Change in the SDAS by Sr modification and AlB_3 grain refinement in A357

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Abstract

Hypoeutectic Al-Si alloys exhibit a mixture of dendritic and eutectic microstructure. The mechanical properties of these alloys are significantly affected by the size of dendrites and size and distribution of eutectic phase ratio. There are several works in literature about the addition of Sr and refinement of Si structure and its correlation with the mechanical properties. In this work, Al7Si alloy was used and three conditions were tested where the additions of Sr and B were investigated. Samples were produced by casting in sand moulds and microstructural analysis were carried out by measuring the SDAS, Si morphology and eutectic phase ratios.

Keywords: Casting, Grain refinement, Modification, Microstructure, A357

Özet

Ötektik altı alaşımların dentritik ve dentritik+ötektik mikroyapı dağılımı mekanik özellikleri etkilemektedir. Mekanik özelliklerden süneklilik üzerine ile elde edilen silisyum modifiyesinin etkisi birçok araştırmacı tarafından dile getirilmiştir. Bu çalışmada ötektik altı alaşımlardan A357 alaşımı çalışılmıştır. Deneysel çalışmalarda Sr modifikasyonu ve son yıllarda kullanımı artan Ti içermeyen B ilaveli tane inceltme işlemleri uygulanmıştır. Dökümler gaz gidermeli ve gaz gidermesiz olarak gerçekleştirilmiştir. Elde edilen numunelerin mikroyapısal analizi yapılmıştır. Mikroyapısal analizde dendrit boyutları, Si yapıları incelenmiştir. Ayrıca Ti içermeyen B ilaveli tane inceltme sonuçları ile literatürde mevcut olan Ti içeren tane inceltme çalışmaları tartışılmıştır.

Anahtar Kelimeler: Döküm, Tane İnceltme, Modifikasyon, Mikroyapı, A357

1. Introduction

Al-Si alloys are preferred choice of materials in the transportation industry due to their low density/high strength ratios, good corrosion properties and excellent castability characteristics. These properties are mostly met by the design parameters particularly required by the automotive industry. Some examples include engine blocks, cylinder heads, pistons etc. Many other steel-based parts are being replaced by aluminium alloys [1].

The mechanical properties of Al-Si alloys are majorly defined by the grain size, secondary dendrite arm spacing and Si morphology [1-3]. On the other hand, one of the most important defects that may exit in liquid aluminium that effects the mechanical properties is called bifilms [4]. These defects are entrained from the surface by turbulence. Thus, uncontrolled degassing operations may lead to the increased population of bifilms in the melt and the quality may

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therefore decrease [4].
Sb and Na were used to modify Si morphology from lamellar to fibrous in order to increase mechanical properties of Al-Si alloys. In the last decade, Sr has been the favourite modifier because Sr is non-toxic, not volatile as Sb and Na and do not fade. The mechanism has been defined as the retardation of Si growth by Sr presence in the alloy [5]. In addition to the modification by Sr, Al-Ti-B master alloys are added 1 to 1000 ratio to promote finer dendrite formation. Both of these melt treatments have been known to be beneficial to the increase of the mechanical properties [6]. With further increase in the cooling rate during solidification, even finer Si eutectic and finer dendritic structure can be obtained [7]. Furthermore, the effect of Sr modification and grain refinement have been found to be decreasing the porosity content [8]. Thus, the control of microstructure has predominant effect over the quality of the final cast part.

As an alternative to the Ti grain refinement, Ti-free B grain refiners have been studied. Arnberg [9] proposed that more globular dendritic network was established and Dispinar [10] found that more localised pore distribution was achieved with B grain refinement. In addition, since Al-B has eutectic reaction; in the absence of peritectic reaction, as in the Al-Ti phase diagram, the fading of the grain refiner is not observed with the Ti-free B grain refiners.

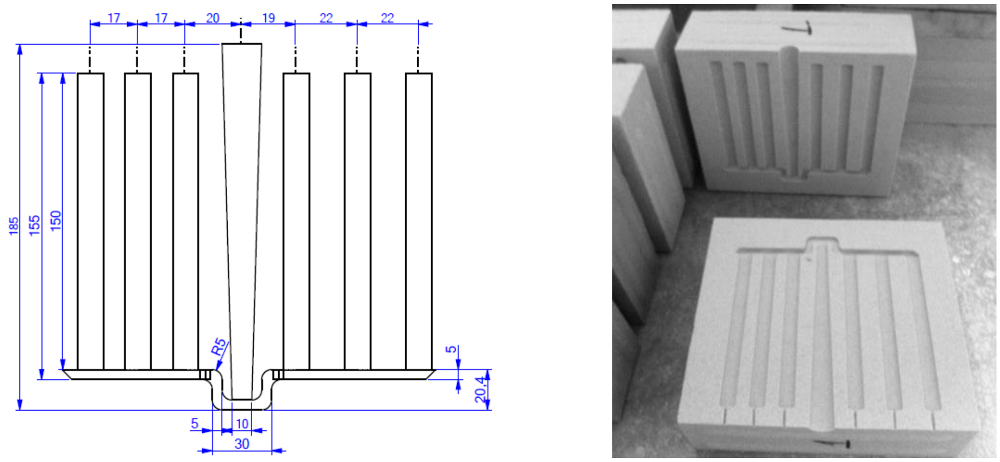
Therefore in this work, the effect of Sr modification and B grain refinement over the microstructure has been investigated with Al-7Si alloy.

2. Experimental work

The chemical composition of the alloy studied in this work is given in Table 1. 10 kg of charge was melted in a SiC crucible in resistance furnace at 730^{o}C. The castings were made into sand moulds where the dimension is given in Figure 2. The casting conditions were selected to be (i) as-received, (ii) Sr modified, (iii) AlB_3 grain refined; before and after degassing with Ar for 20 minutes. Thus, overall, six conditions were investigated.

Table 1. Chemical composition of A357 alloy

Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
6,60-7,40	0,20	0,02	0,03	0,30-0,45	0,04	0,08-0,14	Rem.



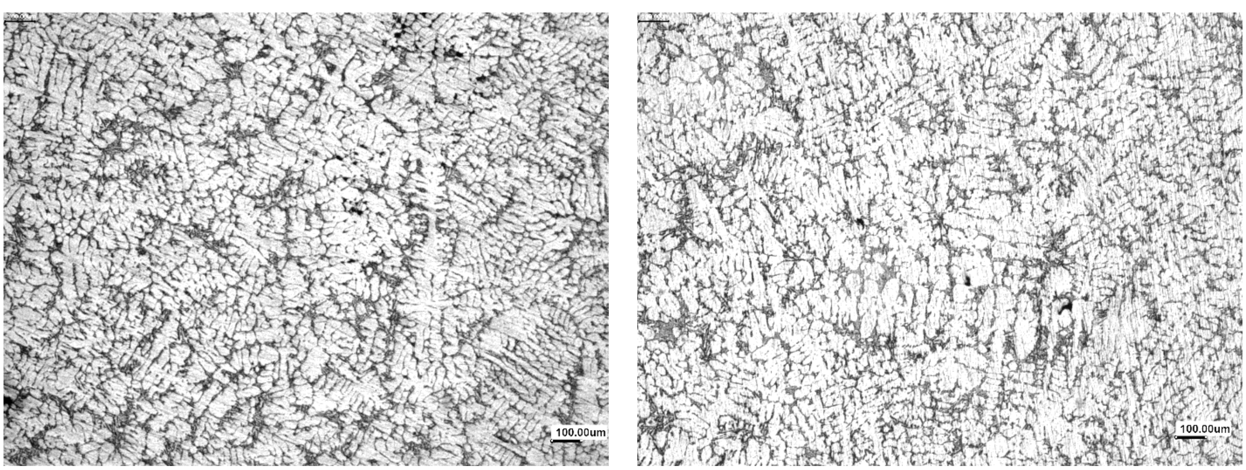
a) b)

Figure 1. a) Dimension of the mould b) Sand mould after shake out

Secondary dendrite arm spacing (SDAS) was calculated by using Clemex Image Analysis software from the microstructures obtained from the sand castings. Microstructural analysis was carried on optical microscope (Nikon).

3. Results

The microstructural analysis results of all the castings before and after degassing, as-received, Sr modified and B grain refined are given in Figures 2-4.



a b

Figure 2. Microstructures of the untreated melt (as-received condition).
a) before degassing, b) after degassing

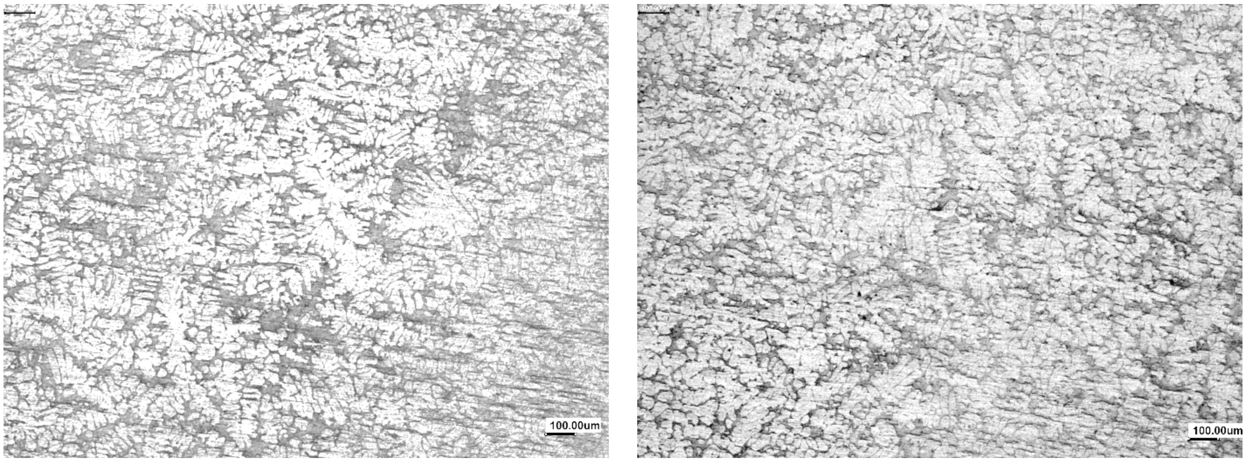


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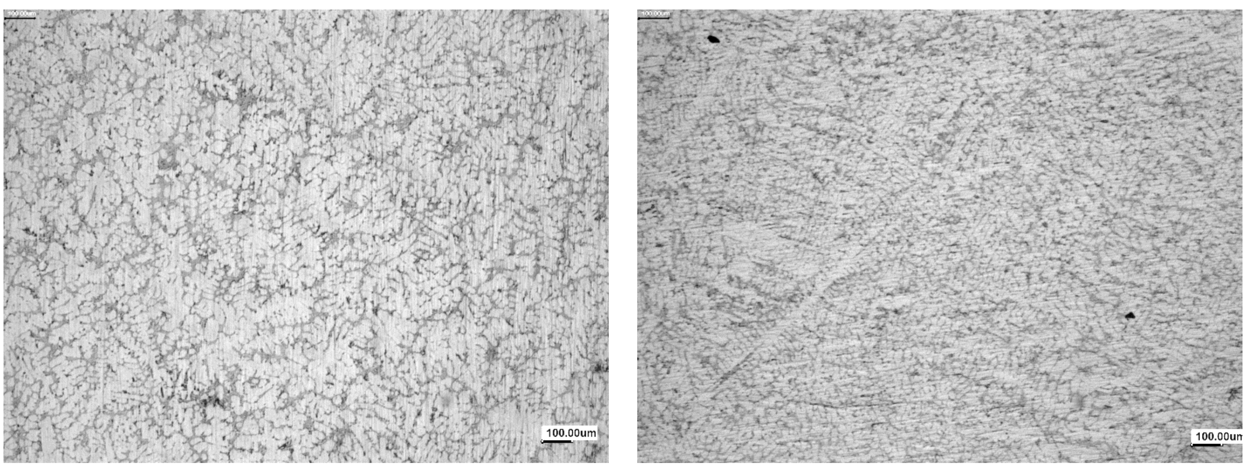
Figure 3. Microstructures of the Sr modified alloys.
a) before degassing, b) after degassing



a b

Figure 4. Microstructures of the AlB3 grain refined alloy.
a) before degassing, b) after degassing

The average secondary dendrite arm spacing measurements from the image analysis results are given in Figure 5.

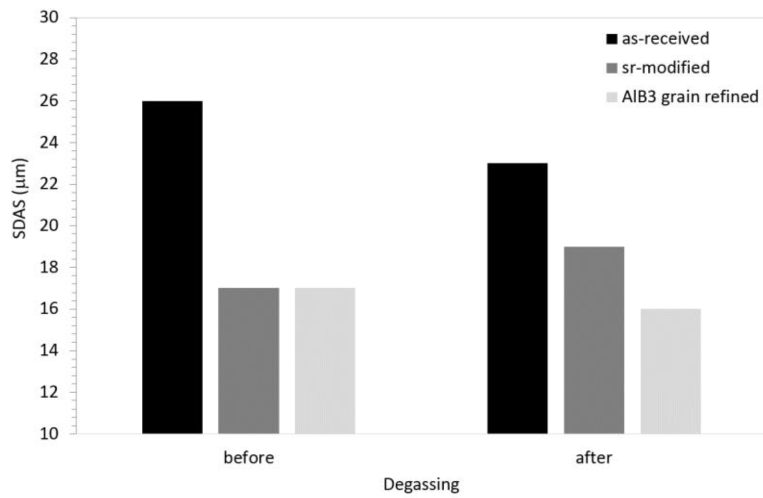


Figure 5. SDAS measurement results

Melt quality measurements were made by reduced pressure test and bifilm index results are summarised in Fig 6.

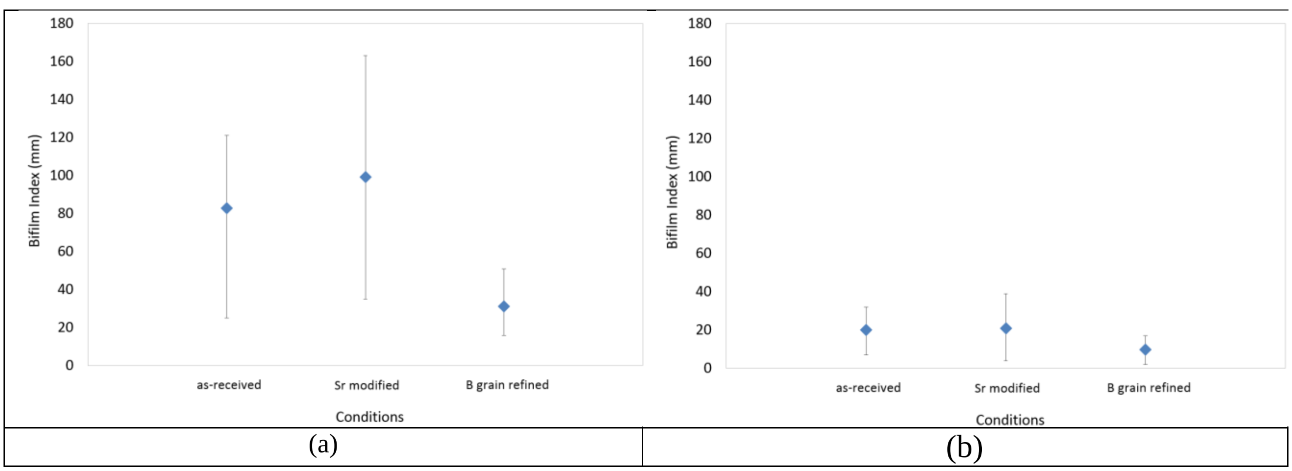


Figure 6. Bifilm index change of the melts
a) before degassing, b) after degassing

4. Discussion

As seen in Figure 2-4, the dendrite arms spacing is almost similar particularly for the Sr modified and B grain refined melts. Average SDAS values are around 17 µm for both cases before and after degassing. The untreated melt had the highest SDAS amongst the experimental work carried out. It was 26 µm. It is all so surprising that in the Sr modified alloy, although there were no grain refiners, the SDAS value was quite similar with the AlB_3 grain refined castings. It is well known that the eutectic structure is refined into finer fibrous form by Sr modification and eutectic temperature is depressed. However, this should only change the feedability and the final eutectic phase ratio. This could be supported by the fact that bifilm index of Sr modified alloy was quite high before degassing. It appears that bifilms has act as heterogeneous nucleation sites for primary dendrites where SDAS is 17 μm (Figure 5-6). This is also proven by the increase in SDAS from 17 μm to 19 μm in the degassed melt with Sr modified alloy. The index was decreased from 80 to 20 mm. Thus the number of nucleants were decreased resulting in increased SDAS.

In a similar scenario, SDAS values of AlB_3 grain refined castings were unchanged for untreated and degassed melts (Fig 5). If the bifilm index values were to be compared, it can be seen that these values are also same (Fig 6).

Arnberg had found that in the absence of Ti, B grain refinement resulted in more globular and compact dendritic structure. However, this was not observed in this study. As seen in Figure 4, there are no compact dendrites. This is possibly due to the presence of minor amount of Ti in the alloy (see Table 1). Dispinar had studied the effects of B grain refinement and in their study, special alloy was provided by Elkem that was Ti-free and found similar results as in the case of Arberg.

It is interesting to note that by the addition of B into the melt, low bifilm index was achieved even before degassing (Fig 6). In the untreated melt, the bifilm index was around 80 mm and by addition of boron, this was dropped down to 20 mm. It is most likely that B reacts with bifilms to either sedimate or to heal bifilms as Campbell suggested.

Conclusion

By the degassing of the melt with Ar, bifilm index can be decreased significantly resulting in higher quality castings.

With B grain refinement, even before degassing, high quality melts can be achieved (i.e. low bifilm index).

Acknowledgment

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