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FLUIDITY CHARACTERISTICS OF A356 ALLOY WITH VARIOUS THICKNESS SECTIONED NEW TEST MOULD

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Abstract

Fluidity of alloys are typically carried out in a spiral test mould. Due to the variation of the results, several attempts have been made to optimise the test procedure. Pouring basin has been updated by addition of a stopper and using a defined quantity of melt to be poured. However, one of the discussed issues of the spiral test mould is its fixed size cavity where the liquid is transferred. Therefore, a mould was introduced by Campbell in which a single runner bar was used to feed different thickness sections. In this study, this mould design was used to investigate the effect of temperature (700oC, 725oC and 750oC) and modification (Ti grain refinement and Sr) on the fluidity of A356 alloy. The results were compared with the simulation (SolidCast) to optimise the characteristics of the alloy.

Introduction

Aluminium-Silicon alloys are mainly preferred in several applications due to their high strength/low density ratios. The simplest and economical way of producing parts from this alloy group is casting. One of the limiting factor of casting methods is the fluidity of the liquid metal. The metallurgical factors include composition, microstructure, modification, super heat, melt cleanliness and surface tension. Ravi [1] has reviewed many of these factors. Many of the researches [2-9] have focused on the microstructure where castability was considered as a function of feedability parameters such as eutectic ratio, dendrite arm spacing etc. Campbell [10] has defined five feeding mechanisms which depended upon solidification conditions. Typically, pure metals and eutectic alloys have the highest fluidity in a binary alloy systems as shown in Figure 1.

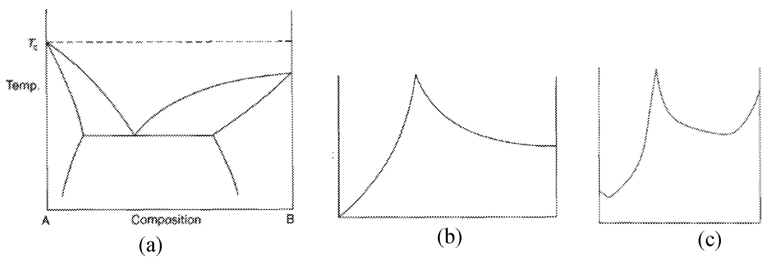


Figure 1: (a) a simple binary alloy with eutectic reaction, (b) fluidity with composition at zero super heat, (c) fluidity with composition certain super heat [10]

In addition, dendrite coherency (particularly secondary dendrite arm spacing), phases that are formed (eutectic ratio and/or intermetallics) and porosity play significant role on the fluidity of the A356. Therefore, the influence of Sr modification and grain refinement has been widely studied [2, 4, 7, 11].

In this study, the aim was targeted to investigate the effect of surface tension on the fluidity by means of using different section thickness mould.

Experimental work

Commercially available A356 alloy was used in this work. The composition of the alloy is given in Table 1.

Table 1: A356 composition used in the experiments

Fe	Si	Ti	Zn	Cu	Mn	Sn	Mg	Pb	Al
0,15	6,7	0,10	0,004	0,02	0,35	0,05	0,35	0,02	rem

Three different pouring temperatures were selected: 700, 725 and 750°C. The alloy was cast in three various composition: as-received, Ti-grain refined and Sr-modified. The fluidity tests were carried out in the revised mould design where the dimension is given in Figure 2.

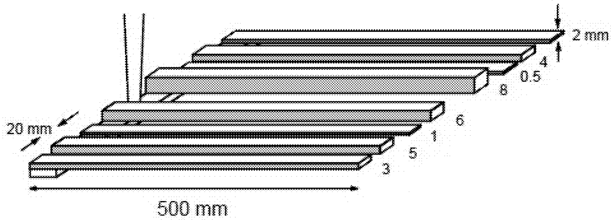


Figure 2: Dimension of the fluidity mould used in the experiments

The moulds were produced by sand moulding with CO_2 hardened AFS60 sands. The same experimental conditions were input to SolidCast simulation program and the results were compared with the casting trials. The basic assumptions used in the software were made according to the casting trial; such as, filling time was selected as 5 seconds. The flow was stopped after 609°C and the critical fraction of liquid (CFL) was set to 0.6.

Results

The fluidity test results were measured in millimetres and summarised in Figures 3-5.

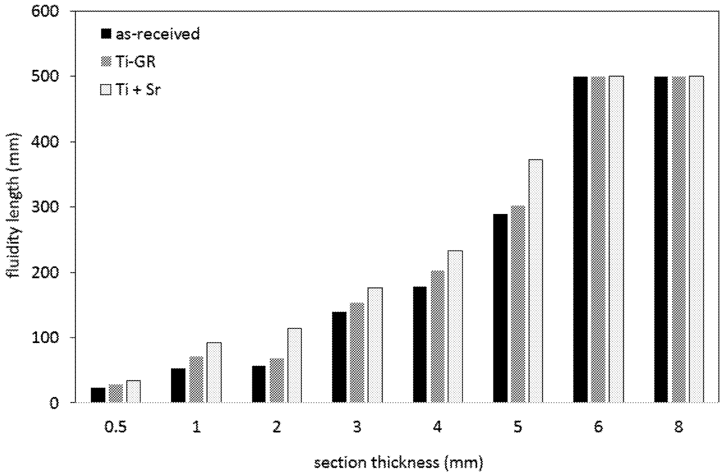


Figure 3: Fluidity length at 700°C according to section thickness

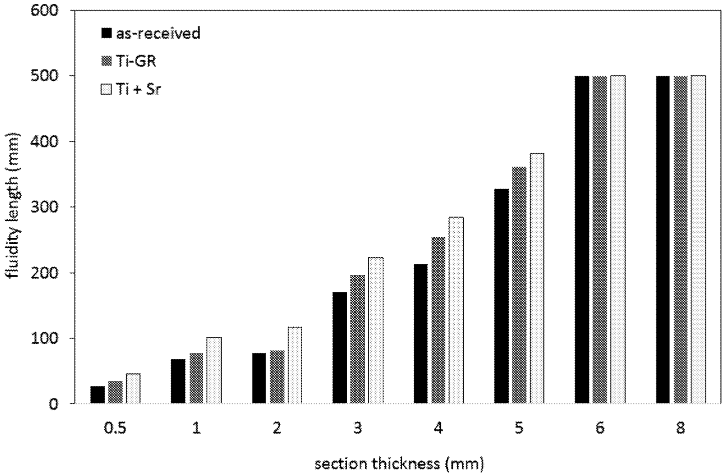


Figure 4: Fluidity length at 725°C according to section thickness

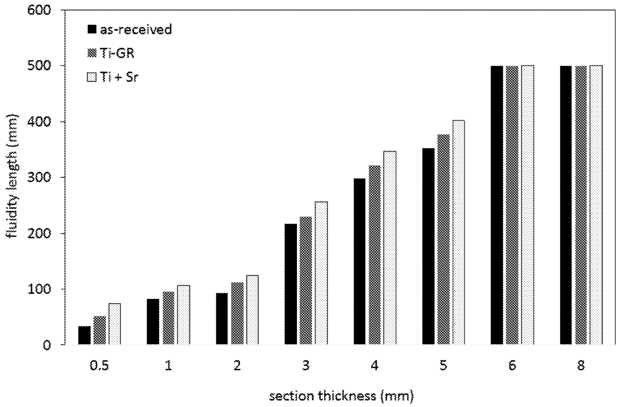


Figure 5: Fluidity length at 750°C according to section thickness

Some of the selected images that show the comparison of actual castings with the simulation is given in Figures 6-8.

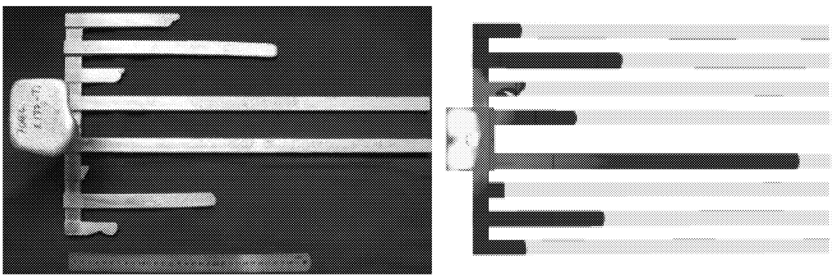

(a) (b)

Figure 6: Fluidity test results of Ti-grain refined A356 at 700°C (a) casting, (b) simulation

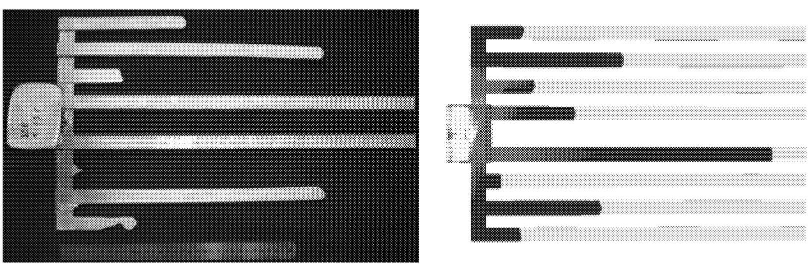
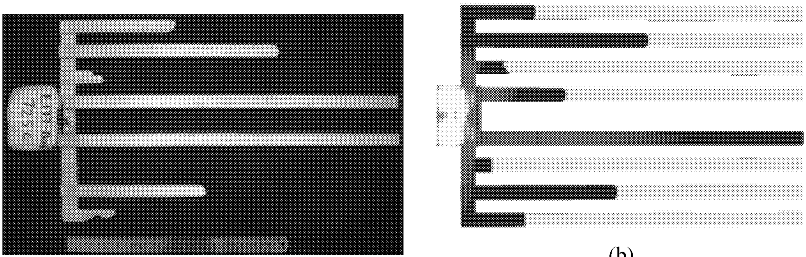

(a) (b)

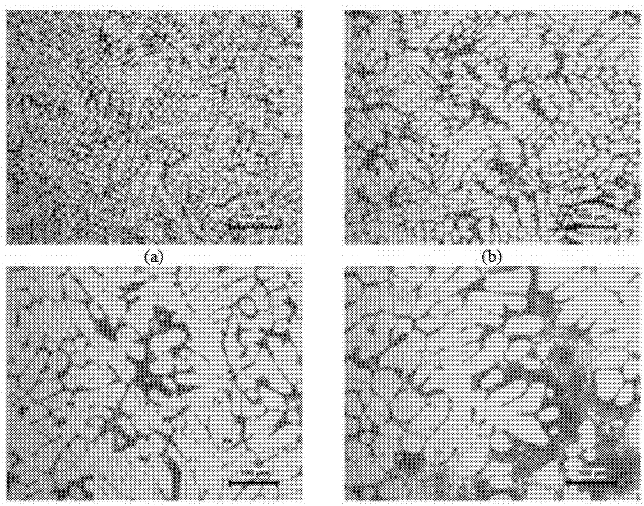
Figure 7: Fluidity test results of Ti-grain refined and Sr-modified A356 at 700°C (a) casting, (b) simulation



(a) (b)

Figure 8: Fluidity test results of as-received A356 at 725°C (a) casting, (b) simulation

All the castings that were produced under different conditions (i.e. 700, 725, 750 and as-received, Ti grain refined and Sr modified) were all subjected to metallographical examination in order to investigate the effect of microstructure on the fluidity. For simplicity, only few of the selected micrographs are given in Figure 9-11.



(c) (d)

Figure 9: Sample cast at 700°C in as-received condition (a) 0.5 mm section, (b) 1 mm section, (c) 5 mm section, (d) 8 mm section

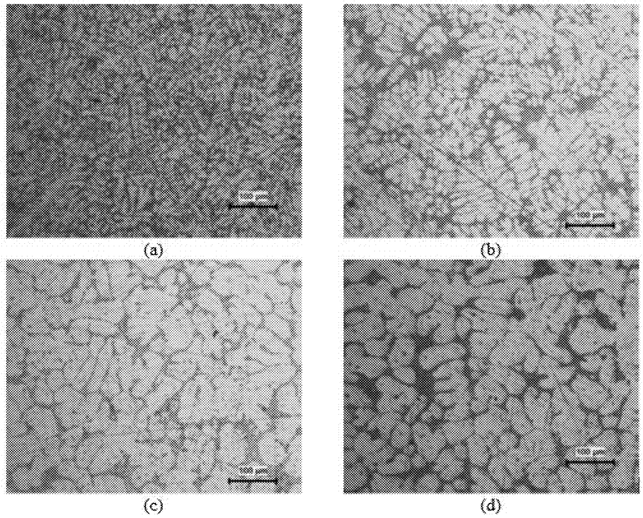


Figure 10: Sample cast at 700°C with Ti grain refined (a) 0.5 mm section, (b) 1 mm section, (c) 5 mm section, (d) 8 mm section

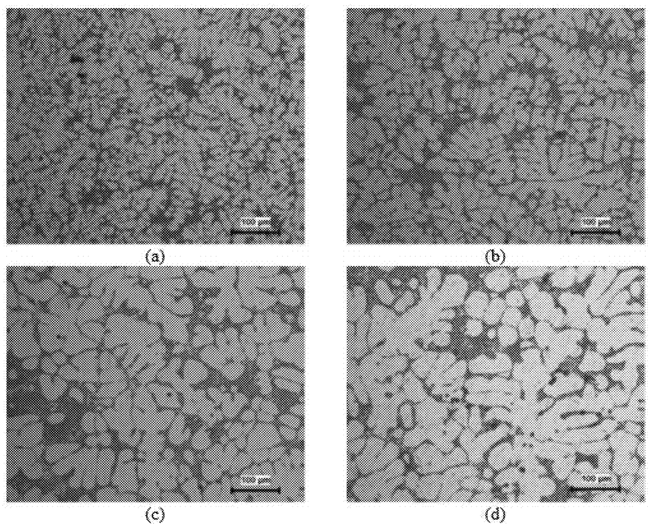


Figure 10: Sample cast at 700°C with Ti grain refined and Sr modified (a) 0.5 mm section, (b) 1 mm section, (c) 5 mm section, (d) 8 mm section

Discussion

As seen from Figures 3 to 5, in all of the tests, regardless of the microstructure (as-received, Ti grain refined or Sr modified) and casting temperature (700, 725, 750°C), 6 mm and 8 mm sections were all filled to the maximum which is 500 mm. On the other hand, 0.5 mm section was the lowest fluidity length with an average around 35 mm.

When the castings were made at 700°C, the fluidity length of as-received alloy and Ti-grain refined was quite close to each other at all section thicknesses. However, the fluidity was significantly increased when the alloy was modified with Sr; particularly at 2, 4 and 5mm sections. When the casting temperature was increased to 725 and 750°C, this apparent effect of Sr modification was less pronounced.

Kwon [4] had used a similar mould design but used 8 channels with same cross sectional areas. The dimension were 5x3x2. It was suggested that for A356 alloy, the grain refinement had increased fluidity even at lower melt temperatures. However, no such results were found in this work when the same cross sections were compared. As Ravi [1] concluded in their review, the influence of grain refinement on fluidity is remains trivial.

As expected, when the melt temperature was increased, the fluidity at all different sections of the mould was increased. However, there were no effect of the critical solid fraction over the experimental works conducted in this study. By Ti grain refinement, the dendritic coherency would have been delayed [3, 9], and as a results, feedability would be increased considerably. However, the fluidity lengths were not that different for the castings in the as-received and Ti-grain refined conditions. The establishment of the planer growth and fine eutectic structure by the addition of Sr was not as dramatic as expected for the thin sections. This may possibly be due to the effect of the melt cleanliness. It has been shown that the presence of oxide inclusions have noticeable effect over the fluidity [4, 8, 11, 12].

Conclusion

The fluidity of A356 increases with grain refinement and further increases with additional Sr modification.
Fluidity of A356 in sand moulds varies with section thickness and it is highest after 5 mm and it decreased exponentially down to 0.5 mm thickness.
Simulation results are in good agreement with the experimental work for the modified fluidity tests for A356.

References

1. Ravi, K.R., et al., *Fluidity of aluminum alloys and composites: A review.* Journal of Alloys and Compounds, 2008. **456**(1–2): p. 201-210.
2. Dahle, A.K., et al., *Effect of grain refinement on the fluidity of two commercial Al-Si foundry alloys.* Metallurgical and Materials Transactions A, 1996. **27**(8): p. 2305-2313.
3. Di Sabatino, M. and L. Arnberg, *Effect of grain refinement and dissolved hydrogen on the fluidity of A356 alloy.* International Journal of Cast Metals Research, 2005. **18**(3): p. 181-186.
4. Kwon, Y.-D. and Z.-H. Lee, *The effect of grain refining and oxide inclusion on the fluidity of Al–4.5Cu–0.6Mn and A356 alloys.* Materials Science and Engineering: A, 2003. **360**(1–2): p. 372-376.

5. Liu, L., et al., *Precipitation of β-Al5FeSi Phase Platelets in Al-Si Based Casting Alloys.* Metallurgical and Materials Transactions A, 2009. **40**(10): p. 2457-2469.
6. Mollard, F., M. Flemings, and E. Niyama, *Aluminum Fluidity in Casting.* JOM, 1987. **39**(11): p. 34-34.
7. Nabawy, A.M., et al., *Influence of additions of Zr, Ti–B, Sr, and Si as well as of mold temperature on the hot-tearing susceptibility of an experimental Al–2% Cu–1% Si alloy.* Journal of Materials Science, 2012. **47**(9): p. 4146-4158.
8. Samuel, A.M., A. Gotmare, and F.H. Samuel, *Effect of solidification rate and metal feedability on porosity and SiCAl2O3 particle distribution in an Al-Si-Mg (359) alloy.* Composites Science and Technology, 1995. **53**(3): p. 301-315.
9. Veldman, N.M., et al., *Dendrite coherency of Al-Si-Cu alloys.* Metallurgical and Materials Transactions A, 2001. **32**(1): p. 147-155.
10. Campbell, J., *Castings*. 2003: Elsevier Science.
11. Liu, L., et al., *Influence of oxides on porosity formation in Sr-treated Al-Si casting alloys.* Journal of Materials Science, 2003. **38**(6): p. 1255-1267.
12. Di Sabatino, M., et al., *The influence of oxide inclusions on the fluidity of Al–7wt.%Si alloy.* Materials Science and Engineering: A, 2005. **413–414**(0): p. 272-276.