# Effect of high solution temperature T6 heat treatment on microstructure of β-AlFeSi phases in Al-Si Alloy

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**ABSTRACT** – Aluminum-Silicon (Al-Si) alloy is a versatile die-casting alloys due to low thermal expansion coefficient and excellent mechanical properties. However, iron in Al-Si composition is considered a harmful element in structural die-casting alloy as it forms brittle β-AlFeSi phases precipitation thus reducing ductility. Controlling the formation of β-AlFeSi phase is essential to improve mechanical properties. Heat treatment can affect morphology of β-AlFeSi phase. In this work, modified T6 heat treatment has been systematically studied on A380 alloy. From the study on morphologies and mechanical properties of the alloys, 515°C is an optimal short-time T6 solution temperature to dissolves the β-AlFeSi intermetallic phase and subsequently improves the elongation property of the Al-Si Alloy.

## 1. INTRODUCTION

The β-AlFeSi phase in die casting Al-Si alloys often severely reduce the quality index of the alloys due to the needle-like structure of the phase that acts as the stress concentrator [1]. The element control method is often used in die-casting industry to transform β-AlFeSi phase to a less detrimental α-AlFeSi phase. However, with the element control, few deleterious effects, such as intermetallics formation, will also negatively effect the alloys properties. Heat treatment is one of the effective methods to minimize the AlFeSi intermetallics detrimental effect. In pratice, this method is not widely used due to:

1) In die casting process, entrapped air can be found in the solidified aluminum alloy. the entrapped air will expand with heat treatment thus causing formation of bumps on the surfaces.
2) The formation of other phases can be affected by heat treatment. Coarsening of Si phase may happen with the heat treatment. [2]

In view of the reasons above, high solution temperature and short time T6 heat treatment method were utilized in the study to avoid both formation of needle-like intermetallic phases and blistering. Heat treatment can utilize high solution temperature due to the low diffusion rate of Fe in Al. A previous study noted that acicular iron phase platelets can be dissolves at the imperfect sites of the crystals during high temperature heat treatment and become shorter ones [3]. At the imperfect sites of the crystal, the silicon, iron or manganese atoms are in a high-energy state and tend to transform to low-energy state, and heat treatment can accelerate the dissolving process. Other study adopted the non-equilibrium heat treatment method, which is above the regular solution in heat treatment temperature [4]. This result in the dissolution effect thus shortening the β phase. Meanwhile another study conducted heat treatment on die casting alloys and considered that the disintergrity in β phase can cause dissolution [5]. However, both studies noted that by heat treatment has no influence to the α-AlFeSi phase fraction. In this study, the effect of solution temperature in short-time T6 heat treatment is analysed to find the optimal heat treatment condition in improving the mechanical properties of the alloy. Morphologies of the Fe-containing phases are observed to compare the size and fraction at different solution temperature. The effect on the mechanical properties is also analysed by comparing the elongation of the heat-treated samples.

## 2. METHODOLOGY

Commercial die casting aluminum alloy A380 was used in the study. A380 is a hypoeutectic alloy with liquidus temperature of 593°C and solidus temperature of 527°C. The composition of A380 are given in Table 1.

Table 1: A380 alloy composition

| Element | Si | Cu | Fe | Mn | Ni | Zn | Mg | Al |
|---|---|---|---|---|---|---|---|---|
| Wt% | 9.0 | 3.5 | 1.0 | 0.4 | 0.3 | 0.3 | 0.2 | Bal |

A380 alloy was casted into the ASTM E 8M-04 standard tensile test bars for the mechanical testing and also microscopic observation. The samples then undergo the heat treatment process under the T6 conditions. Blistering is the main problem of heat treatment of die casting parts. In view of this, the short-time high-temperature heat treatment and water quenching is adopted. Solution temperatures are varied to be at 450°C, 500°C, 515°C and 530°C. The solutionization is set to be 30 minutes for each temperature condition. Following water quenching, the samples are aged at 130°C for 4 hours. The samples are then tested their mechanical properties to examine the elongation. In tensile test, 15 samples were allocated for every condition. The samples are also polished and observed under the optical microscope to study the morphologies.

The intermetallic phases were measured by taking five fields with observed needle-like structure. The βneedles were measured and averaged, combining with the other field to establish the length of the beta phase for a given heat-treatment condition.

## 3. RESULTS AND DISCUSSION

With the increase of solution temperatures, significant transformation of the fraction and morphology of AlFeSi phases were observed. In the 450°C heat treatment samples, no obvious AlFeSi phase change, and β-AlFeSi phase dominates as seen in Figure 1(a) & 1(b). With the increase of the temperature to 515°C, β-AlFeSi phase dissolves and the fraction of β-AlFeSi reduces as seen in Figure 1(c). As the temperature increased to 525°C, α-AlFeSi phase predominates and the fraction of the phase increased as can be seen in Figure 1(d).

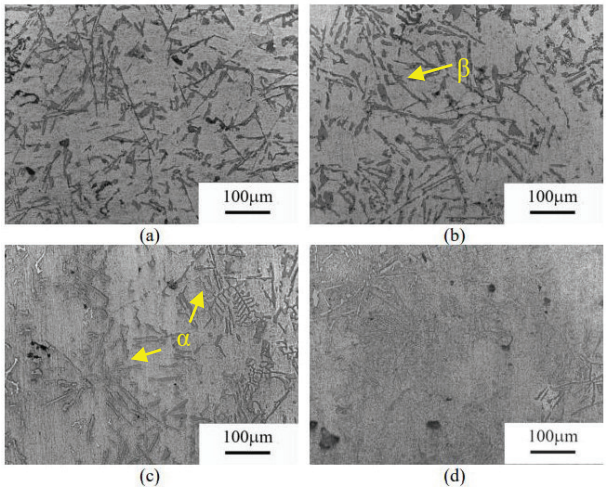


Figure 1 Morphologies of samples from different heat treatment temperatures.

Graph of the effect of solution temperature to the elongation in Figure 2 was obtain from the tensile test. As solution temperatures increases, the elongation improves from 450ºC (1.62%) up to 515ºC (3.39%). However, as solution temperature rises to 530ºC, the elongation reduces significantly to 1.18%. It can be deduced that 515ºC is the optimal solution temperature for improving the elongation property of the alloy.

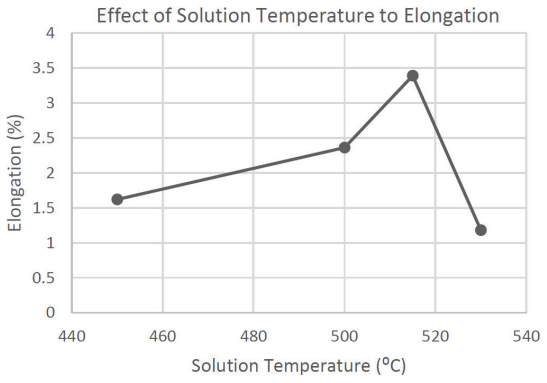


Figure 2 Graph of Elongation vs Solution Temperature

As solution temperatures increases, β-AlFeSi structure changes, where the size decreases and the fraction of α-AlFeSi increases. Morphology of β-AlFeSi did not change at the solution temperature of 450°C. However, β-AlFeSi started to transform as the temperature increased to 500°C. It can be implied that 500 °C is the minimal temperature for the transformation of β-AlFeSi phase. Platelets Al-Fe-Si phase is detrimental due to its role in the formation of stress concentration [1]. The detrimental effect can be reduced if the stress-inducing β-AlFeSi phase can be diminished [5]. From the experimental result, the higher the solution temperature, the less the β-AlFeSi phase, hence the more improvement to the mechanical properties the alloy is.

However, with the higher solution temperature, the morphology of silicon particles will also be further increased due to coarsening; thus weaken the quality index of the alloy. In heat treatment application, temperature should not set to be too high. The heat treatment temperature should be controlled to be approximately 515°C. From the study, β-AlFeSi phase may transform and dissolve during heat treatment at this temperature.

## 4. CONCLUSIONS

The temperature of 450°C is too low for solution temperature to have an affect on β phase microstructure. However as the solution temperature increases to 500 °C, it can transform the β phase in shorter time. At the optimal temperature of 515°C, the high temperature dissolves the β-AlFeSi intermetallic phase and subsequently improves the elongation property of the Al-Si Alloy.

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