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Effect Of Grain Refiner On Microstructure Of Semi-Solid A356 Aluminium Alloy

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Abstract. Grain refining has been studied in the semi-solid-metal (SSM) casting by addition of master alloy Al-5Ti-1B using inclined slope. A356 aluminium alloy was melted at 850 ºC and poured at 660 °C on the inclined slope into the steel mould. Grain refiner was added in various percentages of 0.2%, 0.5% and 1.0% in A356 aluminium alloy melt. Microstructure and microhardness were characterized using optical microscope and Vicker's microhardness tester. The addition of master alloy Al-5Ti-1B not only refined but also increased the globularity of the primary α-Al particles. The higher hardness was achieved with 1% addition of master alloy Al-5Ti-1B.

Introduction

Semi-solid metal (SSM) casting offers distinct advantages over other near-net-shape manufacturing processes as it provide short cycle of the production, good microstructures and properties [1]. Application of inclined plate in the casting processes is a simple process with low equipment cost, which is able to produce feedstock materials for semisolid processing. In the semi-solid-metal processing of Al–Si alloys, the size of the primary α-Al grain plays an important role not only on the final mechanical properties but also on the rheological behavior during mold filling. Most of the alloying elements reduce the size of α-Al grains, but the effective way of reducing the size of grains is the application of grain refiners. Finer grains ensure better mechanical properties, improved machinability, better feeding, silicon morphology changes from flake to fibrous, resulting in improved mechanical properties [2, 3, 4, 5]. Addition of grain refiners to molten aluminum is the most practical and economic casting. In this work the effects of grain refiner on the microstructural evolution and microhardness of A356 aluminium alloy was investigated.

Experimental Method

Commercial A356 aluminium alloy with chemical composition determined by X-Ray Fluorescence as shown in Table 1 was used as experimental materials. A356 aluminium alloy was melted in graphite crucible using electrical melt furnace at 850 ºC. The melt then were allowed to cool to the pouring temperature of 660 ºC before poured into steel mould. The pouring temperature is below the liquidus temperature (obtain from the DSC data of A356 aluminium alloy). The inclined slope casting process was employed in order to produce globular structure. The inclined slope was made from mild steel because the adhesion easily occurred if the thermal conductivity is too high. The inclined slope was tilted at an angle of 45° and the length was fixed at 60 cm. Grain refining was carried out by incorporating Al-5Ti-1B master alloys with various percentage of 0.2%, 0.5% and 1.0% into the melt, which consist of $TiAl_3$ and TiB_2 particles prior cast the SSM slurry. The microstructure evolution and microhardness was studied using optical microscope and Vicker's microhardness tester.

Table 1: Chemical compositions of A356 alloy

Composition	Results (wt%)
Mg	0.1704
Al	93.9702
Si	5.3745
Fe	0.2032
Cu	0.0629
Zn	0.0238

Results and Discussion

Microstructures

Fig.1 shows the optical micrographs of A356 aluminium alloy with various addition of Al-5Ti-1B master alloy. As shown in the micrographs, the well-rounded semi-solid structure is achieved using semi-solid casting process. Fig. 1(a) shows that the microstructure without refiner is fully columnar (dendritic). With the addition of 0.2% Al-5Ti-1B master alloy, A356 alloy shows response towards grain refinement with structural transition from dendrite structure to equiaxed structure of α-Al as shown in Fig. 1(b). The presence of more potent nuclei in the system is the main reason for this transformation. With the increasing amount of addition of Al-5Ti-1B master alloy (0.5 and 1.0%), the structure is not only refined but also the globularity of α-Al particles increased as shown in Fig. 1(c) and (d). Fig. 2 shows the average grain sizes of primary Al with and without the presence of grain refiner. The highest average grain size of 57.4 was attained for the A356 aluminium alloy without grain refiner. With addition of 0.2% and 0.5% Al-5Ti-1B the average grain size reduced to 36.2 and 40.87. The lowest average grain size of 34.71 was achieved with 1.0% addition of Al-5Ti-1B. The grain sizes became much smaller and finer with higher addition of Al-5Ti-1B master alloy. When master alloy of Al-5Ti-1B was added in the A356 aluminium alloy melt, Al_3Ti particles and fine TiB_2 particles will be formed [6]. Thus it increases the potential nucleants in the melt and encouraged the formation of many α-Al particles which result in small grain size of α-Al.

Microhardness

Fig. 3 shows the microhardness of A356 aluminium alloy with and without addition of grain refiner. Without addition of grain refiner, the hardness of A356 aluminium alloy was 53.08HV. However, it was observed that there is an enhancement in hardness of A356 aluminium alloy with the addition of 0.2, 0.5 and 1.0% of Al-5Ti-1B master alloy. The hardness value recorded was 65.7, 64.4 and 69.5HV, respectively. This is due to the change in the microstructure of the alloy. The mechanical properties of Al-Si alloy depend on the shape, size and of α-Al globular grains and eutectic Si [3]. As the grains become finer, the hardness of A356 aluminium alloy increased.

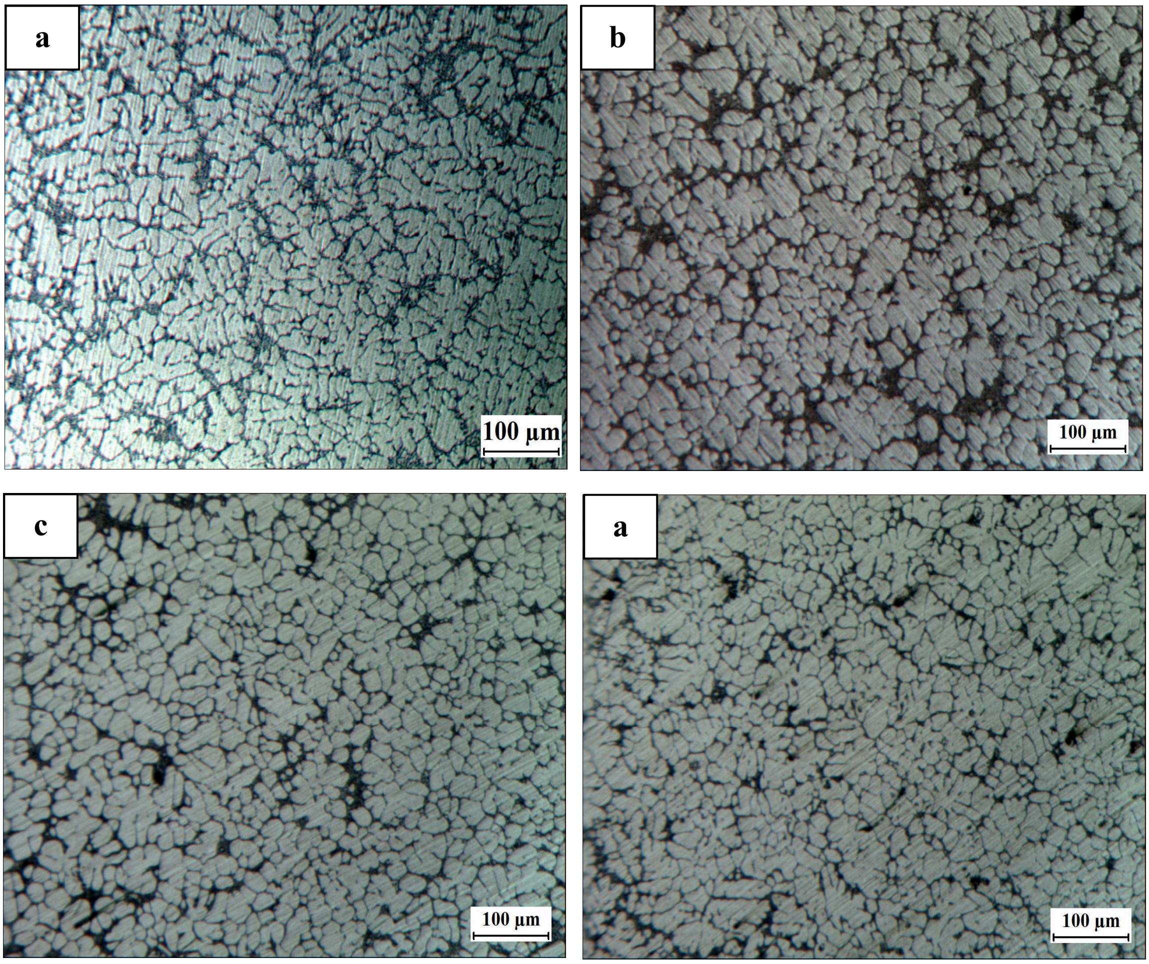

Fig. 1: Optical micrographs of A356 alloy (a) as semi-solid cast alloy; (b) with 0.2% TiB_2; (c) with 0.5% TiB_2 and (d) with 1.0% TiB_2

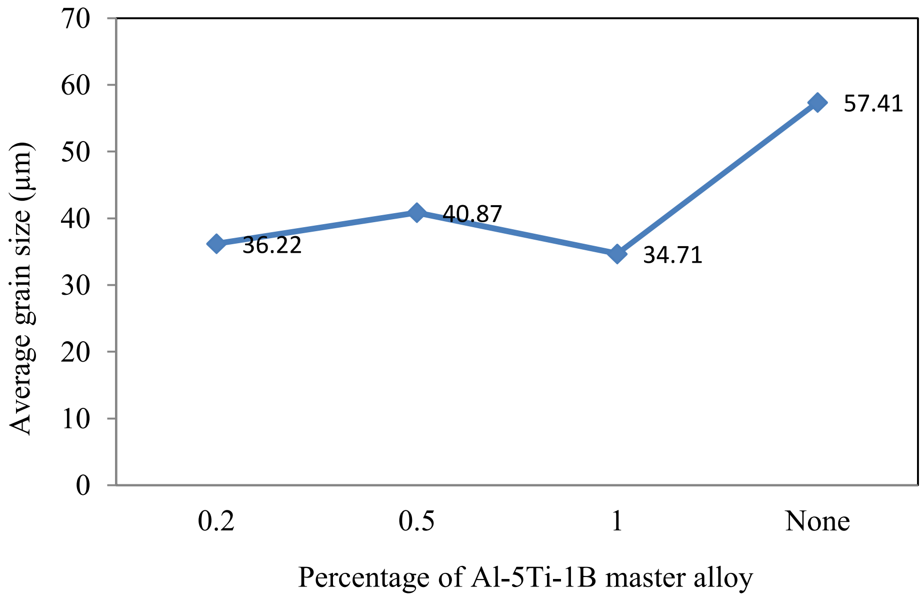

Fig.2: Average grain size of primary Al with and without the addition of grain refiner Al-5Ti-1B master alloy

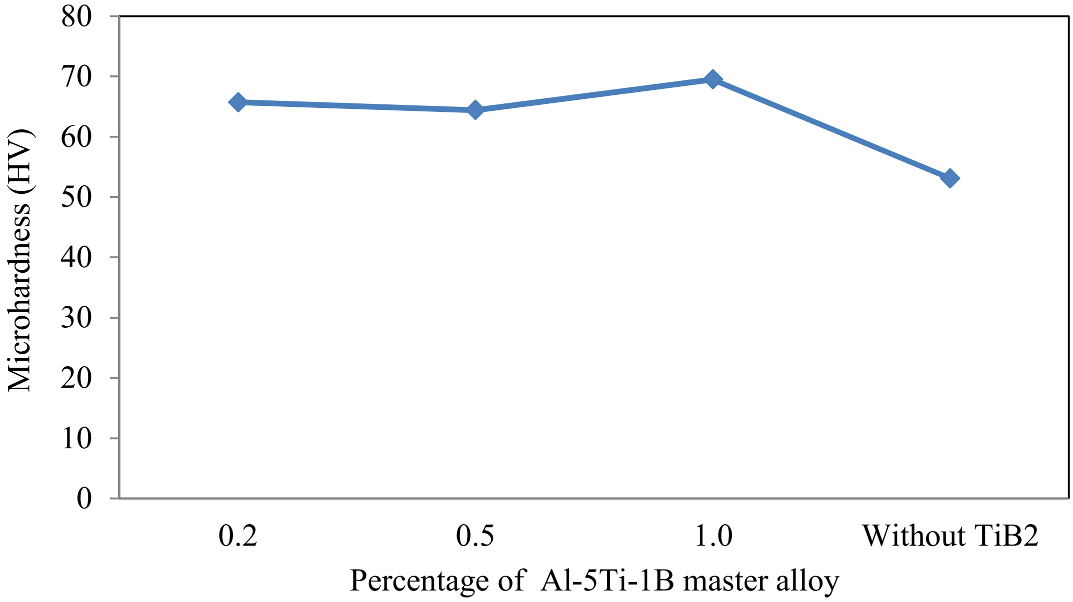

Fig. 3: Microhardness of A356 alloy with and without the addition of grain refiner Al-5Ti-1B master alloy

Conclusions

The microstructure of A356 aluminium alloy was refined and the globularity of the primary phase of α-Al increased with addition of grain refiner. The smallest grain size and the highest hardness of the alloy was achieved with addition of 1% Al-5Ti-1B master alloy.

Acknowledgments

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