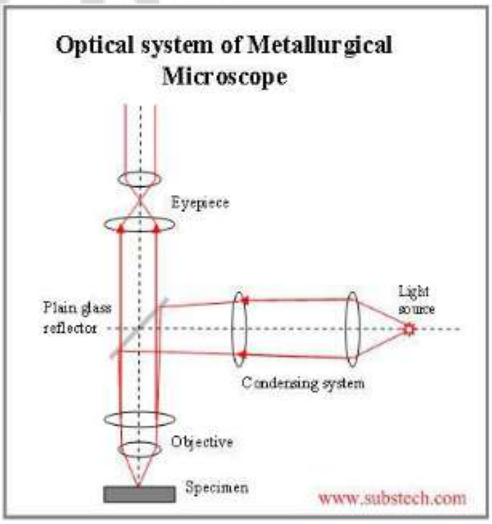


Figure 4.1: Principle of optical microscope

4.2 Microscopic Results

The results of the optical microscopic analysis are represented in the Figure shows the optical micro structure of Al6061 and 5% of tin alloy, Figure shows the optical micro structure of Al6061 and 10% of tin alloy and Figure shows the optical micro structure of Al6061 and 15% of tin alloy

From the below optical micro structure analysis of three different proportions of tin (5%, 10% and 15%). A 0.5% HF solution was used to etch the samples wherever required. Microstructures were examined under the metallurgical microscope. From micro structural analysis, it is observed that Aluminum tin composite having cluster particles and some places are identified without tin inclusions. This was due to varying the contact time between the tin particles and molten aluminum during processing and high surface tension and poor wetting behavior between Aluminum and tin particles. To overcome the surface tension problem and improve wetting properties, a mechanical force can be applied uniformly during distribution of reinforcement in the metal matrix composites. Also when comparing the below three different proportions of tin shall identify the grain structure is uniform and fine in 15% of tin and Al6061 alloys.

4.3 SEM Results

The results of the SEM analysis are represented in the Figure 4.2 shows the optical micro structure of Al6061 and 5% of tin alloy, the microstructure of the sample indicates that the homogeneity of Al grain was observed. Figure 4.2 shows the SEM image of Al6061 and 5% of tin particles. Figure shows the microstructure of Al6061 and 10% of tin and Figure shows the micro structure of Al6061 and 15% of tin particles.

From the diagram you can see that there is an increase in the cluster particle corresponding to temperature rise. . Although there is an increase in the particle clustering with increase processing temperature, it was observed that the tendency for formation of particle cluster was greater in the higher holding time than in the low holding time. The growth of porosity is not restricted by low viscosity liquid. During high temperature particle cluster is high and has a big contact with matrix and reinforcement.

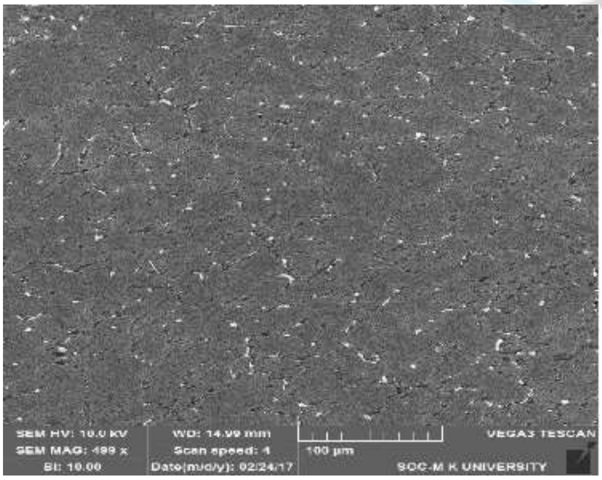


Figure 4.2: Micro structure of Al6061 and 5% of tin

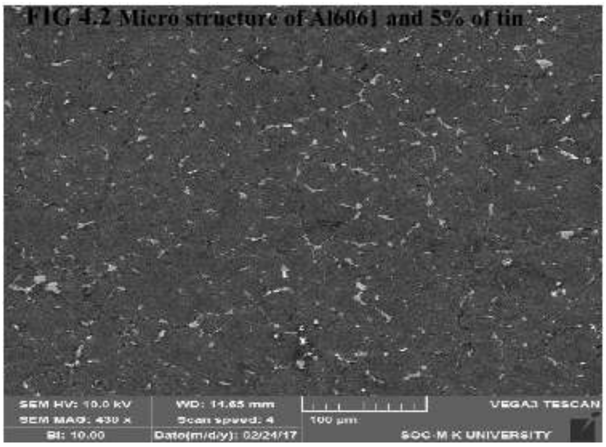


Figure 4.3: Micro structure of Al6061 and 10% of tin

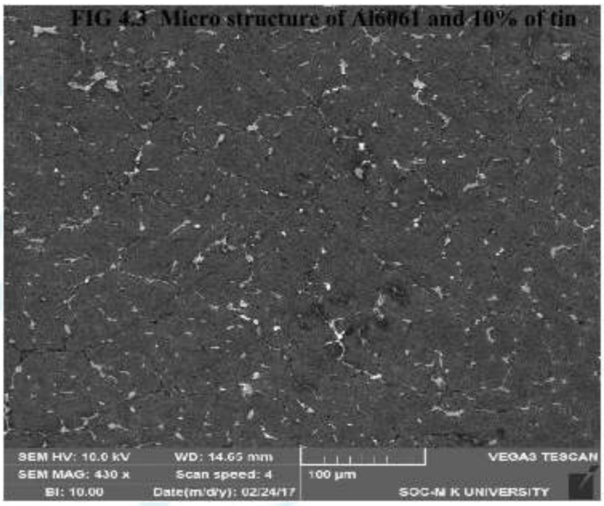


Figure 4.4: Micro structure of Al6061 and 15% of tin

4.4 Hardness Measurements

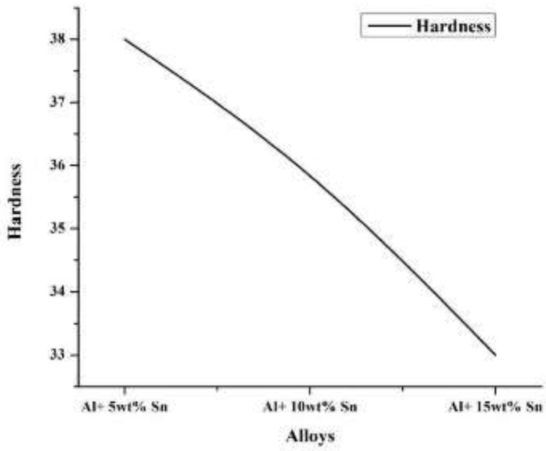


Figure 4.5: Alloys composition Vs Hardness

The graph shows Figure that it is observed that there is an increase in the hardness of Al6061 with addition of 5, 10 and 15 wt % of tin particulate. The graph shows the variation of hardness of Al6061 alloy with Tin reinforcement particulate. It can be concluded that the addition of wt. % of Tin particulate results in increasing the hardness. The hardness of a soft material such as Aluminum matrix is increased when it is reinforced with a hard particulate i.e., Tin.

4.5 Ultimate Tensile Strength

The graph shows Figure 4.6 that the variation of ultimate tensile strength (UTS) of base alloy, when reinforced with 5, 10 and 15 wt. % of Tin particulates. The ultimate tensile strength of Al6061- Tin composite material increases as compared to the cast base Al6061 alloy. The microstructure and properties of hard ceramic Tin particulates control the deformation of the composites. Due to the strong interface bonding, load from the matrix transfers to the reinforcement resulting in increased ultimate tensile strength. This increase in ultimate tensile strength mainly is due to presence of Tin particles which are acting as barrier to dislocations in the microstructure. The improvement in ultimate tensile strength may also be due to alloy strengthening of the matrix, followed with a reduction in grain size of the composites, and the formation of a high dislocation density in the Al6061 alloy matrix due to the difference in the thermal expansion between the metal matrix and the Tin reinforcement.

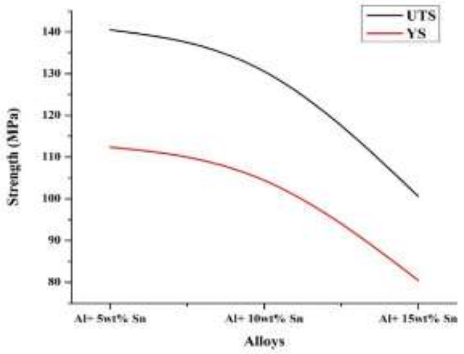


Figure 4.6: Alloys composition Vs Strength

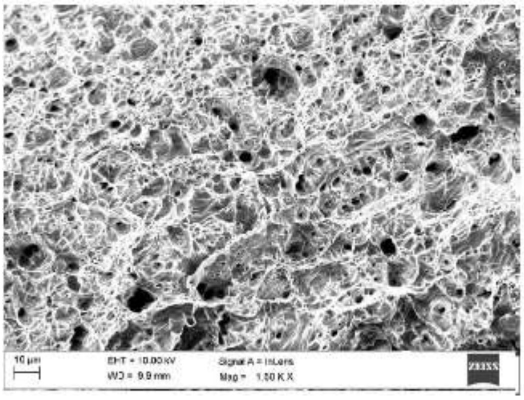


Figure 4.7: Al6061 – Sn 5%

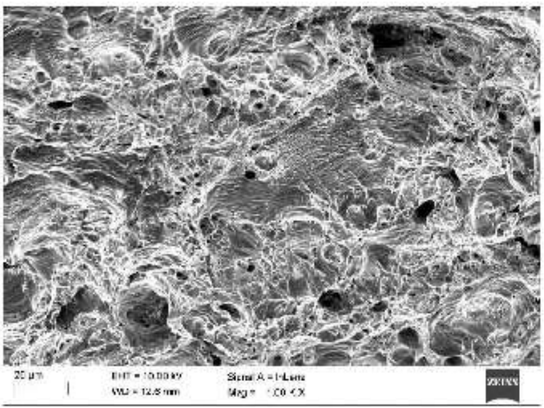


Figure 4.8: Al6061 – Sn 10%

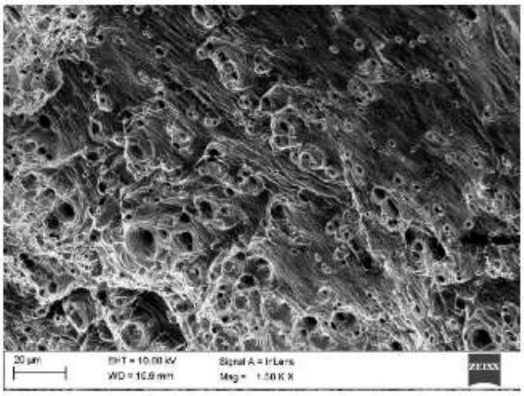


Figure 4.9: Al6061 – Sn 15%

4.6 Yield Strength

The graph shows Figure 4.6 that the variation of yield strength (YS) of Al6061 alloy matrix with 5, 10 and 15 wt. % of Tin particulate reinforced composite. It can be seen that by adding 15 wt. % of Tin particulates yield strength of the Al6061 alloy decreased from 112 MPa to 80 Mpa. This decrease in yield strength is in agreement with the results obtained by several researchers, who have reported that the strength of the particle reinforced composites is highly dependent on the volume fraction of the reinforcement. The decrease in YS of the composite is obviously due to presence of hard Tin particles which impart strength to the soft Aluminum matrix resulting in greater resistance of the composite against the applied tensile load Hard particles creates some restriction to plastic flow in case of any particle reinforced composition through providing composition strength

4.7 Density

The graph shows in Figure 4.10 that the density increases while increasing the weight of tin with aluminum 6061 alloys.

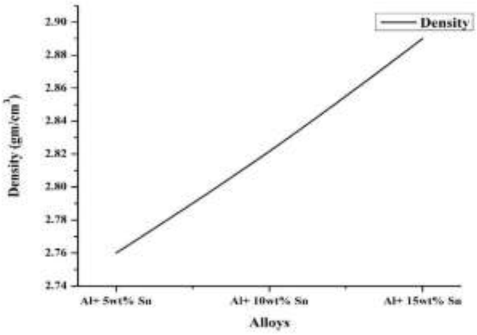


Figure 4.10: Alloys composition Vs Density

4.8 Percentage of Elongation

The graph shows in figure the percentage of elongation decreases when the percentage of tin added to the Al6061 alloys

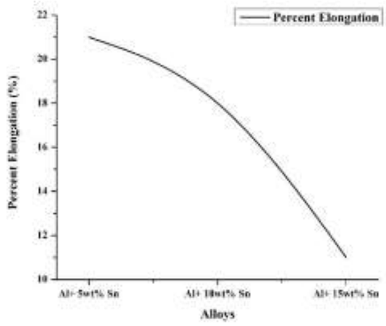


Figure 4.11: Alloys composition Vs Percent Elongation

5. Conclusion

A study on the effect of tin element over the micro structural and mechanical characteristics of an aluminium alloy was successfully investigated in this research, where aluminium 6061 alloy is alloyed with varying weight fractions of tin element and successfully incorporated by the means of stir casting. Stir casted aluminium-Sn alloys were characterized by means of optical microscope and SEM so as to evaluate the evaluation of micro structure and its grain refinement with respect to tin addition. It was observed that a reduction in grain size occurs with respect to tin addition while SEM results expose nil detrimental phases and inter metallic formation during the entire casting. It can also be stated that defects involved during casting such as porosity was found nil. Characterization of mechanical properties including hardness and strength demonstrated a reduction in its value with respect to tin addition and s reduction in ductility was also observed. Examination over the failed tensile specimens through SEM also explained the same mechanism and the ductility reduction. Density of the developed specimens was found increasing with respect to addition of tin element into aluminium matrix.

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