

The study on the influence of Si addition on the microstructure and hardness Al-Si alloys

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Abstract:

Alloys composed mostly of aluminum have been very important in aerospace manufacturing since the introduction of metal skinned aircraft. Silicon is good in metallic alloys used for casting. This is because it increases the fluidity of the melt, reduces the melting temperature, decreases the contraction associated with solidification and is very cheap as a raw material. Silicon also has a low density (2.34 g cm^{-3}), which may be an advantage in reducing the overall weight of the cast component. Silicon is hard and hence improves the abrasion resistance.

The aluminum silicon alloy is prepared by conventional die-casting method with approximately 7.5wt%, 12.5wt% & 17.5wt% Si. In this study, the influence of silicon addition on the microstructure and hardness of Al-Si has been investigated. This project gives a comparison of microstructure property between hypoeutectic, eutectic and hyper eutectic aluminum silicon alloy. The increase in silicon content results in an increase in the hardness of the Al-Si alloys.

Keywords

Eutectic, Hypereutectic, Hypoeutectic, microstructure

1. Introduction

Aluminum-silicon based alloys are well-known casting alloys with high wear resistance, low thermal-expansion coefficient, good corrosion resistance, and improved mechanical properties at a wide range of temperatures. These properties lead to the application of Al-Si alloys in the automotive industry, especially for cylinder blocks, cylinder heads, pistons and valve lifters. [1].

The refinement of microstructure can be achieved through high cooling rate or chemical modification. Usage of Al-Si-Cu-Mg alloys at temperature above 230°C is however limited due to coarsening of Si particles and dissolution of Cu- and Mg-bearing phases.

The silicon content in standardized commercial cast aluminum-silicon alloys is in the range of 5 to 23 wt%. The structure of the alloys can be hypoeutectic, hypereutectic, or eutectic, as can be seen on the equilibrium phase diagram. The properties of a specific alloy can be attributed to the individual physical properties of its main phase components and to the volume fraction and morphology of these components. [1-4]

2. Alloy

An alloy is a material that has metallic properties and is formed by combination of two or more chemical elements of which at least one is a metal. The metallic atoms must dominate in its chemical composition and the metallic bond in its crystal structure. Commonly, alloys have different properties from those of the component elements. An alloy of a metal is made by combining it with one or more other metals or non-metals that often enhances its properties. [4]

3. Aluminium alloys

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 typical alloying elements are copper, magnesium, manganese, silicon, and zinc. Surfaces of aluminium alloys have a brilliant lustre in dry environment due to the formation of a shielding layer of aluminium oxide. Aluminium alloys of the 4xxx, 5xxx and 6xxx series, containing major elemental additives of Mg and Si, are now being used to replace steel panels in various automobile industries. Due to such reasons, these alloys were subject of several scientific studies in the past few years [2].

4. Aluminium-Silicon alloy

Aluminium-Silicon alloys are of greater importance to engineering industries as they exhibit high

strength to weight ratio, high wear resistance, low density, low coefficient of thermal expansion etc. Silicon imparts high fluidity and low shrinkage, which result in good castability and weldability. Al-Si alloys are designated 4xxx alloys according to the Aluminium Association Wrought Alloy Designation System. [4]

5. Experimental Details

The present study has been carried out in order to achieve the following objectives

1) To conduct mechanical and Tribological properties for following composition of Al-Si alloy, prepared by die casting process .

a) Hypo –Eutectic (Si -7.69%)

b) Eutectic (Si-12.2%)

c) Hyper –eutectic (Si-17.28%)

2) To examine the microstructural properties of the alloys in the laboratory.

3) To compare the hardness with the microstructural properties.

Finally, to put forward some recommendations towards the use of this alloy for aerospace industry, automobile spare parts manufactures and other products.

5.1 PREPARATION OF ALLOYS

Al-Si alloy with varying Si percentage where prepared by melting commercially pure aluminium and commercially pure silicon. In graphite fit crucible in a high frequency induction furnace and melt was held at 720°C in order to attain homogeneous composition. The metal which possess low melting temperature is allowed to melt in the last because if it allowed to melt with metal which possess highest temperature then lowest melting temperature metal will get burn. The molten metal is pouring in mould cavity and allow to solidify in the mould. The die heat temperature is around 250°C. In order to remove the slag from the molten metal 20gms/5kg alloy slag removal flux is added.

5.2 COMPOSITION

The alloys were prepared and chemical analysis of their ingredients was done. The chemical composition alloys is given in Table-5.1 The cast iron mould was employed to investigate the solidification phenomena of the alloys. The melts were degasified with tetrachlorethane tables.

			TIC
Aluminium (Al)	85.3	80.5	74.4
Silicon (Si)	7.87	12.21	17.61
Copper (Cu)	0.0057	2.07	1.84
Ferrous (Fe)	4.43	5.06	5.86
Manganese (Mn)	0.048	0.085	0.129
Nickel (Ni)	0.010	0.0099	0.011
Zinc (Zn)	0.024	0.0076	0.0084
Titanium (Ti)	0.0002	0.0039	0.0088

Table 5.1 composition table of hypo eutectic, eutectic and hyper eutectic Al-Si alloy.

5.3 METALLOGRAPHY

For the microstructural examination all the three prepared alloy is sliced into small pieces with flat surface. Using standard metallographic techniques of grinding on water proof emery paper with grit size of 400, 600, 1000, 1200, 1500, 2000 in specification. Diamond paste and kerosene on a wheel cloth were used for the final polishing. The polished samples were etched with Keller's reagent (1% vol. HF, 1.5% vol. HCl, 2.5% vol. HNO₃ and rest water). We prepared for 200ml in which HF= 2ml, HCL=3ml, HNO₃=5ml distilled water=190ml The microstructures of the samples were examined under ZEISS optical microscope.

5.4 MICROSTRUCTURE ANALYSIS

With optical microscopy, the light microscope is used to study the microstructure; optical illumination systems are its basic elements. For materials that are opaque to visible light (all metals, many ceramics and polymers), only the surface is subject to observation, and the light microscope must be used in a reflective mode. Contrasts in the image produced result from differences in reflectivity of the various regions of the microstructure.

5.5 MICRO-HARDNESS TEST

Micro hardness testing is widely used to study fine scale changes in hardness. The usual method to

ELEMENT	COMPOSITION		
	HYPO EUTECTIC	EUTECTIC	HYPER EUTEC

achieve a hardness value is to measure the depth or area of an indentation left by an indenter of a specific shape, with a specific force applied for a specific time. Here the applied load and the resulting indent size are small relative to bulk tests, but the same hardness number is obtained.

6. Result And Discussion

6.1. MICRO STRUCTURAL

Optical microscope (OM) was used to study the microstructures of all the three alloys s are shown in Fig.4.1 and 4.3 respectively. In microstructure the white region represent Al matrix and the globular shaped particles represent Si. Coarse acicular Si particle are distributed along the primary aluminium boundaries which indicated the non uniform distribution of the Si particle throughout the aluminium matrix are shown in fig 4.1(a) and primary Si ,aluminium dendrites are shown in fig 4.1 (b) .

6.1.1 HYPO EUTECTIC MATERIAL

The image shows that, in hypo eutectic alloys the Al-Si alloy the Si particles are loosely packed and it is less denser when compared with other two.

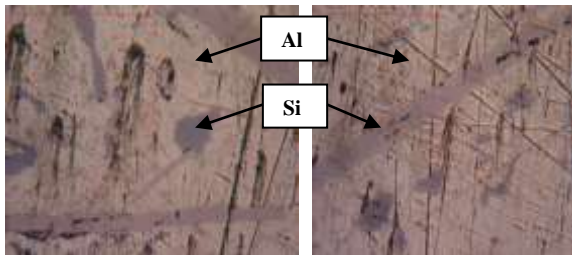


Fig 6.1: Optical microscopy micrograph of hypo eutectic silicon and aluminum dendrites

6.1.2 EUTECTIC MATERIAL

In eutectic Al-Si alloy, the Si particles are more tightly packed compared to the other two.

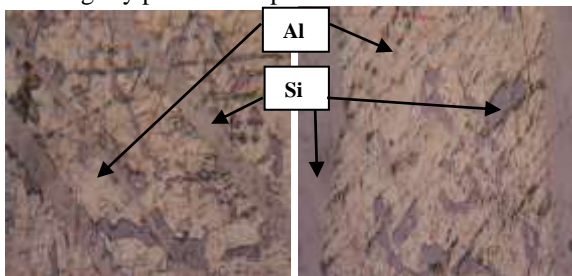


Fig 6.2: Optical microscopy micrograph of eutectic silicon and aluminum dendrites

6.1.3 HYPER EUTECTIC MATERIAL

in hyper eutectic Al-Si alloy, the matrix are denser but they are not much closely packed as the eutectic Al-Si alloy.

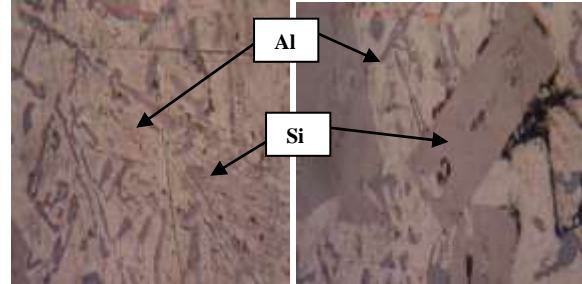


Fig 6.3: Optical microscopy micrograph of hyper eutectic silicon and aluminum dendrites

6.2 VICKERS HARDNESS TEST

The micro hardness test of all samples were conducted using Vickers hardness testing machine with dwell time of 15 second and applied load of 0.050 kg during the test. For each composition, three indentations were taken and average value was reported .The following shows the calculated Vickers hardness number.

MATERIAL	ELEMENT	VHN
1	Aluminium	108.9HV
	Silica	268.1HV
2	Aluminium	284.6HV
	Silica	175.2HV
3	Aluminium	130.0HV
	Silica	444.3HV

Table 6.1:The variation of Vickers hardness number of Al-7.69% Si, Al-12.2% Si and Al-17.28% Si

7. CONCLUSION

After the interpretation and discussion of all the results of the all three samples tested it can be concluded that the alloy of Al-12Si has more Si particles. The density of Si particles in eutectic material is more compared to that of hypo and hyper eutectic materials and also the hardness value of eutectic material is greater than that of hypo and hyper eutectic material.

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