"Microstructural and mechanical properties of eutectic Al–Si alloy with grain refined and modified using gravity-die and sand casting"

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ABSTRACT

This paper attempts to investigate the influence of the microstructure and mechanical property changes on sand casting and permanent die casting alloys by grain refinement, modification combined action of both (Al–3Ti–1B + Al–10Sr) and without grain refinement and modification effect. The microstructures of the castings are studied by optical microscopes. The microstructure and mechanical properties (tensile strength, hardness and impact strength) was tested of as cast, treated (grain refined and modified) samples. The test results are shown improvement in mechanical properties in treated melt by sand casting and permanent die casting than cast alloy due to this change was due to improvement in grain size and microstructure, and comparison microstructure and mechanical property with each other.

Keywords- **Grain Refinement, Modification, Al-Si alloy, Microstructure, tensile, hardness, impact.**

I. INTRODUCTION

Grain refinement is considered to be one of the most important and popular melt treatment processes for aluminum–silicon alloys castings. The use of grain-refiners to improve castings mechanical properties is widespread in aluminium industry, and its associated benefits on final products are well documented [1]. Grain refinement of aluminium alloys provides a number of technical and economic advantages, including reduced ingot cracking, better ingot homogeneity, susceptibility to hot cracking is reduced and mechanical properties are improved significantly [2]. Grain refinement improve the quality of castings by reducing the size of primary a-Al grains in the casting, which otherwise will solidify with coarse columnar grain structure. Fine equiaxed grain structure leads to several benefits, such as uniform distribution of second phases and microporosity, improved feeding ability [3], high yield strength, high toughness, improved machinability and excellent deep drawability of the products [4]. Several mechanisms take place in the formation of grains in a casting during solidification. In general, there are two factors that contribute to the formation of grains. First, there must be the presence of suitable substrates in sufficient amount to act as heterogeneous nucleation sites. Secondly, there has to be sufficient undercooling to facilitate the survival and growth of the nuclei. The undercooling can be achieved by either rapid cooling to generate bulk undercooling and/or by partition of solute during solidification to generate constitutional undercooling. Both of these criteria have to be fulfilled to obtain a small grain size in a casting [5].

The present investigation is an attempt to investigate the possibility of improving the mechanical properties of eutectic Al-Si alloy by sand casting and permanent die casting and with and without grain refinement Al-3%Ti-1%B and modified by Al-10%Sr. Eutectic alloy was refined with Influence of sand casting and permanent die casting on tensile strength, impact strength and hardness has been studied with and without grain refinement adding.

II. EXPERIMENTAL PROCEDURE:

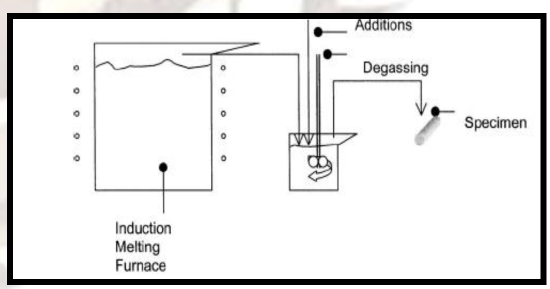

Fig. 1. Schematic representation of the manufacturing process

The industrial processing route and the sample taking method that served to provide the starting material to be characterized are shown in Fig. 1.Table 1 presents the chemical composition of the eutectic Al–Si alloy [6-7].

Table 1 the Chemical Composition of Cast Alloy

Material	Si	Mn	Cu	Al	Mg
Al-Alloy	11.8	0.097	1.150	83.95	0.66
Material	Sn	Pb	Fe	Zn	Ti
Al-Alloy	0.001	0.001	0.65	0.95	0.034

The master alloy shown in table 1. was melted in graphite crucible in induction melting furnace under cover flux GR 6512 and the melt was held at 800°C, then melt was degassed with 1% hexachloroethane tablet and molten metal was stirred with argon gas .After fluxing and proper degassing, 1% Al-3Ti-1B wrapped in aluminum foil, was added to the molten alloy with stirring of the melt at 800°C.This was followed (after 10 minute of addition of grain refiner) by addition of 1% of strontium in the form of Al-10%Sr master alloy to the melt. After the holding for 10 minute, dross was removed and subsequently molten alloy was poured in sand and gravity-die casting.
Sample required for various tests were carried out from following condition, shown in Table 2.

Table 2. Specimen condition

Casting	**Specimen**	
Sand casting	Without grain refinement and modifier	With grain refinement and modifier
Permanent die casting	Without grain refinement and modifier	With grain refinement and modifier

Studies were cut from castings. Specimen were polished and prepared by standard metallographic procedure.

III. RESULTS & DISCUSSION

1. Microstructural study

Fig. (2-5) show photomicrographs of eutectic alloy. It is observed that the addition of 1% of Al-3Ti-1B master alloy grain refiner to eutectic alloy significantly refine coarse α-aluminum dendrites to fine equiaxed α-aluminum dendrites. Modification refines the primary and eutectic silicon crystals and changes the morphology of these crystals. The change in microstructure from coarse columnar grain structure to fine equiaxed grain structure and coarse dendritic structure to fine dendritic structure in case of Al–11.8Si alloys and with change in plate like eutectic Si to fine particles resulted in high mechanical properties of Al–Si alloys.

Fig 2. Without (Grainrefinement+Modifier) using gravity die casting

Fig 3. With (Grain refinement +Modifier) using gravity die casting

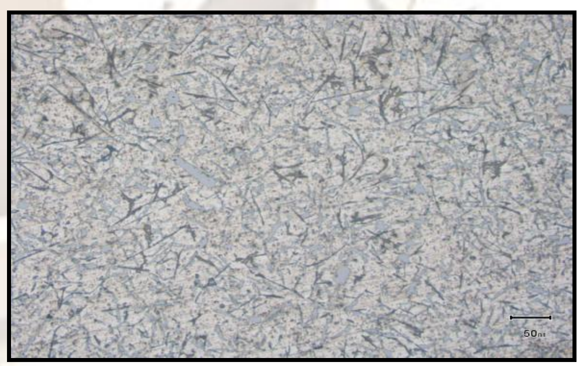

Fig 4. Without (Grainrefinement+Modifier) using sand casting

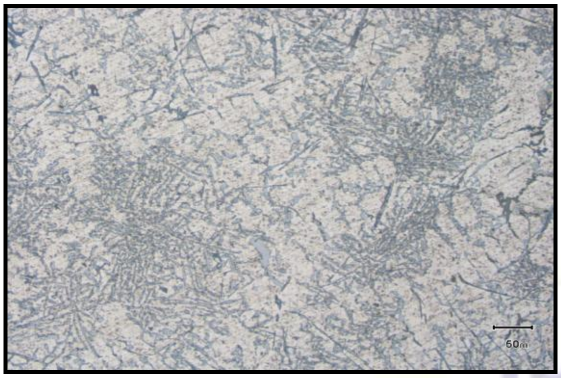

Fig 5. With (Grain refinement+Modifier) using sand casting

2. Mechanical properties

Fig.6 shows the graph of Hardness Vs Cast condition for sand casting and permanent die casting
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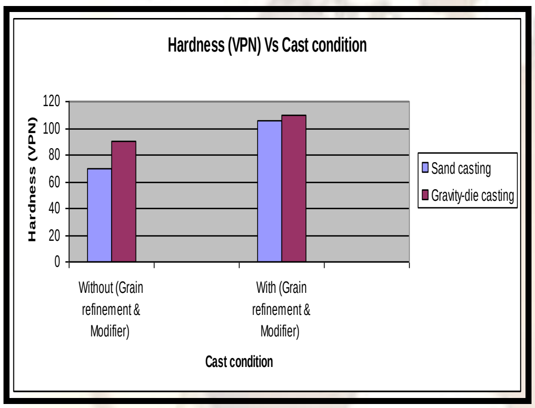

Fig. 6 Hardness Vs Casting Condition

Fig.7 shows the graph of Ultimate Tensile Strength Vs Casting condition for sand casting and permanent die casting.

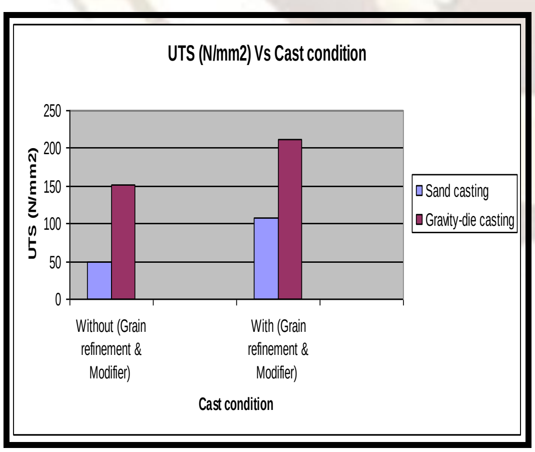

Fig.7 Ultimate tensile strength Vs Casting Condition

Fig.8 shows the graph of Impact strength Vs Casting condition for sand casting and permanent die casting.

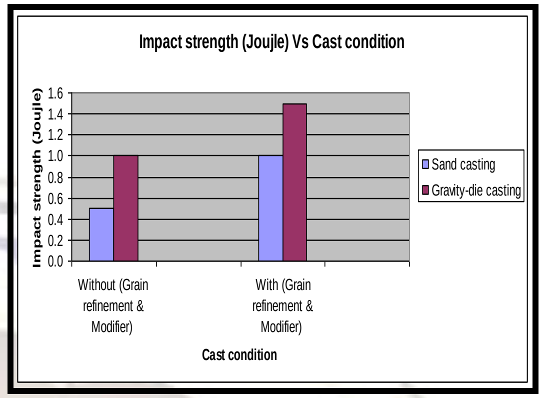

Fig.8 Impact Vs Casting Condition

Case I: Sand and permanent die castings of eutectic Al-Si alloy (without grain refinement and modification).
In case of sand casting obtain value hardness 70 VPN, Ultimate tensile strength 49 (N/mm^2) and Impact strength 0.5 joule. In permanent die casting hardness is 90 VPN, Ultimate tensile strength 151 (N/mm^2) and Impact strength 1 joule. With reference to Fig. 2 and 4 microstructure shows a coarse columnar α-Al dendritic structure and unmodified needle/ plate like eutectic silicon.

Case II: Sand and permanent die castings of eutectic Al-Si alloy (with grain refinement and modification).
Increase hardness is 70 to106 VPN (51%), Ultimate tensile strength 49 to 107 (N/mm^2) (118%) and Impact strength 0.5 to 1 (100%) joule in sand casting and in case of permanent die casting hardness is 90 to 110 VPN (22%), Ultimate tensile strength 151 to 211 (N/mm^2) (40%) and Impact strength 1 to 1.5 joule (50%) as compare to case 1. Here increase in mechanical properties, due to addition of grain refinement and modification. Fig.2 shows a coarse columnar α-Al dendritic structure and unmodified needle/ plate like eutectic silicon in case of without grain refinement, modification. After addition Sr as a modifier it reduces in interfacial tension, increases the contact angle between aluminium-silicon, allowing the aluminum to envelop and arrest the growth of silicon crystal and refinement with (Al-Ti-B) which form AlB_2/ TiB_2 intermetallic compound throughout the mass of molten metal, these nuclei or seeds, which acts as heterogeneous nucleating sites during solidification and convert coarse columnar aluminium dendrites to fine and more distributed α- Al dendrites as shown in Fig.3 and 5.

IV. CONCLUSIONS:

1) In both casting method sand and permanent, Addition grain refinement, modification combined action of both (Al–3Ti–1B + Al–10Sr) to eutectic alloy

significantly refines coarse columnar α-aluminum dendrites to fine equiaxed α-aluminum dendrites.

2) In sand casting addition of modifier get near to double mechanical property. In permanent casting get more property than sand casting, also refine alloy has more property than without refine alloy.
3) Grain refinement reduces inter-dendrite arm spacing of α-aluminum dendrites.
4) After modification, Eutectic silicon particles are spheroidized in the matrix of aluminum.

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