The Effect of Bifilm and Sr Modification on the Mechanical Properties of A413 Alloy

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Abstract

Microstructure of Al-Si alloy has coarse silicon and this structure is known dangerous for mechanical properties due to its crack effect. Sr addition is preferred to modify the coarse silica during solidification. Additionally, Bifilms (oxide structure) are known more dangerous defect which is seen in light alloys frequently. It is aimed that negative effect of bifilms on the properties of the alloys tried to be removed degassing process and to regulate microstructure of the alloy. In this study, the effect of degassing and Sr modification on the mechanical properties of A413 alloy was investigated.

1. Introduction

Al and its alloys are preferred by many industries such as automobile, aerospace and aircraft because of their superior properties such as high specific strength, good formability, good machinability and easy castability [1-3]. A413 alloy is an Al-Si alloy that used for production of engine box, measuring box, cylinder and pump pieces and thin-walled casting components [4, 5]. It is a material that needs to be developed constantly since it is used in critical applications. It is required to keep up the casting quality in order to improve the mechanical and microstructural properties of the alloy. In other words, it is very important to carry casting with optimum conditions in order to get best result from the experiments. Microstructure of Al-Si alloy has coarse silicon and this structure is not preferred because it decreases the mechanical properties of the alloy by giving brittleness. Sr addition is preferred to modify the coarse silicon during solidification [6, 7]. Sr modification also increase the castability (casting quality) of the A413 alloy. In the modification process, the orientation of the Si grains is restricted by Sr and more ductile structure is achieved. The mechanical properties, therefore, are enhanced [8]. Improving the casting quality is key point for a good casting [9, 10]. Defects must be reduced from the structure before and during casting.

As mentioned above that bifilms are the defects seen in light alloys such as Al-Si alloy casts frequently [1, 11]. They occur from oxide films (Al₂O₃) that came from ingots or melts used before casting or that formed due to turbulence during casting. It is aimed to remove bifilms by some applications such as degassing and grain refinement from the structure in order to increase mechanical properties and to regulate microstructure of the alloy. Degassing process is vital to clean bifilms [4, 11-13]. In this process, argon gas is given to the bottom of the crucible thanks to means of a rod immersed in the melt, and it is provided that while this low-density gas moves to the top of the crucible, it can clean bifilms, besides hydrogen [1].

In this study, the effect of degassing and Sr modification on the mechanical properties of A413 alloy was investigated.

2. Experimental Procedure

Chemical composition of the A413 alloy which was used in this study are given in Table 1.

| Table 1. Chemical composition (in wt. %) of the alloy used in the study. |
|-----------------|---|---|----|---|---|---|---|---|---|
| Alloy | Si  | Fe  | Cu  | Mn | Mg | Zn  | Ti  | Al  | Rem. |
| A413 | 11.7 | 0.1 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | Rem. |

The alloy used in the study was obtained as primer cast ingots. A resistance furnace that has 22 kg capacity was used to melt the alloy. Sr additions were made once the melt temperature had reached 670 °C. Castings were realized after 10 min of Sr addition. The degassing process was applied with Ar gas. The parts are casted into the tensile test molds which are 13 mm in diameter and 150 mm in length given in Figure 1.

Castings were made firstly for as-received condition when the alloy in the crucible is melted. The second and third casting was realized for Sr modification and degassing, respectively. Analysis of microstructure and mechanical properties were done on every parameter.
Figure 1. Image of tensile test mold

3. Result and Discussion

Microstructural images of castings for Sr addition and as-received are given as a representative in Figure 2.

Figure 2. Microstructure images of castings for Sr addition and as-received

It can be understood on the images that microstructure morphology of A413 was changed by Sr addition. As known that A413 alloy has 12 % Si and it displays eutectic morphology after the solidification (Figure 2). Silicon morphology was affected by Sr addition which is transformed the microstructure from coarse and long size to fine and short size [8, 14]. This effect of Sr can be observed on the microstructure images of the alloy, clearly.

Figure 3. UTS and YS results of the alloy for as-received and modified, a) No degassing condition, b) Degassed condition

UTS and YS results of the alloy for all conditions (degassed, no degassing, as-received and Sr modified) were presented in Figure 3. This chart is quite explanatory in order to understand effect of Sr modification and degassing process on the mechanical properties of the alloy. As shown on Figure 3, before degassing UTS values of the alloy for as-received parameter are lower than UTS results of the alloy for Sr modified parameter. It can be understood that Sr modification affects the UTS results, but this effect is quite low for no degassing condition. UTS results of as-received parts is the highest for degassing condition. It can be said that degassing process increases UTS and YS values of the alloys for all conditions. Similar
Effect of Sr modification and degassing was seen for YS values of the alloy. It was seen that Sr modification did not affect the results of UTS and YS for degassed condition well but get worse the results of UTS and YS for degassed condition. If the experiment parameters is investigated together, it can be understood that the best result was obtained from as-received and degassed conditions. However, if the results are examined in terms of stabilization, modified and degassed alloys are the best. Degassing is crucial process to improve the mechanical properties of the alloys. As known in the literature [12, 15], Degassing is made to clean bifilms from melt and therefore, it increases the casting and liquid quality. These knowledges were promoted in this study.

Figure 4. e % and QT results of the alloy for as-received and modified, a) No degassing condition, b) Degassed condition

Results of e % and QT were presented in Figure 4. It is seen on the chart that Sr addition decreases e % value for no degassing and degassed conditions. If looking at the results in terms of stabilization, results of Sr modified alloy are more stable. Similar to UTS and YS results mentioned above e % results were affected by degassing process, positively. In general, degassing is beneficial process to improve the mechanical properties, but it decreases the stabilization of e % results according to Figure 4b. If average results are examined, it can be said that degassed and non-modified parameters are optimum for this study. QT results are also affected by degassing and Sr modification similar to e %. Degassing improved QT value for both Sr modified and non-modified alloy. It can be thought about these results that degassing process cleans the structure from bifilms and therefore casting and liquid metal quality can increase. Effect of this can be understood by comparing of degassed and non-degassed QT values.

4. Conclusion

Effect of Sr modification and degassing process on the mechanical properties of A413 alloy were investigated in this study and conclusions of the study summarized below:

1- Sr modification affects the silicon morphology.
2- Bifilms are effective on the mechanical properties.
3- Degassing increases the mechanical properties by cleaning bifilms from the structure.
4- Sr modification is not suggested to improve the mechanical properties of A413 alloy.

References


