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Research Article

# Microstructural Modifications in Squeeze Cast Al-7.0 wt% Si-0.3 wt%Mg alloy

Kavin.S[Ȧ*], Bhagyanathan.C[Ȧ], Ravi.M[Ḃ]

[Ȧ]Manufacturing Engineering, Sri Ramakrishna College of Engineering, Coimbatore, Tamil Nadu, India
[Ḃ]Material Science, National Institute of Interdisciplinary Science and Technology, CSIR Trivandrum, Kerala, India

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### *Abstract*

*Aluminium alloys with silicon as the alloying element is one of the major alloy being cast widely across the world. This is because of the primary reason that intricate components can be cast out easily with this composition. And this is due to the high fluidity imparted by the eutectic Si phase. Most of the attractive properties found in A356 aluminium alloy are governed by the microstructures. Hence controlling the microstructure will allow us to directly control the various interlinking properties. An attempt has been made to control the microstructure of eutectic silicon phase of the A356 aluminium alloy. Squeeze casting of Al-7.0wt% Si-0.3wt% Mg were made with and without the addition of strontium. Microstructural modifications has been observed and it is found that strontium provides a positive effect that is been expected.*


***Keywords:*** *Aluminium alloy, Squeeze casting, Modifications, Microstructure refinement.*

## 1. Introduction

Aluminium is one of the most versatile of the common foundry metals with cast product consuming, as a world average of 20%. Aluminium has an excellent combination of properties such as low density, good thermal and electrical conductivities and good corrosion resistance. These properties are mainly controlled by the microstructure and morphology of the eutectic silicon phase. There are also other important factors such as impurities, intermetallics, etc. These factors are in turn influenced by how the Al-Si binary eutectic nucleates and forms structure during solidification and by the heat treatment process. The extended application of these alloys for automotive components has created the need for a more in-depth understanding of the effects of microstructure on the machinability of the cast components. In these alloys, Mg is added into Al–Si alloys as a key alloying element in order to induce aging hardening behaviour by the precipitation of $Mg_2Si$. Most of the Aluminium–silicon eutectic or near eutectic alloys are cast to produce majority of pistons and are known as ‘piston alloy’, which provides the best overall balance of properties.

Squeeze casting was one of the most convenient ways of converting the alloy into the finished product. Much research has been done on squeeze casting and extensive literature can be found on squeeze cast A356 and influence of various additives. Kimura, et al, 2002 investigated on the influence of the abnormal structure, such as coarse a phase, scattered chill structure or cold shut, on the reliability of mechanical properties in the squeeze cast AC4CH in Japanese Industrial Standard (JIS) (Al–7.3%Si–0.3%Mg) aluminium alloy which is the commercial LM 25 alloy.

Abou El-khair conducted a research programme to find the effects of squeeze pressure (70, 100 and 160 MPa) and heat treatment T6 on the structure, hardness and tensile properties of cast Al-6Si-0.3Mg alloys.

Comparison of the grain size and mechanical properties of Al-Si Alloy components produced by different casting methods as observed by Abdulkabir Raji, shows an interesting result. Articles of same shape and size were produced using Al-8%Si alloy from sand casting, chill casting and squeeze casting methods. The observed results shows that the grain size of the microstructures of the cast products increased from those of squeeze casting through chill casting to sand casting. Conversely, the mechanical properties of the cast products improved from those of sand casting through chill casting to squeeze casting.

The effect of Sr, Ti, Fe and the intermetallics formed during the direct squeeze-casting of Al-7Si-0.3Mg alloy is well known and documented. (Dong, et al, 1999), (Pengting Li, et al, 2013). The superior mechanical properties compared with that of the gravity die cast was revealed. Especially, the ductility of LM25 alloy is increased from 1.7% (Gravity die casting) to 8% (Squeeze casting) in T6 heat treatment condition. They also reasoned that the increase in mechanical properties is mainly due to (1) the removal of porosity, (2) a decrease in Si particle size, and (3) a refinement of the Fe-Si-aluminide particles. They also concluded that the direct squeeze-casting is more immune towards the Fe impurities

*Corresponding author: **Kavin.S**

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due to the formation of smaller Fe-Si aluminides than those in the die cast materials.

## 2. Experimental Procedure

About 2Kg of LM25 alloy ingots were cut into suitable sizes for charging into the crucible. The cut pieces are first mechanically cleaned with acetone. Mild steel tools which come into contact with molten metal were suitably coated with graphite and dried properly by heating. The ingots were preheated before charging for melting. The furnace and ovens were periodically checked for rate of heating and set temperature. When the crucible kept in the furnace attains 700-750°C, the preheated ingots were charged into it. Half of the coverall flux (preheated to 120-130°C) was sprinkled over the charge during the time of charging itself. The remaining half of the flux was sprinkled when the charge was just melting. The temperature of the melt was measured and monitored frequently using Chromel–Alumel thermocouple

Degassing Process is done to remove hydrogen in molten metal. The hydrogen rejected during the solidification of the melt leads to porosity in the casting and significantly impairs the mechanical properties of the alloy. The most common technique of degassing aluminium melt in foundry is the use of a purge gas (nitrogen or argon) which is bubbled through the melt with a lance, a porous plug or a rotary impeller degasser.

Two samples are prepared, one with the addition of strontium and the other without the addition of strontium. Strontium is added in the form of Al-10Sr master alloys. Master alloys were cleaned to remove all types of dust, oil, grease etc., particles from the master alloys. These are preheated to 150°C to remove any water vapors on it and plunged into the melt and held for 7 minutes for complete dissolution and homogenization of the melt. Degassing is done after every addition, inorder to avoid the fading of modification. The inclusions present in the melt were usually considered as undesirable as it leads to reduction of mechanical properties. Skimmers were used to remove inclusions.

Squeeze casting die cavity must be preheated first using the scrap metal. Then the molten metal was poured into squeeze cast die and pressure around 150Mpa is applied for about 3-4 minutes. After the solidification, ejection pins were used to remove the component from the die cavity. The specimens were then cut into suitable size and subjected to T6 heat treatment cycle.

## 3. Results and Discussions

### *3.1 Microstructure*

To study the phases formed in casting samples from casting has cut to 20 X 15 mm and polishing with emery paper of grade 80,100,220,400,600 and 100 followed by cloth polishing. Selvit cloth of grade 6 μ, 3 μ, and 1.5 μ is used. With the help of optical microscope microstructures have taken for samples with and without the addition of strontium both at lower magnification and higher magnification.

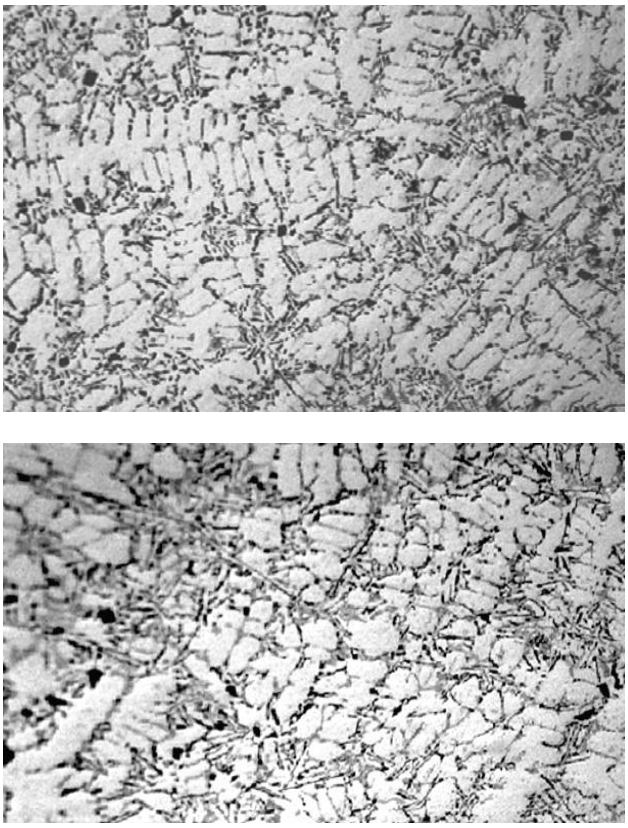

**Fig.1** Microstructure of modified and unmodified sample x200

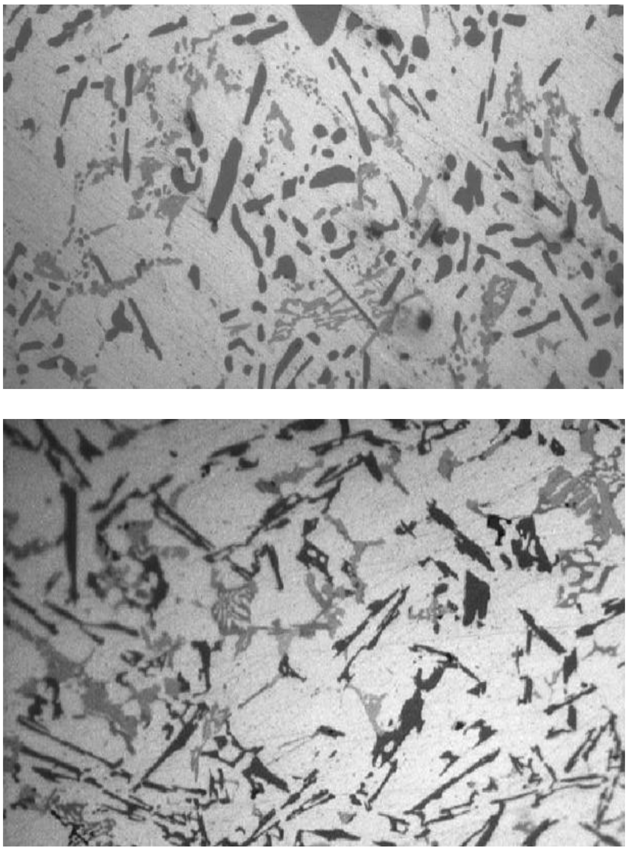

**Fig.2** Microstructure of modified and unmodified sample x500

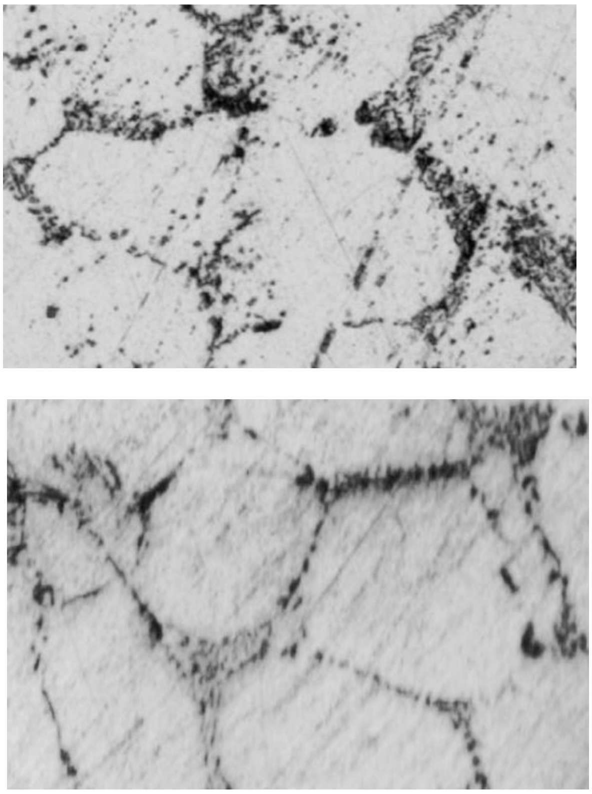

**Fig.3** Microstructure of modified and unmodified sample x1000

The optical microstructures of squeeze cast A356 aluminum alloy show the presence of Si in acicular form in the aluminum matrix. This acicular Si needle will also act as stress risers in the alloy and during tensile loading these needle like silicon particles will act as a point where the crack can initiate leading to lower mechanical properties hence heat treatment of these castings are essential in order to change the silicon morphology which can lead to improved properties at as cast conditions are given below.

The fineness of the α-dendrites is characterized by its arm spacing and its distribution. Heat treatment of A356 also proved to be an important stage in producing fine grained alloys. Microstructure of squeeze cast A356 has dendritic structure with very fine and rod like eutectic phase. This modification can be classified into class 4 refinement

*3.2 Chemical Composition*

**Table 1** Composition of sample without strontium

| Material | Percentage |
|---|---|
| Silicon (Si) | 7.04% |
| Magnesium (Mg) | 0.38% |
| Iron (Fe) | 0.03% |
| Zinc (Zn) | 0.01% |
| Chromium(Cr) | 0.01% |
| Lead (Pb) | 0.0017 |
| Nickel | 0.01% |
| Manganese (Mn) | 0.03% |
| Titanium(Ti) | 0.07% |

The compositions of both the samples are observed by the spectrometer. The presence of strontium is confirmed to be affecting the eutectic microstructure in a positive way.
Further the other impurities are to be controlled to a sub-optimal level in order to study the exact effect of modification.

**Table 2** Composition of sample with strontium

| Material | Percentage |
|---|---|
| Silicon (Si) | 6.97% |
| Magnesium (Mg) | 0.33% |
| Strontium (Sr) | 0.02% |
| Iron (Fe) | 0.01% |
| Zinc (Zn) | 0.01% |
| Chromium(Cr) | 0.01% |
| Lead (Pb) | 0.18% |
| Nickel | 0.01% |
| Manganese (Mn) | 0.04% |

## 4. Conclusions

Effective utilization of aluminium proves to be a vital source for many manufacturing and automobile systems. Since different casting yields different properties, it is of prime important to choose the most optimum casting process based on the applications. Aluminium silicon alloy is produced through squeeze casting process in two different experiments. In one of the experiment the specimen is cast with the addition of strontium and the other without the modification.

Microstructures of both the specimens are observed and its chemical compositions are evaluated to reach the following conclusion:

1) Microstructure of the squeeze cast alloy without any strontium indicates that the eutectic Si morphology consists of coarser primary silicon and unmodified acicular eutectic silicon and randomly oriented intermetallic phases.
2) After the addition of Strontium as a microstructure refiner to alloy and studying its influence on microstructure, it is clear that the microstructure has been modified to a great extent.
3) Heat Treated (T6) condition also worked in favor of modification by precipitating the fine Si particle throughout the aluminium matrix.

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