Effect of Sr on Melt Quality and Mechanical Properties of A360 Alloy
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ABSTRACT
There is always a demand for high quality parts for automotive and aircraft industries and Al-Si alloys are widely used due to their good castability and mechanical properties. Strontium modification of Al-Si alloys has also many advantages for the production of high quality casting parts. However, Sr has high affinity to oxygen and spinel oxides of Sr on the surface of the liquid may form depending on the holding time. Therefore, Sr amount in the melt can decrease by time. The main objective of this study is to investigate the behavior of Sr under different casting conditions. Sample collection was made at 4th and 17th hours of holding time at 700°C and 750°C casting temperatures. Microstructural analysis and reduced pressure test (RPT) were used to evaluate microstructure and melt quality. Tensile tests were performed using round bar tensile specimens with a diameter of 10 mm. It was found that both Sr modification and bifilm index was decreased significantly over time. It was also seen that mechanical properties were increased by Sr modification.

1. Introduction
Aluminium-silicon based alloys are widely used especially due to their good mechanical properties, corrosion resistance and castability, for light weight components in automotive and aerospace industries where it is used for cylinder blocks and heads, plain bearings, internal combustion engine pistons and cylinder liners [1-3]. The mechanical properties of Al-Si alloys depend significantly on the morphology of eutectic silicon. Modification is one of the most important melt treatments for aluminium-silicon alloys castings. Desired properties of Al-Si alloys can be achieved by modification in two different ways, either by rapid cooling rate or by addition of certain modifier elements, such as Sr or Na [2,3]. With modification the morphology of eutectic is changed from coarse, brittle flakes which leads to poor mechanical properties to finer and fibrous structure [4-5]. Primary aluminium exists as dendrites in the structure of a hypo-eutectic Al-Si alloy. The eutectic silicon phase crystallizes into a coarse, plate-like morphology during eutectic formation. This coarse morphology of eutectic silicon is disadvantageous for the casting parts. The stress concentrations on sharp corners of this structure can result in fracture during the use. Proper modification can minimize stress concentration in these regions and improve the mechanical properties of the alloy [6-8].

Fading effect which is because of the increasing holding time at high temperatures and varying treatment times may also affect the efficiency of Sr on the modification of Al-Si alloys [9]. Another important factor which changes the melt quality is the oxide-films suspended in melts for a long periods. During casting, these oxide-films may fold double and cause cracks after solidification [10].

In this work the effect of holding time on modification was investigated by comparing modified and unmodified alloys at 700°C and 750°C. Reduced pressure test and tensile tests were used to assess changing mechanical properties and metal quality by measuring the bifilm index of samples.

2. Experimental Procedure
The A360 alloy ingot was cut into smaller pieces and charged crucibles in resistance furnace. The melts were modified with Sr by adding an Al-15%Sr master alloy. In order to observe the effect of temperature on the modification, the melts were held at temperatures of 700°C and 750°C. For each temperatures four metal casting and four lost-foam casting were carried out at 4th and 17th hours. The samples were cut into smaller pieces for microstructural analysis. The chemical composition of the alloy is summarized as in Table 1.

### Table 1. The chemical composition of A360 alloy

<table>
<thead>
<tr>
<th>Element</th>
<th>Fe</th>
<th>Si</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ni</th>
<th>Ti</th>
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</table>

For the investigation of eutectic-Si morphology of modified and unmodified samples, optic microscope and Clemex vision software were used. In order to measure Bifilm index of samples, reduced pressure test was used.

The spectral analysis was carried out after 4 hours and 17 hours of holding time at two different temperatures, in order to investigate the effect of holding time on Sr fading.

Tensile test specimens were also prepared and their tensile strengths and elongation % determined in order to observe the modification and different casting conditions on the mechanical properties of A360 alloy.

### 3. Results and Discussion

The microstructures of modified and unmodified, alloys are compared in Fig 1 and Fig 2. The effect of Sr modification can be clearly seen in finer eutectic microstructure of modified samples. When the holding time is raised to 17 hours, the eutectic silicon area decreases. However, the effect of modification can still be seen even after this holding time. The eutectic microstructure of samples which was rapidly cooled in metal-molds are even finer at the same conditions.

The relation between tensile strength and average bifilm index measurements of samples collected from 700°C and 750°C and 4th and 17th hours of holding times are given in Fig 3, Fig 4, Fig 5 and Fig 6. In order to observe the effect of Sr modification, alloys were prepared as Sr modified (300 ppm) and unmodified at 700°C and 750°C. It can be clearly seen that the bifilm index of the samples which were modified with Sr decrease significantly at both temperatures. Moreover, the higher holding times decrease the bifilm index of samples. Besides that, tensile...
Strength values of modified samples also increase as a result of low bifilm index and Sr modification.

Figure 3. The relation between tensile strength and average bifilm index measurements of unmodified and modified samples at 700°C and 4 hours holding times.

Figure 4. The relation between tensile strength and average bifilm index measurements of unmodified and modified samples at 700°C and 17 hours of holding times.

Figure 5. The relation between tensile strength and average bifilm index measurements of unmodified and modified samples at 750°C and 4 hours of holding time.

Figure 5. The relation between tensile strength and average bifilm index measurements of unmodified and modified samples at 750°C and 17 hours of holding time.

4. Conclusion

The following conclusions can be drawn from the experimental work:

1. Sr modification results in finer eutectic silicon in A360 alloy. As the holding time increases from 4 hours to 17 hours the eutectic silicon takes a coarser shape at same Sr concentrations.

2. Increasing holding time of melts, modified with 300 ppm Sr has lower bifilm index, compared to
the unmodified alloys and the samples that have lower holding times. Optimum results were obtained from modified samples that were cast after 17 hours of holding time.

3. Considerable Sr fading was observed after holding 4 hours in furnace. Moreover, when holding time was increased to 17 hours in furnace, it was seen that Sr content was lower than 50 ppm in both temperatures.

4. There is a strong correlation between bifilm index and mechanical properties of A360 alloy. As bifilm index decreased, mechanical properties are improved.

References


