FLUIDITY OF MODIFIED AND UNMODIFIED Al-Si ALLOYS IN ALUMINA INVESTMENT SHELL MOULDS

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Abstract

The present work was aimed to assess the influence of Si content, superheat, modification and mould preheat temperature on the fluidity. The fluidity spirals were made using alumina filler materials and the colloidal silica binder. The fluid increases with the increase of Si content, super heat and shell mould preheat temperature, but decreases with Sr modification.

Keywords: *Al-Si alloy, fluidity spiral, super heat, mould preheat temperature, alumina, modification.*

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1. INTRODUCTION

Aluminum alloys are widely used in automotive industries. The fluidity of Al-Si alloys increases with increasing Si content reaching a maximum at 17-18wt% Si [1]. The fluidity of hypereutectic Al-Si alloys is better than that of hypoeutectic and eutectic compositions. This is due to the high heat of fusion of primary silicon which is 4.5 times higher than the heat of fusion of pure aluminum [2]. Fluidity is a widely accepted measure of the alloy's ability to fill the mold cavity. Because of its importance in casting, the fluidity of casting alloys has been studied extensively over decades [3-5]. Generally, whether a mold cavity can be filled completely or its details can be replicated depends not only on the alloy's characteristics but also on the mold properties, such as its dimensions, geometry, material, temperature, etc, and casting process parameters, such as temperature and pressure.

The objectives of the present work was to study the influence of superheat of liquid metal, content of Si, modification of Al-Si alloy with strontium and preheat temperature of investment shell mould on the fluidity.

2. MATERIAL AND METHODS

Different Al-Si alloys were gravity cast in the investment shell moulds. The Si content was varied to get hypoeutectic, eutectic and hypereutectic Al-Si alloys. Alumina was used as the filler materials to make investment shell moulds. The investment slurry was prepared by adding the filler materials to the colloidal silica binder. The silicon radicals in the colloidal silica binder were 30%. The primary coats (first two coats) were stuccoed with fine silica grains of AFS fineness number 120 and the remaining backup coats with sand grains of AFS fineness number 50. All the investment shell moulds were preheated as per the design of experiments before pouring the liquid metal. The Al-Si alloys were melt in an induction furnace and they were super heated before pouring into the moulds [6-8]. The liquid alloy was modified with strontium (Sr). The fluidity spiral made from the alumina filler material is shown in figure 1. The length of fluidity spiral was 500 mm. The investment shell mould is shown in figure 2.

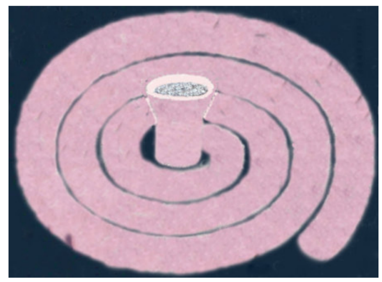

Figure 1: Fluidity spiral.

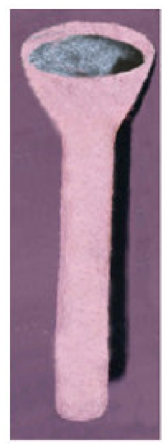

Figure 2: Alumina investment shell mould.

3. RESULTS

In the present investigation three Al-Si alloys (figure 3) were considered. Alloy-1 was the hypoeutectic alloy; Alloy-2 was eutectic alloy; Alloy-3 was hypereutectic alloy. The alloy-1 consists of 5%Si; the alloy-2 consists of 12.6%Si; the alloy-3 consists of 15%Si. The coarse grain structure was revealed in the optical microstructures without modifier as seen in figures 4(a), 5(a) and 6(a). When modified Al-Si alloys with Sr, the fine grain structures were observed in the microstructures as shown in figures 4(b), 5(b) and 6(b). The primary dendrites are seen in the scanning electron microscopy (SEM) image of the eutectic alloy as shown in figure 5(c). The secondary dendrite arms were not grown up because of Sr modification. The orientations of dendrites are due to skewed coupled zones.

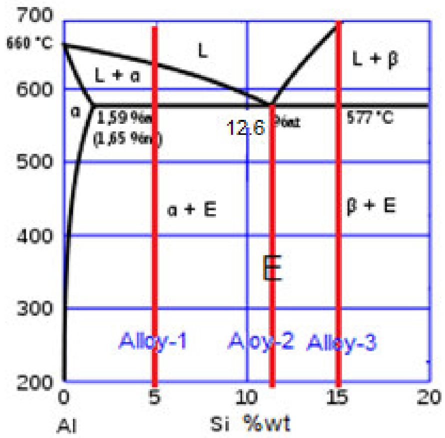

Figure 3: The binary phase diagram of Al-Si system.

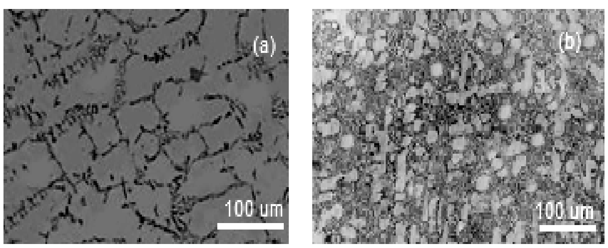

Figure 4: Microstructure of Al-5%Si alloy: (a) unmodified and (b) modified with Sr.

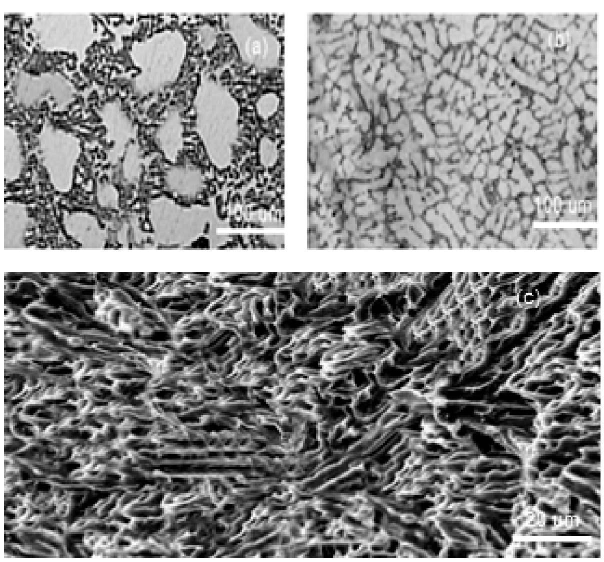

Figure 5: Microstructure of Al-11.3%Si alloy: (a) unmodified and (b) modified with Sr and SEM image of eutectic.

3.1 Effect of Si content on fluidity

As the Si content increases the fluidity of Al-Si alloy increases as shown in figure 7. The fluidity was measured at constant pouring temperature of 750°C and mould-preheat temperature of 400°C. The increase of Si content has changed the liquidus temperature of the alloys, and hence changed the superheat. At eutectic composition, aluminum dendrites are present due to a skewed coupled zone. The dendrites disappear at a higher Si content than eutectic. The fluidity of Al-Si alloys had a maximum at a silicon content well above the eutectic composition. After this maximum in fluidity, further additions of Si would reduce the fluidity due to the increase in number of hypereutectic silicon particles interfering with the metal flow. The modified Al-Si alloy had better fluidity than unmodified Al-Si alloy.

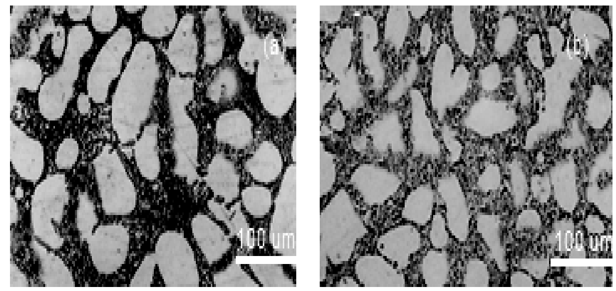

Figure 6: Microstructure of Al-15%Si alloy: (a) unmodified and (b) modified with Sr.

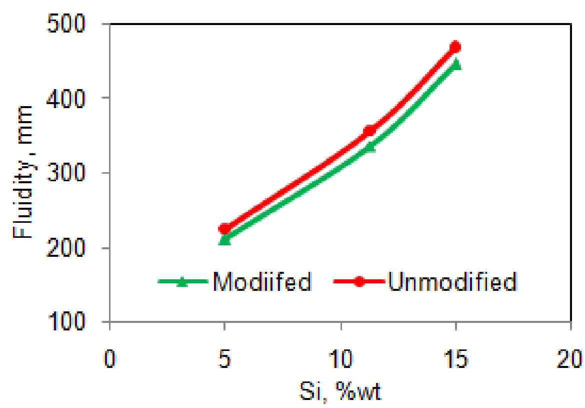

Figure 7: Effect of Si content on fluidity: unmodified and modified with Sr.

3.2 Effect of superheat on fluidity

The effect of superheat of liquid metal on the fluidity is shown in figure 8. The mould-preheat temperature was 400°C. The fluidity of eutectic Al-Si alloy increases with the increase of superheat. If the melt was at a higher temperature relative to its freezing point, it would remain in the liquid state longer throughout the metal casting operation, and hence its fluidity would increase.

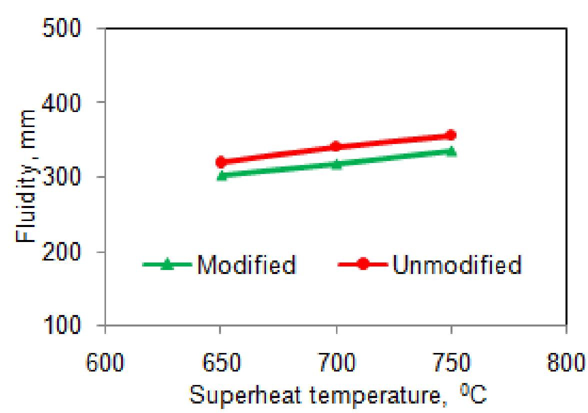

Figure 8: Effect of superheat temperature on fluidity: unmodified and modified with Sr.

3.3 Effect of mould preheat on fluidity

The effect of superheat of liquid metal on the fluidity is shown in figure 9. The fluidity was measured at constant pouring temperature of 800°C for eutectic alloy. The fluidity increases with the increase of mould pre-heat temperature. This was due to reduced temperature gradient which would prolong solidification process.

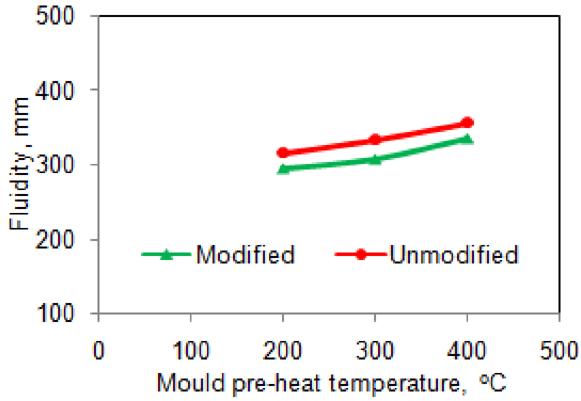

Figure 9: Effect of superheat on fluidity: unmodified and modified with Sr.

3.4 Effect of modification on the fluidity

As the Sr content increased in the Al-Si alloy the fluidity was decreased (figure 10). In the modified Al-Si alloys the undercooling was higher than critical value of 6-8°C.

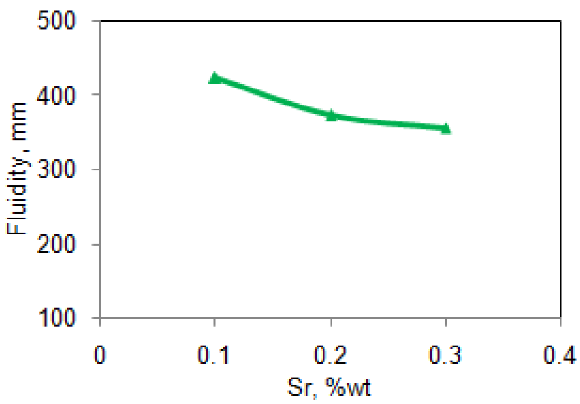

Figure 10: Effect of modifier on fluidity.

4. DISCUSSION

The influence of superheating on the crystallographic characteristics of alloys revealed that superheating shifts its eutectic reaction toward higher level of silicon accompanying with the appearance of Al-dendrite in the hypo eutectic and eutectic Al-Si alloys [9]. But, when hypereutectic Al-15%Si alloys were superheated at 800°C the primary silicon particles became finer. Kolsgaard [10] has reported that the fluidity length, measured with a spiral test in sand mould, increases linearly by increasing superheat. The hypoeutectic Al-Si alloys that precipitate dendrites with complex shapes, show lower fluidity than hypereutectic alloys that precipitate simple plate-like crystals.

Since fluidity is determined by phenomena occurring at the initial stage of solidification, the effect of eutectic modifying agents in Al-Si alloys would not be expected to give any large effect [11]. The effect of additions on the constitution and properties of the oxide skin may, however, be more significant. Modification of Al-Si hypoeutectic alloys, by adding Sr, gives strength and ductility to the casting. Plate-like coarse silicon particles are converted into fibrous particles. Kotte [12] found that both Na and Sr reduce fluidity to some extent, but with Sr the reduction in fluidity was less than with Na. An important function of mould preheating is to reduce the heat transfer rate between the flowing metal and the mould. The smaller the temperature difference between the mould metal, the longer the metal will retain its heat and remain fluid.

The fluid spirals cast in the alumina investment shell moulds are shown in figure 11. The length of fluid spiral increases with increase of Si content and superheat, but it decreases slightly with addition of strontium.

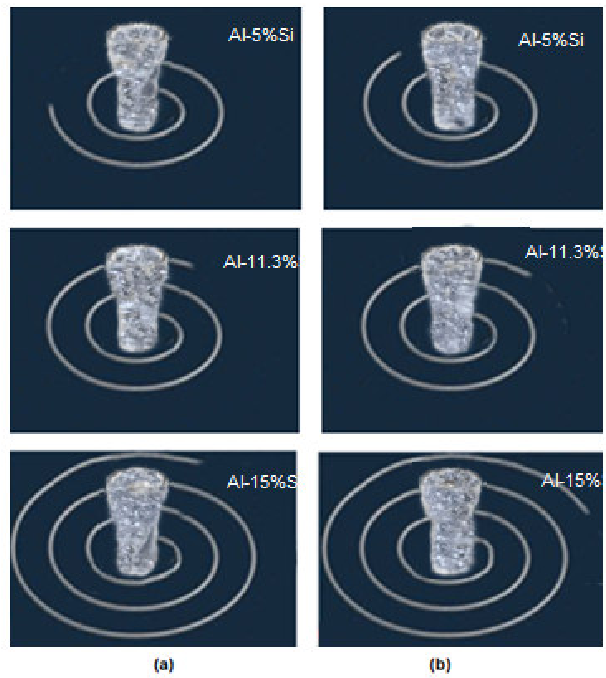

Figure 11: Fluid spirals cast in (a) modified and (b) unmodified Al-Si alloys.

5. CONCLUSIONS

The fluidity increases with the increase of Si content, super heat and shell mould preheat temperature. The fluidity decreases with Sr modification of Al-Si alloy.

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