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# Effect of superheating temperatures on microstructure and properties of strontium modified aluminium-silicon eutectic alloy

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**Abstract:** In the present investigation, it is observed that as the superheating temperature is increased up to a certain optimum temperature, the eutectic silicon becomes more globular and well distributed all over the entire structure. At the same time, the iron rich β needles become thinner and thinner as the superheating temperatures are increased. The melts, which were superheated at 730°C and 740°C, the broken surfaces of the cast samples showed some white regions. On the other hand, when the melt was superheated at 750°C, the fractured surfaces of the cast sample did not show any accumulation of white phases. The SEM analysis showed that the concentration of strontium on those white regions was more than any other areas. At optimum superheating temperature, all phases are refined and well distributed throughout the entire structure, resulting higher strength and ductility.

**Keywords**: Globular, Concentration, Optimum, Ductility

## 1. INTRODUCTION

The modification treatment causes the disappearance of primary silicon with the formation of solid solution dendrites (α-Al) and fine globular eutectic silicon instead of needle like structures. A considerable improvement in mechanical properties was associated with the resulting structural changes. However, the literature review [1-5] shows that the exact role of the modifying element is not yet clearly understood. On the basis of the evidence available, it appears desirable to explore further the effects of strontium on the structure and properties of aluminium-silicon alloy in more detail. However, the general theme of the present work is to investigate the effects of superheating temperatures in the modification of Al-Si eutectic (LM-6 type) alloy with strontium, especially on the morphology of silicon and iron, and hence the overall properties of the alloy.

## 2. EXPERIMENTAL DETAILS

### 2.1 Preparation of charging and moulding materials

Charging materials consisted of Al-13% Si (LM-6 type) alloy and Al-10% Sr temper alloy. The temper alloy was cut into small pieces (5-8 mm) and was added to the charge at the beginning of the melt. As varying degrees of modification exist, it was difficult to decide upon the optimum amount of strontium needed to modify the LM-6 type alloy effectively. From the findings of previous investigators [3, 4, 6], it was decided to add about 0.1% strontium to modify the alloy used in the present study.

The green sand mould consisted of sand grains having sub-angular shape and 10% bentonite clay to which about 6% water was added. They were mixed together in a mulling machine. The surface hardness and the moisture content of the green sand aggregate were monitored by using Green surface hardness tester and Speedy moisture tester, respectively.

### 2.2 Melting, casting and testing

Firstly, the required amount of charge materials was kept in the crucible and it was then put in an electric furnace (Nobertherm N81/13) for melting and superheating the charge. Three melts were superheated separately at temperatures of 730°C, 740°C and 750°C, and the melts were held at these temperatures for about 5 minutes [4]. Each melt was then stirred and the dross was skimmed off from the top. The pouring of the melts was carried out at about 710$^o$C in to the green sand moulds in a continuous stream.

Tensile tests were conducted with a Universal Testing Machine (INSTRON 5482), and the total strain and the ultimate load for each of the tests were displayed on the monitor screen. Further analysis on the ultimate tensile strength and percentage elongation were calculated from these results. The results were averaged from two determinations.

### 2.3 Metallography

The metallographic specimens were polished in usual manner with final polishing being carried out by hand, and they were etched in 0.5% aqueous HF acid for about 20 seconds. A Universal microscope (OLYMPUS CK40M) was used for the micro-examination and recording of the representative structures. The scanning electron microscope (SEM) used in this work was a Cambridge S4 Stereoscan fitted with Energy Dispersive Analyzer.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Effect of superheating temperature on structural modification of the cast alloy

Figure 1 shows the structures of unmodified and Sr modified Al-Si eutectic alloy, both were superheated at 750$^o$ C and cast at 710$^o$ C. It can be seen that due to modification, the plate shaped primary silicon has disappeared from the structure and needle shaped eutectic silicon has become globular, while the iron rich Chinese script shaped α-phase has transformed in to fine needle shaped β-phase.

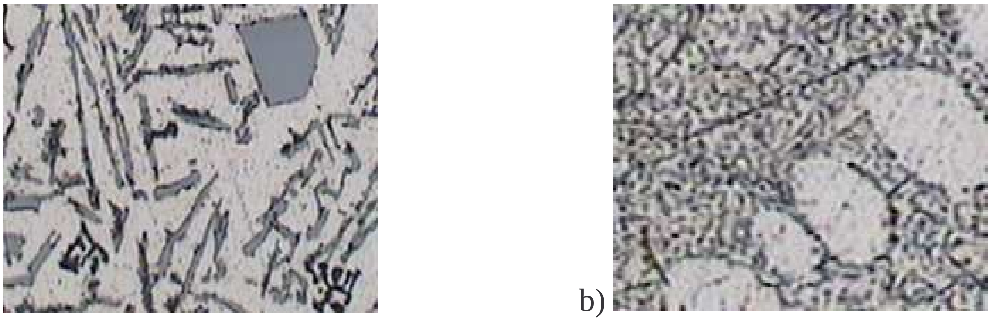
a) b)


Figure 1. Microstructures of Al-Si eutectic alloy, (a) Normal and (b) Modified, X 200

The Al-Si eutectic (basic LM-6 type) alloy usually contains numerous alloying and impurity elements. These elements present various non-ductile particles and intermetallic compounds in the structure (Figure 1a). Iron is the main impurity element present in aluminium-silicon alloy and it produces deleterious effects on ductility and corrosion resistance of the alloy. However, in the presence of magnesium, iron forms an intermetallic compound $FeMg_3Si_6Al_8$. It has Chinese script morphology when eutectic and globular when primary [7]. Iron also forms $(FeMn)_3Si_2Al_{15}$ with manganese, often in the shape of Chinese α-script, thus removing the embrittling effect of $FeSiAl_5$, which forms β-needles [8].

Figure 2 shows the microstructures of the same Sr modified alloy, but superheated at 730°C and 740°C. It can be seen that when the alloys are superheated at lower temperatures, say either at 730°C or 740°C and cast at 710°C, the iron rich β-needles appear in the structures prominently. These iron rich β-needles are very hard and brittle. On the other hand, when superheating temperature is increased to 750°C, the iron rich β needles become very thin and fine (Figure 1b). It does mean that the alloy has been modified effectively at that superheating temperature (750°C) compared to other temperatures, such as 730°C and 740°C.

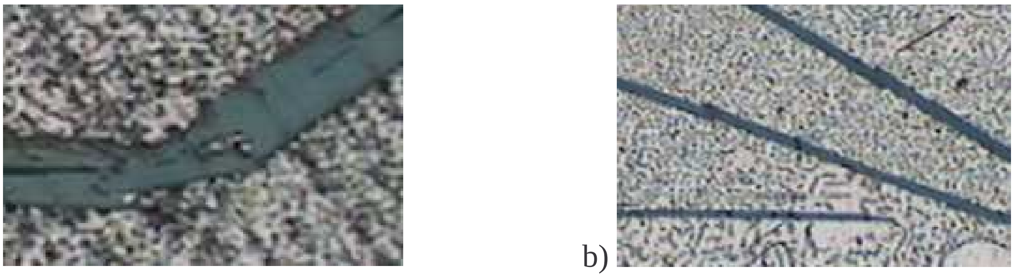

a) b)

Figure 2. Microstructures of Sr modified Al-Si eutectic alloy superheated at (a) 730°C, and (b) 740°C, X 200

### 3.2 Effect of superheating temperature on properties of the cast alloy

It can be seen from Table 1 that when the superheating temperatures of the melts are 730°C and 740°C, the tensile properties do not improve much for modified alloys. However, when the melt is superheated at 750°C, the tensile properties of modified alloy have increased markedly. This means that at 730°C and 740°C, the melts are not modified properly, while at 750°C the modification is effective. The brittle and hard iron rich phase (β needles) becomes finer and finer as the superheating temperature is increased, reducing its deleterious effect on the properties of the alloy. Due to this structural refinement, the tensile properties of the alloy have enhanced significantly. Similar observations have also been reported by other investigators [9, 10].

Table 1.
Effect of superheating temperatures on tensile properties of the cast alloy.

| Superheating Temperature ($^o$C) | Modification | UTS (MPa) | Elongation (%) |
|---|---|---|---|
| 730 | Unmodified | 150 | 6.00 |
| | Modified | 150 | 6.50 |
| 740 | Unmodified | 154 | 6.00 |
| | Modified | 155 | 7.00 |
| 750 | Unmodified | 155 | 6.25 |
| | Modified | 165 | 9.00 |

### 3.3 Effect of superheating temperature on fractured surfaces of the cast alloy

During present investigation, it is observed that the fracture surfaces of the unmodified cast samples are more or less similar in appearance, while the surfaces of modified samples have some different appearances. The melts, which are superheated at 730$^o$ C and 740$^o$ C, show some white regions in the fractured surfaces. Whereas the melt, which is superheated at high temperature (750$^o$ C), does not show such accumulation of white phases in the fractured surfaces. The SEM analysis showed that the concentration of strontium on those regions was more than any other areas of the fractured surfaces. It is believed that some undissolved strontium may appear in those white regions of the cast specimens, especially which are melted at low superheating temperatures. This has aggravated the conditions of the specimens during tensile tests and fractured at lower load. Therefore, 750$^o$ C may be regarded as the optimum superheating temperature for modification of Al-Si eutectic alloy with strontium.

## 4. CONCLUSIONS

The following conclusions can be drawn from the results of the present investigation:

a. For the best combination of structure and properties of the Al-Si eutectic base alloy, strontium modification must be carried out at a superheating temperature of 750$^o$C.
b. Modification eliminates the primary silicon crystals and refines eutectic silicon needles as well as iron rich β-needles, reducing their embrittling effects on the alloy.
c. Proper modification minimizes sources of stress concentration regions in the cast samples, thereby improving the properties of the alloy.

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