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Study of Porosity, Shrinkage and Surface Roughness on Al-Si Eutectic Alloy

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Abstract— **Aluminium silicon eutectic alloy generally called L-M 6 contains 10 to 13 percent by weight silicon. Modification is adopted to strengthen the alloy. Due to its good casting properties, high strength to weight ratio and excellent corrosion resistance, this alloy finds applications in automobile aircraft and marine industries. This alloy is best suited for automobile components like piston, cylinder, intake manifolds and other such components. Literature Survey reveals that eutectic alloy encounters porosity and shrinkage cavity after solidification. Hence it is proposed to eliminate the porosity and shrinkage cavity with a help of gating system and improve surface roughness.**

Experiments have been carried out using standard test bar casting without and with gating system. During melting the alloy is treated with modification.

Experiments are carried out for ultimate tensile strength, hardness, porosity; shrinkage and surface roughness are conducted for ultimate tensile strength, hardness, porosity, shrinkage and surface roughness.

Test results reveal that apart from improved strength, castings made from this alloy has been very good surface finish after modification. Also test bar incorporating additional gating system results in considerable reduction in porosity and shrinkage.

I. INTRODUCTION

Casting is a manufacturing process by which a liquid metal is poured into a mould cavity to get a desired shape.

Leading Industries such as Railways, Ship building, Aerospace, Aircraft industries prefer Light metal alloys with needed properties. The mechanical properties of cast product are fully depending on the processes during production. The defects formed at each step of production affects the behavior of the metal. Therefore minimizing defects at each step of production is necessary for casting production.

Among the Commercial Aluminium alloys, Aluminium-Silicon alloys show very good casting properties and less tendency to corrosion.

LM6, the eutectic alloy of Al-Si is best suited for castings based on its properties. LM6 contains 10-13% by weight of Silicon. Aluminium has a density of 2.7 gm/cc and Silicon has a density of 2.3 gm/cc. So silicon is one of those elements that can be added to aluminium without loss of weight. Al-Si alloys can be sand cast, die-cast and suitable for low pressure casting. The Al-Si Phase diagram is shown below.

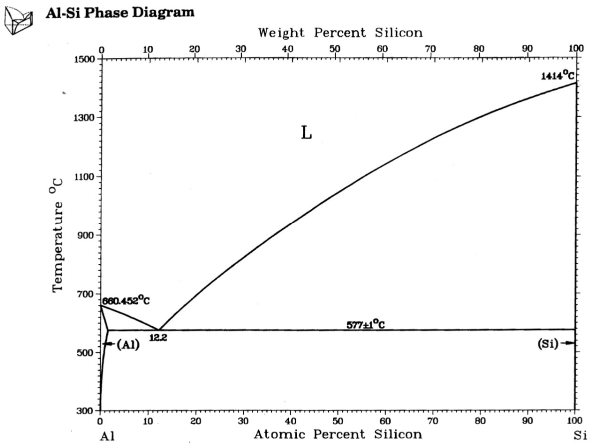

Figure 1: Aluminium Silicon Phase Diagram

Quality of Castings from LM 6 alloy can be produced by adopting suitable melting practice with addition of Coverall, Degasser, Grain Refiner and Modifier. In this work the properties of LM6 alloy with and without gating system are studied. The Solidification and composition determines the microstructure of Al-Si alloys.

Silicon plates with thick sides and ends in the Al-Si alloys acts as internal stress risers in the microstructure are reduced by adding grain refiners. Grain refiners yield an equi-axed structure and improve resistance to hot tearing, decreases porosity. In this work ‘Nucleant-2’ grain refiner is used. While casting of Al-Si alloy, gases get dissolved. Degassers are used to remove these dissolved gases. In this work ‘Degasser-190’tablets are used. From the time the Al-Si alloys are discovered, experimental studies on modification of Al-Si alloys are still going on till today.

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This is due to the huge importance of modification in the engineering field of alloy design and production of cast Al-Si alloy components with consistent and superior quality.

The composition of most Al-Si foundry alloys is in the vicinity of the eutectic point in order to take full advantage of its excellent castability, and these alloys normally contain about 50 - 90 vol% (Al-Si) eutectic. Hence, the (Al-Si) eutectic is important in determining the mechanical properties of Al-Si foundry alloys. There is a need to understand eutectic solidification and modification mechanism in Al-Si alloys.

Several theories have been put forward to explain eutectic solidification and modification mechanism in Al-Si alloys. M D Hanna,S Z Lu and A Hellawell suggested that AlP present in Al-Si alloys serve as potent nucleation sites for eutectic silicon(3). This is thought to be as a result of the similarities between the crystal structures of silicon and AlP. Shankar et al. proposed that β-(Al, Si, Fe) intermetallic phases present in the alloys also serve as nucleation sites for the eutectic silicon during eutectic solidification as shown in fig 2. C B Kim and P W Heine also reported that AlP, existing aluminium dendrites and other unidentified particles present in hypoeutectic Al-Si alloys serve as nucleation sites for eutectic silicon at different degrees of under cooling during eutectic solidification(4).

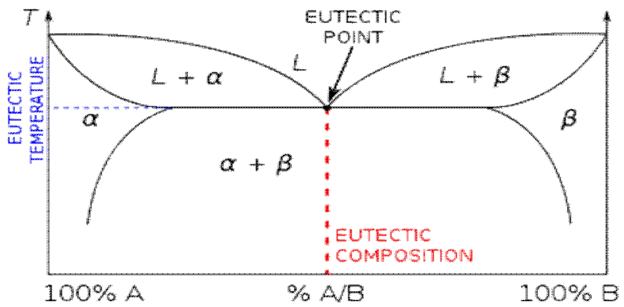

Figure 2. Eutectic Reaction

Basically there are two classes of theories on the mechanism of modification. They are restricted nucleation theory and restricted growth theory. According to restricted nucleation theory, modifier neutralizes the heterogeneous nuclei of AlP which is a nucleant for eutectic silicon or it reduces the diffusion coefficient of silicon in the melt. This enhances under cooling of the melt before eutectic silicon solidification can take place, thus refining of the eutectic silicon structure occurs. According to restricted growth theories, the adsorption of modifier preferentially takes place on twin re-entrant grooves or growing surfaces of the silicon phase, restricting the silicon growth during eutectic silicon growth, and thus requiring eutectic solidification to occur at large under cooling. This causes the eutectic silicon phase to grow isotropic ally with a fine fibrous structure rather than anisotropic ally with a faceted (plate-like) structure. Therefore, modification is usually accompanied by a depression of the eutectic temperature (2). This morphological transformation to fine fibrous eutectic silicon structure is eutectic modification which is accompanied by enhanced mechanical properties.

An important change that takes place upon addition of modifier to an Al-Si alloy is with the number of twins(3). Twin density in unmodified silicon flakes is very low and twin spacing is around 0.4 - 1.0 mm on a typical cross section while twin density is much higher in the modified silicon with twin spacing between 0.005 μm and 0.1 μm, which allows silicon to bend and branch more easily to form a fibrous structure.

Al- Si eutectic alloys are suitable for large intricate and thin walled casting in all types of moulds, also used where corrosion resistance or ductility is required. They are suitable for engine parts, pistons of I.C engines, pulleys, and marine casting.

II.EXPERIMENTAL DETAILS

A. Moulding flasks and test bars

To study the properties of casting test bars are prepared. The pattern is made in accordance with British standard specification and universally adopted to study properties of as castings. Green sand moulds are used for the casting and pouring temperature is maintained at 710°c. At the start of the pouring mould is kept at an angle of 45 degree to the vertical and brought upright position as the head fills. Pouring is carried out steadily and over a period of 10 second to avoid turbulence. Moulding flasks may be made up of mild steel, with 320mm length andϕ150 mm dia, it's both ends are opened.

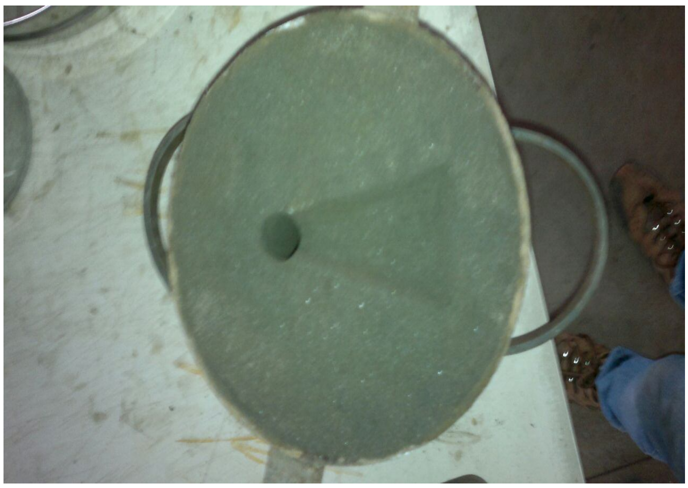
Figure 3. Moulding flask with groove for runner

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B. Test bar preparation

Test bar pattern is made according to A.S.T.M specification. Top portion of the test bar act as runner.
Fig shows the test bar with full dimensions. The enlarged head will act as riser during solidification and as runner pouring and compensate the volumetric shrinkage.

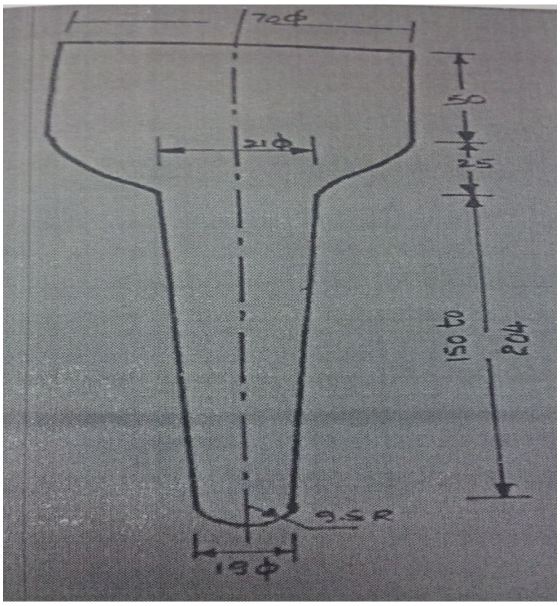

Figure 4. Test Bar Standard Dimension

C. Prepare the mould

Foundry sand are mixed with water, binder and aditivies to form green sand. The pattern is then placed carefully with green sand or chemically bonded sand. The pattern is placed on the molding box and rammed throughly.In test bar casting there is no need for runner and riser because its enlarged portion will act as runner for pouring molten metal.But in conventonal full mould casting it requires gating sysytem, its top and bottom portion is placed in the moulding box. The wooden pattern then carefully removed from the mould box leaving the shape of the test bar in the sand.

D. Melting Procedure

The furnace is heated and the raw materials in the form of ingot are charged. When the ingot reaches a pasty condition, cover flux (coveral-2) is sprinkled over it at a rate of 5gm/kg. When the temperature is raised to 760degree Celsius, the hot metal is tapped in to a crucible. Again, cover flux sprinkled over the surface at same rate. The dissolved gases are removed by adding degasser and refined by grain refiner (5). These all are immersed and stirred in the hot metal with a suitable plunger. The coverall flux cover layered at top are then removed and the hot metal is poured in to the moulds.

E. Sodium As A Modifier

Quenching experiments have been carried out on cast Al-Si eutectic alloys show that additions of sodium affect both the nucleation and growth of the silicon phase. The sodium not only changes the growth morphology of the silicon from the plates like to the fibrous form but also prevent silicon nucleating ahead of the eutectic growth front.

F. Additives

Along with modifying agents, we used other additives to get sound casting. These are
Coverall flux (containing various salts likes' alkalis' chlorides and alkali fluorides) is used to prevent oxidation of molten metal.
Grain refiner is used to produce a fine grain structure. Grain refinement improves resistance to hot tearing, decreases the porosity and increases mass feeding. In this work, 'Nucleant-2' grain refiner is used.
Degassing agents are added to the alloy to remove the dissolved gases. In this work, 'Degasser 190' tab is used

G. Fluxing

Mixtures of various salts which is used as cover fluxes forms a layer on the molten liquid protects it from oxidation and reaction with gases in atmosphere. Alkaline chlorides and various fluorides constitute the composition of Cover fluxes.

H. Degassing

The Degasser in the shape of tablet is added to the hot metal to prevent the gas absorption in it. The degasser contains chemicals in it decomposes and release gas bubbles in the hot metal. The most popular degasser is hexachloethane c2cl2 (Degasser 190) which are quite suitable for small melts.

I. Grain Refining

In the present work grain refining has been done with master alloy consisting of Aluminium, Titanium and Boron. From the studies it is clear that a greater number of nuclei will allow more grains to form resulting in a fine grain size. Hence addition of effective nuclei is done by chemical grain refinement. Titanium diboride and Titanium aluminide which are added to the hot metal soon start the formation of Aluminium grains. Thus this grain refinement provides fine

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porosity, shrinkage distribution and reduces hot tearing. The grain refiner is added at a rate of 2.5gms/kg.

J. Pouring molten metal

Pouring the molten metal in to the mould cavity through the runner, in this project work Al- Si Eutectic alloy is used as molten metal. Before pouring molten metal in to the mould cavity, Grain refiner, Degasser and Na modifier added.

Figure 5. Pouring of molten metal to the mould

Test bars with and witout gating system are made for different tests shown in the below figures.

Figure 6. Test bar without gating system.

Figure 7. Test bar with gating system

III. RESULTS & DISCUSSIONS

i. STRENGTH

By modification a substantial improvement in ultimate tensile strength is observed. In unmodified Al-Si alloy, the silicon is in the form of large plates like structure with sharp edges (2). So whenever there is a formation of crack, it will propagate at a faster rate when it is subjected to additional load. But by treating the alloy with modification, the silicon structure become fibrous, which contribute higher ultimate tensile strength. However modification with a gating system gives higher tensile strength.

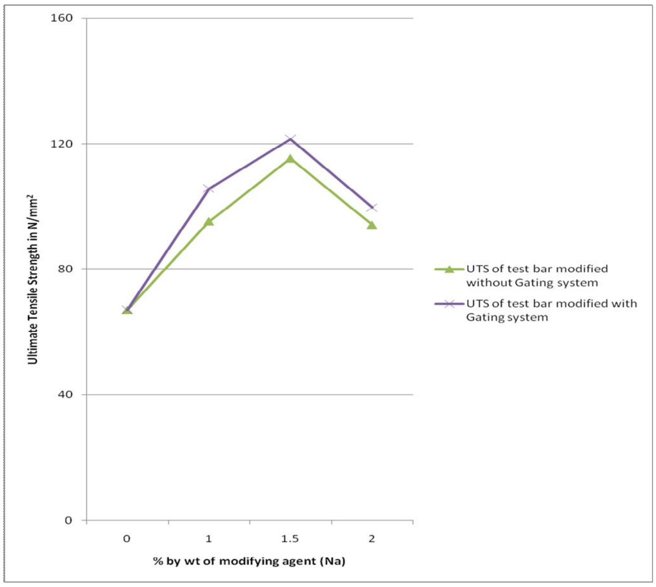

Figure 8. Effect of UTS on modified with & without Gating system of test bars

ii HARDNESS

Rockwell hardness number for the specimen is checked with 1/16" steel ball indenter. The average values are taken and shown in the figure 3. Modification with a gating system gives higher values.

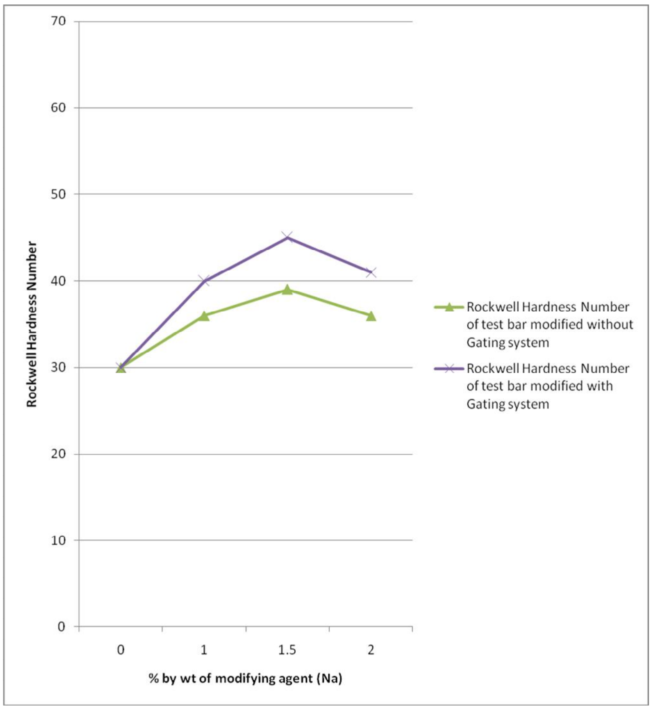

Figure 9. Effect of HRB on modified with & without Gating system of test bars

iii.POROSITY

The Cast alloy with the gating system has been machined uniformly. The machined longitudinal part has been divided in to two equal parts with the help of lathe and hacksaw frame(8). These parts then with the help of single point machine tool surface finished and viewed through microscope for pores.
The number of pores on the specimens with gating system are viewed through microscope are mentioned in the figure below

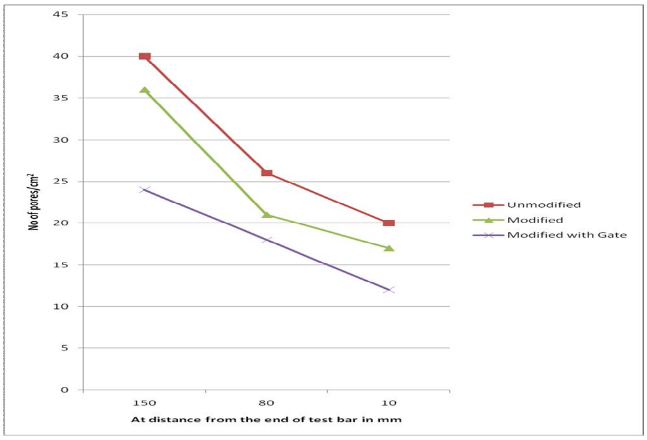

Figure 10. Graph showing no of pores/cm^2 at 150,80,10 mm distance from the end of test bar.

iv. VOLUMETRIC SHRINKAGE

Volumetric Shrinkage is much lower for modified with gating system and hence the weight of test bar is increased as shown in table 1.

Table 1. Weight of test bar for different treatments

S.No	Treatment	Weight of Test bar in gram
1	Unmodified	609
2	Modified	620
3	Modified with Gate	646

v. SURFACE ROUGHNESS

Surface roughness has been checked with Profilometer. The specimens have been placed in the profilometer,with the help of probe sensor and the roughness has been checked as shown in the computer supported Profilometer.The roughness is found to be 10.36 micrometer at the gate side and 4.27 at the bottom side as shown in the figures 11 &12.

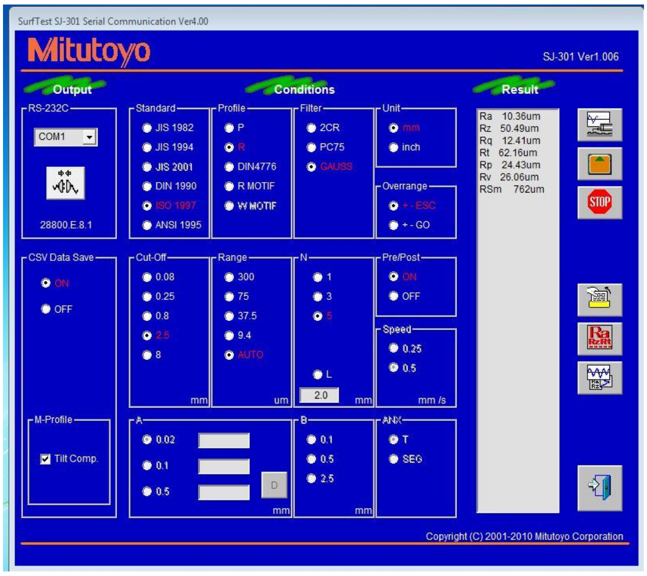

Figure 11. The computer interface reading of the profilometer at the top side of the specimen with gating system when viewed through Profilometer.

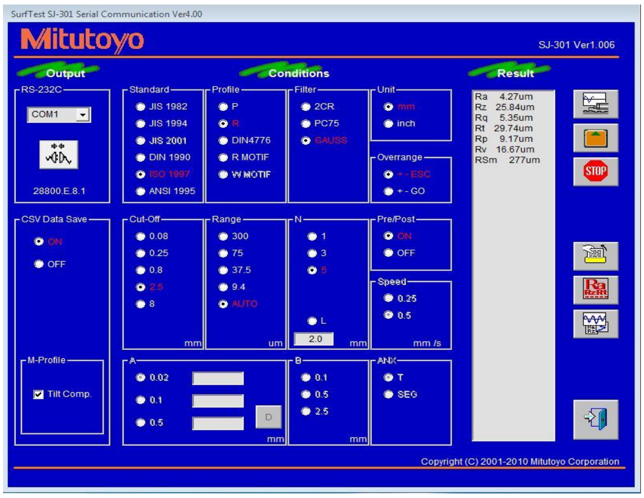

Figure 12. The computer interface reading of the profilometer at the bottom side of the specimen with gating system when viewed through Profilometer.

IV .CONCLUSIONS

From the experiments conducted to study the Al-Si eutectic alloy using modification and modification with gating system, the following are the conclusions.

- Modification treatment using sodium modifier with and without gating system increases the mechanical properties such as ultimate tensile strength, and hardness. The optimum values are obtained at 1.5% by weight addition of sodium modifier.
- The surface finish is found to be good for modifier with gating system test bar. Also porosity found decreasing with the gating system
- Volumetric shrinkage on the test bar with gating system has been considerably reduced for test bar subjected to modification with gating system.
- Modification with Gating enhances tensile strength and hardness.

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