Effect of Strontium on Surface Modification of Al-Si Alloys Cast in Investments Shell Moulds

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Abstract: The effects of strontium content in the primary coats on the refinement of grain structure on the surface of cast samples have been investigated. The Al-9%Si were cast in strontium coated investment shell moulds. The grain size was powerfully affected by the presence of strontium in the primary coats of investment shell moulds. The formation of Al_2Si_2Sr and β-Al_5SiFe phases were revealed on the surface of the test samples.

Keywords: Investment casting, Al-Si alloy, strontium, colloidal silica binder, Titania.

1. INTRODUCTION

The grain refinement mechanisms of Al-alloys are still the subject of research. The two major microstructural components of the hypoeutectic Al-Si casting alloys are the primary α-Al solid solution dendrites and the Al-Si eutectic, therefore the mechanical properties mostly depend on the properties of these structural constituents [1, 2]. The eutectic silicon crystallizes into a coarse, plate-like morphology during the formation of the eutectic, which is mechanically disadvantageous for the casting, because sharp corners concentrate stress, which can cause fracture during the use of the casting. The most commonly used modifier element is strontium (Sr) because even a few hundred ppm of Sr can result a very fine, fibrous structure.

The scheme of current work is that the metal-mould reactions are expected with the liquid state manufacturing process like casting. Instead of adding strontium as a modifier to liquid Al-Si alloy, the strontium coating was given as primary coat on the investment shell moulds to improve surface characteristics rather than of core Al-Si alloy. The present work was to investigate the impact of strontium coated investment shell moulds on the surface modification of hypoeutectic Al-Si alloys.

2. MATERIALS METHODS

The chemical compositions of hypoeutectic Al-Si alloy is given in table 1. In the present work, hypoeutectic Al-Si alloy was cast in the investment shell moulds. The colloidal silica binder was used to fabricate the investment shell moulds from Titania as reinforced filler material. The silica content in the colloidal silica binder was 30%. In order to achieve the modification effect on the surface layer of the casting, during preparation of investment shell mould, the suitable content of Strontium was added: 3, 6, 12% mass in Titania filler material. Two grades (primary and backup sands) of stuccoing sand were employed in the present investigation. Finer grade silica sand having AFS grain fineness number 120 was employed for primary coats. This is synthetic sand. This sand was used for first two coats, called prime coats to get good surface finish and every detail of the wax pattern. Coarser grade sand having AFS grain fineness number 42 was employed for back up coats. This is river sand. The backup sand was employed to develop more thickness to the shell walls with minimum coats. The thickness of shell moulds were 10 mm. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made. The hypoeutectic Al-Si alloy was melted in a resistance furnace under vacuum. The liquid alloy was gravity poured into the pre-heated investment shell moulds. The shell moulds were knocked off by hand hammer after solidification of the molten (figure 1). The castings were cleaned with soft brush and visually inspected for pins and projections [3-22].

Table 1: Chemical composition of Ni-base super alloy

Element	Si	Cu	Mg	Fe	Sr	Ti	Mn	Al
Al-Si alloy	9.0	3.2	0.05	0.3	0.08	0.005	0.8	Balance

Tensile tests were carried out on Universal testing machine according to ASTM E8 [21] standard. Also, Brinell hardness test was carried out to measure the surface hardness of the as-cast samples.

Figure 1: Hypoeutectic Al-Si alloy cast in Strontium coated Titania investment shell mould.

3. RESULTS AND DISCUSSION

The refinement of eutectic silicon induced by the strontium is clearly visible on the surface of cast samples (figure 2b). With increasing content of Sr in the filler material, the number of Si particles (figure 2b) increases with increasing strontium content, so the eutectic becomes finer. Therefore, the modification effect is more intensive on the surface of the cast samples. The core areas of the cast have coarse grain structure (figure 2a). However, the marginal decrease in the grain size is observed with increasing content of SR in the filler material. Introduction of Sr to the filler material caused the formation of Al_2Si_2Sr intermetallics. Figure 3 shows the presence of isolated Sr-rich intermetallics near the dendrite-Al interface. However, these Al_2Si_2Sr precipitates were not observed to nucleate eutectic silicon when the eutectic reaction commenced. Also, the addition of Sr to filler material refines of the iron-rich intermetallics, β-Al_5FeSi. In Sr-containing investment coats, Al_2Si_2Sr is likely to form around Al dendrite as shown in figure 4a. When the Fe content is high enough, the pre-eutectic β-Al_5FeSi platelets are formed prior to the eutectic Al-Si reaction.

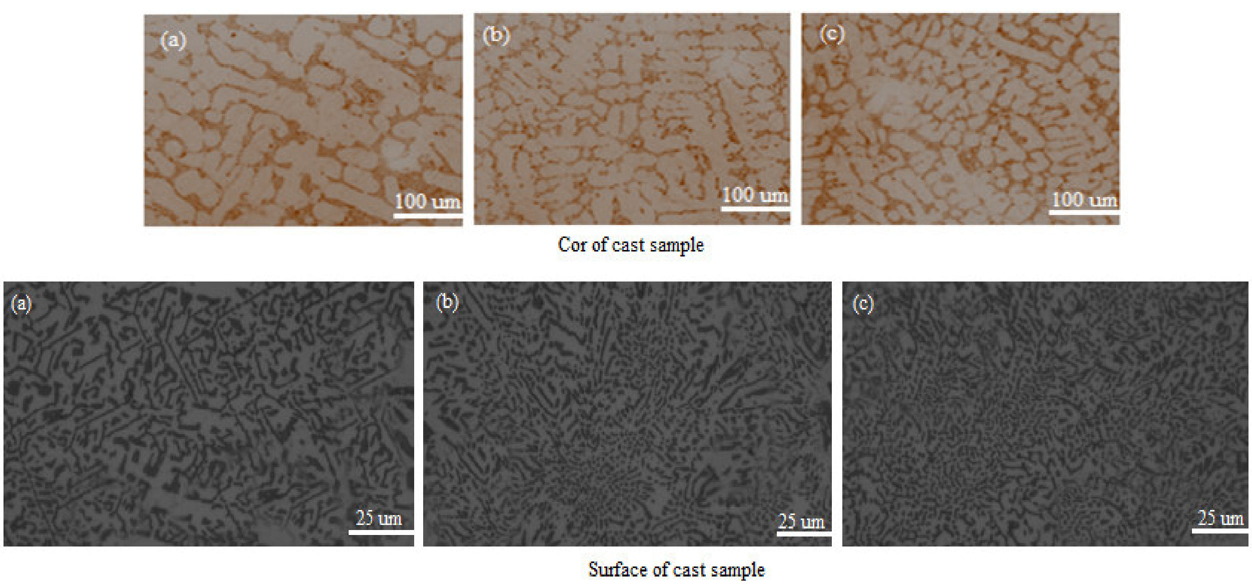

Figure 2: Microstructure of hypoeutectic Al-Si alloy (a) 3%, (b) 6% and (c) 12% Sr in primary coats of investment shell moulds.

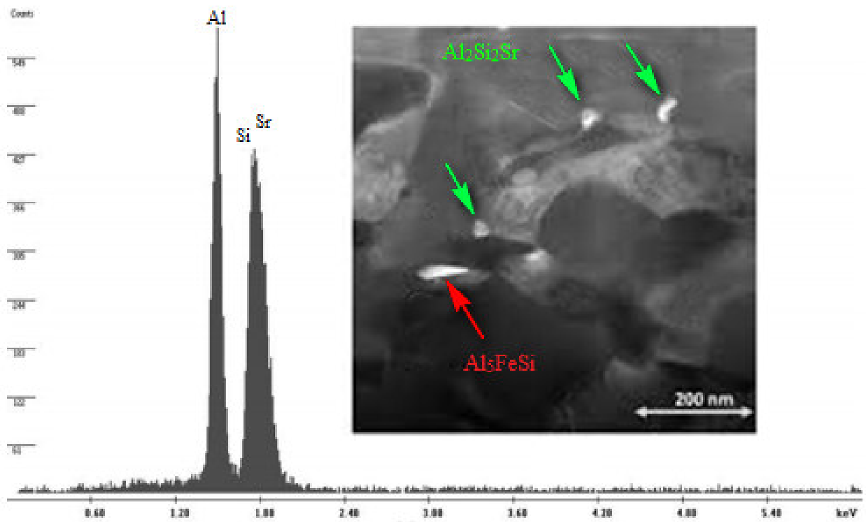

Figure 3: EDS analysis showing the formation of Al_2Si_2Sr intermetallic phase on the surface of the cast samples.

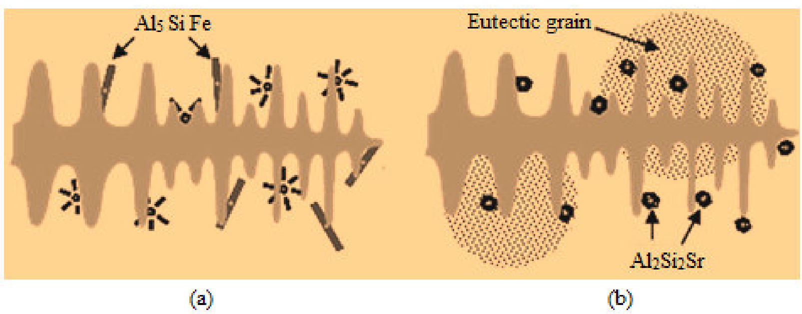

Figure 4: Schematic illustration of solidification sequence with the formation of Al_2Si_2Sr, primary Al dendrite, pre-eutectic b-Al_5FeSi, and eutectic Al-Si.

Figure 4: Effect of B content in primary coats on tensile properties of Al-Si alloy

S.No.	Sr content in primary coats, %	UTS, MPa	Surface Hardness, (HV)	0.2% YS, MPa
1	3	162.22	82	78.25
2	6	149.68	78	70.47
3	12	140.46	72	66.94

The ultimate tensile strength, hardness and yield strength increased with increase of Sr in the primary coats of investment shell moulds due to fine grains formed on the surface of test specimens.

4. CONCLUSIONS

Mechanical properties of Al–9%Si alloy cast in investment shell moulds depend on the shape, size and size distribution of α-Al grains, silicon particles and Al_2Si_2Sr and β-Al_5SiFe phases on the surface of the test samples. The increase in mechanical properties consists of two parts:

- the breakage of the elongated primary α-Al grains into more uniformly distributed α-Al grains by refinement
- the plate like eutectic silicon to fine broken particles of silicon.

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