International Journal of Engineering Innovation & Research
Volume 2, Issue 5, ISSN: 2277 – 5668

Microstructure of Tin Dispersed Aluminum-Silicon Alloys Prepared By Solidification in a Wedge Mold

J. K. Singh
Assistant Professor, Dept. of Met. Engg. IIT (BHU)
E-mail: jksingh_jayant@yahoo.com, Mob. + 918765172866

S. N. Ojha
Professor and Former Head,
Department of Met Engg. IIT (BHU)

***Abstract* – Present paper discusses the microstructure of tin dispersed A356 alloy with particular emphasis on the distribution of tin in the alloy. A wedge mold made of cast iron has been utilized for the preparation of aluminum-silicon-tin alloys. Optical microscopic studies have been presented for the distribution of tin in hypoeutectic Aluminum-Silicon alloys. The breaking of dendritic arm resulting from the differential cooling rate achieved during the solidification as a result of changing cross section has been presented.**

***Keywords* – Aluminum-Silicon-Tin Alloys, Breaking Of Dendrites, Electric Furnace, Supercooling.**

I. INTRODUCTION

Aluminum-tin alloys, due to excellent property of tin as a lubricating agent and high thermal conductivity of the solvent aluminum are the ideal material for lubrication of steel-backed bearings [1]. Among the various materials, aluminum alloys, developed for bearing application has been increased considerably in recent years. Combination of low cost with good bearing qualities to a greater extent [2] than any other alloys, Al-Si-Sn alloy may be an attractive alternative to the more commonly employed alloys for the purpose. A356 comes under the class of Aluminum-Silicon (Al-Si) alloys [3].When Al-Si alloy solidifies, the primary aluminum forms and grows in dendrites or Silicon phase forms and grows in angular primary particles. If Si percentage is less than it is hypoeutectic, as in the case of A356. At room temperature, hypoeutectic alloys consist of a soft and ductile primary aluminum phase and a hard and brittle eutectic silicon phase.

The Al-Si alloy usually has some other coexisting elements such as Copper, Magnesium, Manganese, Zinc and Iron, as magnesium exist in the case of the A356 aluminum alloy.Al-Siclass of alloys constitutes the majority of Aluminum cast parts produced, due to their superior properties and excellent casting characteristics. Within this family, Al-Si-Cu (e.g. A319) and Al-Si-Mg (e.g. A356) cast alloys are frequently employed in automotive applications.As cast aluminum alloy, A356 after procuring from a certified local vendor, its composition was verifiedby spectroscopy and the exact composition as found is given in the following table number 1.

In the present article, attempts have been exercised to disperse tin in an A356 aluminum alloy by solidifying the melt in a cast iron wedge mold. This is done so that a differential cooling rate can be utilized to study the effect of cooling rate on the refining of grains.

Following is the Al-Si and Al-Sn phase diagrams as shown in the figures 1 and 2

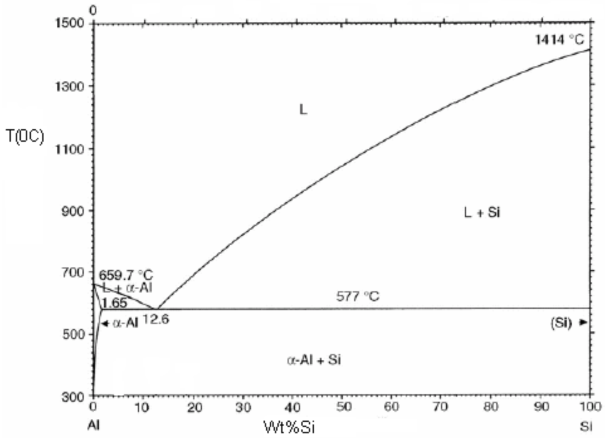

Fig.1. Aluminum- Silicon phase diagram [4]

Following are the information that can be extracted from this phase diagram,

- At the extreme left, the phase which exists is alpha aluminum which is regarded as a solid solution of silicon in aluminum. Due to the fact, that silicon has very little solid solubility in aluminum and hence this phase has the FCC crystal structure.
- At the extreme right the existing phase is having the diamond cubic crystal structure and this phase may be regarded as the solid solution of aluminum in silicon.
- The eutectic composition in the phase diagram is at nearly 11.5 wt % Si and the eutectic reaction can be given as, L ↔ Alpha aluminum + Silicon

In other words it can be said that if the liquid is cooled in equilibrium manner through the eutectic point from a temperature of nearly 570^0 C the liquid will be decomposed into two solids namely alpha aluminum and silicon and vice-versa.

Table 1: Composition of A356 Aluminum alloy as received

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
Weight %	6.5-7.5	0.6 max	0.25 max	0.35 max	0.2-0.45	0.35 max	0.25 max	Balance

International Journal of Engineering Innovation & Research
Volume 2, Issue 5, ISSN: 2277 – 5668

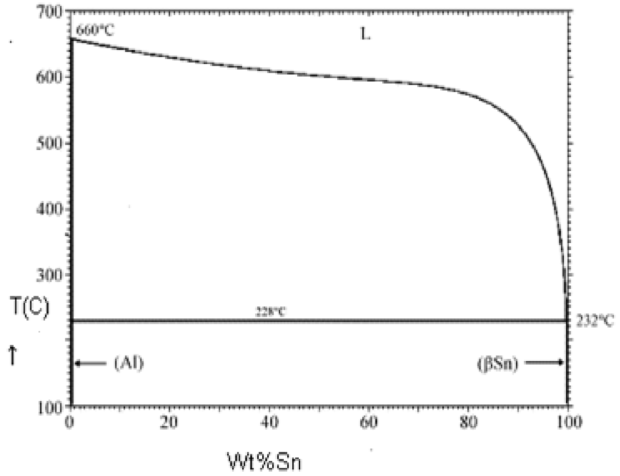

Fig.2. Aluminum- Tin phase diagram [5]

It is well known that aluminum and tin are two kinds of metals having different physical properties such as melting point and density.Tin has the density of $7.2x10^{-3}$kgm/m^3 and aluminum has $2.7x10^{-3}$kgm/m^3 which means that there is a huge density difference. Also tin has melting point of aluminum, 933K differs by a large margin from that of tin, 503K. Both the aforesaid factors, lead to the gravity segregation of tin in the solidified microstructure [6] A large solidification range can easily be observed in the phase diagrams and it is quite evident from the diagrams that there is very little solid solubility is existing between the phases involved in the phase diagrams and thus, it is very difficult to disperse tin in an aluminum alloy up to a desired level so as to use these alloys as a good bearing material.

Due to these factors the use of these alloys has been restricted to a very limited extent. Attempts have been made in the article to disperse tin in an hypoeutectic aluminum silicon alloy in aluminum by the virtue of thevertical centrifugal casting machine coupled with impeller mixer bottom discharge assembly. Till now no attempts have been made in this direction.

Anil[7] utilized spray forming technique to disperse tin in an aluminum-silicon alloy but the problem is that the spray forming technique is not best suited for bulk production of the alloy due to the fact spray forming processes are free forming process comprising of a lot of interdependent variables. Under such type of circumstances, it is difficult to predict the shape, porosity and deposition rate for an alloy. Entrapment of gases during the solidification may also lead to the generation of porosity in the microstructure. Thus the inherent complexities associated with the process aided with a paucity of robust control makes the process ineffective towards commercialization. The present paper may be an alternative to the aforesaid process able to generate a reasonably good microstructure of Al-Si-Sn alloy.

II. Experimental Details

2.1: Materials Required

Followings were the materials required for the preparation of the alloys

- Commercial A356 aluminum alloy
- Commercial tin (98.00wt%pure)

Fireclay powder (-150 mesh size) was used for mould coating

2.2: Equipment

In thepresent article, it has been attempted to have a solidified structure with different cooling rates. In order to achieve it casting process was necessary so that different cooling rates can be produced. So, instead of repeating the same casting process multiple times at different cooling rates, a scheme was devised to use a mold of conical shape made on a wooden pattern in such a way that its cross-sectional area keeps on changing. This change in the cross-sectional area and also the resulting specific volume leads to provide different cooling rates for the mold. The mold was made up of Cast Iron to sustain the temperature of aluminum melt. The dimension was such decided as to obtain a conical cast structure of height 5 inches with its diameter being 1cm at the bottom and gradually increasing to 5cm at the top, as schematically shown in figure 3.

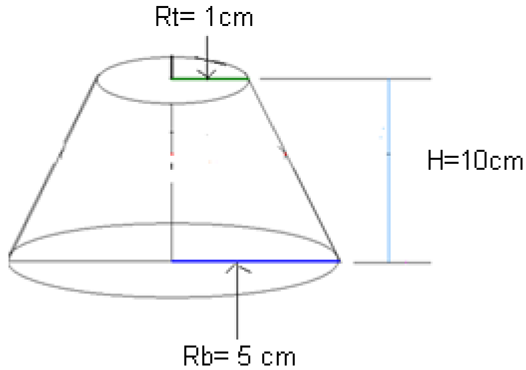

Fig.3 Schematic line diagram of the wedge mold

Apart from the wedge mold, other equipment required were an electric furnace for melting purposes.

2.3: Experimental procedure

The furnace used for the purpose was electric furnace in which a temperature of 650^0C was maintained. A superheat of around 75^0C was given to the melt. In order to prepare the A356 alloy having a dispersion of tin, a stirrer was used to carry out an effective mixing of tin in the aluminum A356 alloy. The necessity of an effective mixing was derived from the density difference existing between A356 and tin so that settling of tin in the alloy thus prepared can be restricted during the course of solidification. Proper care had been taken for homogenization as well. A vigorous stirring by the stirrer was provided to the melt till it got partly solidified. Tin addition has been done in two amounts viz 1% and 10%.

Sample for microstructural characterization have been taken from the castings thus produced and polished. The polished samples have been etched with freshly prepared

International Journal of Engineering Innovation & Research
Volume 2, Issue 5, ISSN: 2277 – 5668

Keller's reagent which was a mixture of nitric, hydrochloric acid and hydrofluoric acid, as given in table 2, and examined under optical microscope to study the dispersion of tin in the alloy.

Table 2: Composition of freshly prepared Keller's reagent for etching aluminum alloys

Component	Quantity (ml)
Hydrofluoric Acid	2
Hydrochloric Acid	3
Nitric Acid	5
Water	190

III. Microstructural Characterization and Discussion

Aluminum-silicon alloy A356 has been solidified in the wedge mold and the microstructure thus obtained have been discussed in this chapter.

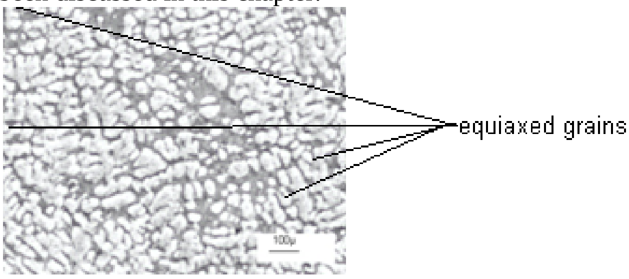

Fig.4. A356 +1% Sn in the wedge mold (100X for the zone immediate to the mold wall, showingthe presence of some equiaxed grains

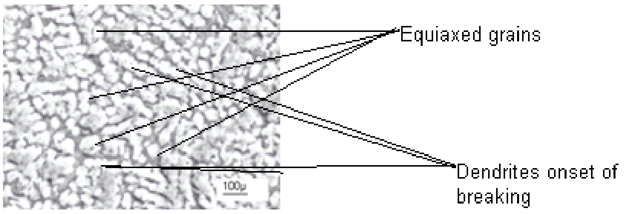

Fig.5. A356 +1% Sn solidified in the wedge mold (100X), for the zone at center showing the formation of equiaxed grains.

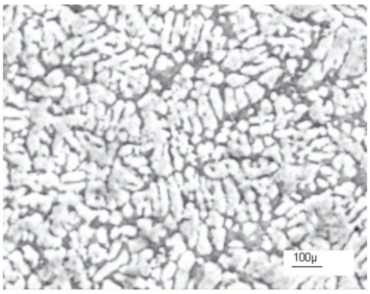

Fig.6. A356+1%Sn microstructure (100X), for the zone between mold wall and the center of the casting prepared in the wedge mold.

The microstructure as shown in the Fig 5 and 6are the microstructures obtained for the A356 alloy having a dispersion of 1% Sn within it. Both the aforesaid microstructures are corresponding to the central zone of the wedge mold casting of the alloy. It can be very easily seen from the figures that columnar grains of α- aluminum alongwith some grains of equiaxed nature were formed. The formation of columnar grains in the zone can be explained as follows.

During the solidification of liquid melt at the center of the wedge mold a low nucleation rate was there due to the homogeneous nature of the nucleation. The melt was at a reasonable distance from the wall of the mold and hence there was very little probability for heterogeneous nucleation to occur. At the same time low nucleation rate was followed by a dominating crystal growth. As soon as nucleation started in the zone in the vicinity of the wedge mold wall, temperature in the zone, for which the microstructures have been shown, started to increase towards the equilibrium freezing temperature. This rise in temperature may be attributed to the release of the latent heat of fusion. When such type of situation prevails in the melt during the solidification, there was an inversion of temperature ahead of the formed crystals in the zone which was immediate to the mold wall (made of cast iron having thermal conductivity value, k= 55.0 W/m^{0}C and specific heat at constant pressure C_p = 456.0 J/Kgm^{0}C). The temperature ahead of the interface fallen instead of increase. Such a situation is what is referred to as "temperature inversion". Due to this phenomenon, there occurred dendritic growth and crystals of the previous zone ie in the vicinity of the mold wall, lying on the interface shooted out the dendritic arms into the supercooled liquid melt and hence the columnar crystals formed. The presence of equiaxed grains associated with columnar grains can be attributed to the overlapping of the zones of constitutional supercooling when the solid-liquid interfaces advancing from the opposite sides of the wedge mold approach each other at the center of the ingot during the course of solidification of A356 alloy in the wedge mold.

The formation of equiaxed grains in the areas near the mold wall is a common phenomenon that occurs in the case of freezing of metals/alloys, shown in the 4. The microstructure as shown in the figure corresponds to the contour of the wedge mold. In a narrow band, following the mold contour there was a zone called chill zone where melt had experienced a larger undercooling and hence a high nucleation rate plus a low growth rate. The occurrence of these two simultaneous phenomena led to the formation of equiaxed grains in the microstructure of the alloy thus produced as a result of solidification in wedge mold.

IV. Conclusions

1. Wedge mold solidification is able to produce different types of microstructures such as equiaxed, columnar and a mixture of both.
2. Thermal conductivity of mold material had an important role in tailoring the microstructure of the alloys thus produced.

3. More or less a uniform dispersion of tin in A356 aluminum alloy can be exercised by the wedge mold method.

ACKNOWLEDGEMENT

The authors greatly acknowledge the help and support of the staff and students of the metallurgical engineering department of IIT (BHU) for their help in the preparation of the manuscript.

REFERENCES

[1] Wang Zhitong and TianRizhao : "Handbook of Aluminum Alloy and Its Forming, Central South University of Technology Press, Changasa", (1988), P 103.
[2] J.P.Pathak, S.N.Tiwari and S.L.Malhotra: "Metals Technology", 6, (1979), Pp442-445.
[3] Haizhi Ye.: "An overview of the development of Al-Si alloy based material for engine application",JMEPEG, vol. 12(2003), ASM International, Pp. 288-297.
[4] www.globalsino.com: Source Internet
[5] www.sciencedirect.com: Source Internet
[6] Kennis and ZhongyuanWen : " Metal Base Composites, National Defense Industry Press", Beijing, (1952), P52.
[7] M.Anil : "Ph.D Thesis" , Department of Metallurgical Engineering, IIT(BHU), 2007.