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Al-5Ti-B가 레오로지 소재의 미세조직에 미치는 영향

양자오 [1], 서판기 [1], 강충길[#]

Effect of Al-5Ti-B on the Microstructure of Rheology Material

Z. Yang, P.K. Seo, C.G. Kang*

Abstract

Semisolid A356 slurries were prepared by electromagnetic stirring casting and by inoculation of Al-5Ti-B master alloy. As stirring time and addition of Al-5Ti-B are different, the grain size of the primary phase is different. Through the experiment of rheocast in a Buhler horizontal die casting machine, it was found that the finer the equiaxed primary dendrites, the smoother the die filling and better cast quality. Small equiaxed primary dendrite also results in less liquid segregation on the surface.

Key Words : Semisolid metal processes, Rheocast, A356 aluminum alloy , liquid segregation, mechanical property.

1. Introduction

Because of its excellent die filling character, the semisolid die casting process has attracted widely industrial interests and has been regarded as one of the promising near net-shape metal forming processes to manufacture automobile parts, computer parts, and other complex shape products [1-3]. However, the present commercial semisolid metal processes are much more expensive than traditional squeeze casting and high-pressure die-casting. Therefore semisolid metal die-casting is still struggling to gain more shares from the foundry market.

In recent year, many cheap ways to manufacture semisolid slurry have been developed [4-6]. Though these semisolid slurries have similar particle size and similar roundness with those. obtained by MHD stir cast, evidences show that grain size of the primary phase varies greatly in different semisolid slurries [7,8]. All of these semisolid slurries can be successfully cast. Nevertheless, the castibility of different semisolid slurries differs.

Al-5Ti-B master alloy is a commercial grain-refiner. Investigation of the effect of Al-5Ti-B alloy on the rheocast of A356 alloy is of great research value. It not only can change the grain size of the semisolid slurry, but also change the component of the A356 alloy [9]. In the current research, the effect of Al-5Ti-B on the microstructure of rheocast A356 alloy was investigated.

2. Experiments

A standard commercial A356 aluminum alloy was used in this work. The components of the alloy were Si 7.06%, Cu 0.03%, Mg 0.30%, Zn 0.03% Ni, 0.01%, Mn 0.01%, Fe 0.13%, Ti 0.12% Pb0.07% Sn 0.02% and Al balanced in weight percent. Based on DSC determination at the cooling rate of 0.1K/s, the solidus and liquidus of

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[1]. 부산대학교 정밀기계공학과
[#]. 부산대학교 기계공학부, cgkang@pusan.ac.kr:

A356 are 547 ℃ and 617 ℃, respectively. Based on the microanalysis, the volume percentage of the primary phase is 56%. The master alloy is a commercial Al-5Ti-B alloy.

The EMS system uses a three-phase six-pole electromagnetic stirrer, which creates a horizontal stir. The unloaded magnetic induction is about 0.075 T when the input current is 60 A. Molten A356 alloys with and without addition of Al-5Ti-B master alloy were prepared separately. After primary treatment, 1.5 kg of molten A356 alloy was poured into a stainless steel (304) mould with an inner diameter of 80mm and a thickness of 3mm. Electromagnetic stirring was started immediately after pouring. The stirred cooling process can be separated into four steps: pouring, stirred cooling, ripening holding, and die-casting. A Buhler 42 horizontal die-casting machine carried out the semisolid die-casting.

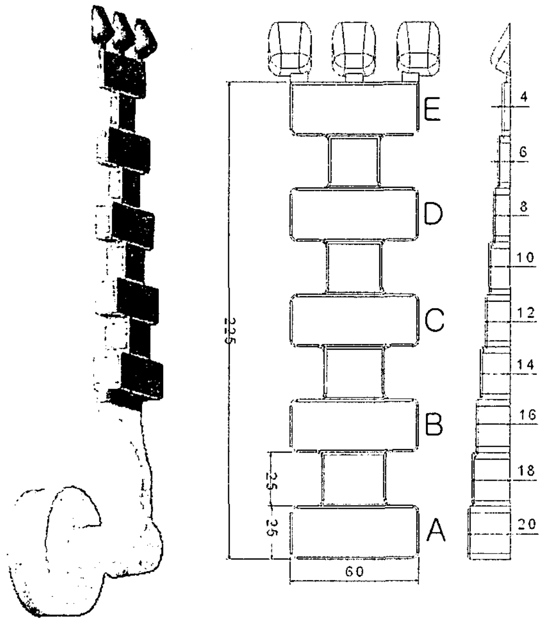

Fig. 1 Shape and size of the specimen

The cavity is a long and narrow 9-step straight cavity with five pairs of side arms extending out symmetrically at the odd steps. From the gate to the over-flow, the side arms were named as Parts A through E, respectively. This design is aimed at investigate the die filling character of long parts with the rib, side branches, and other appendix parts. A large gate size usually has a good filling character. However, in order to avoid the influence of grain size being masked by the effect of large gate, a small gate was used in the current experiment, as shown in Fig. 1.

The injection velocity of the plunger is accelerated to 1.2 m/s before the metallic semisolid flow enter the runner. And the injection velocity was adjusted to target velocity during the cavity filling stage. It includes 0.3, 0.7 and 1.2 m/s.

Metallographic samples of the thixocasting parts were ground and polished until the microstructure could be clearly observed with an Olympus BX60M microscope. Macrostructure of the rheocast parts were observed by Olympus stereomicroscope aided by color etching.

3. Results and Discussions

Fig. 2 and 3 show the microstructure of the semisolid slurry stirred cast under a rotating magnetic field of 0.075T using A356 molten metal without and with addition of Al-5Ti-B, respectively. It can be seen in both cases that grain size decreased as the stirring time prolonged. It is surprising to find that the combination of stirring and addition of Al-5Ti-B does not improve the grain refinement. On the contrary, abnormally coarse primary phase occurs in the stirred cooled a356 alloy that was inoculated by Al-5Ti-B [9].

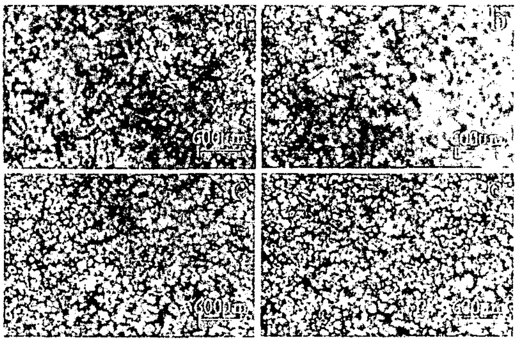

Fig. 2 Microstructures of the semisolid A356 slurries. The magnetic field is 0.075T, the stirring times are (a) 0 s, (b) 10 s, (c) 20 s, (d) 40 s. The pouring temperature is 675 ℃.

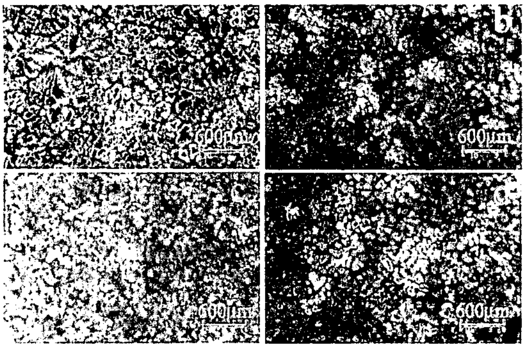

Fig. 3 Microstructures of semisolid A356 slurries inoculated by Al-5Ti-B. The magnetic field is 0.075T, the stirring times are (a) 0 s, (b) 10 s, (c) 20 s, (d) 40 s. The pouring temperature is 675 ℃.

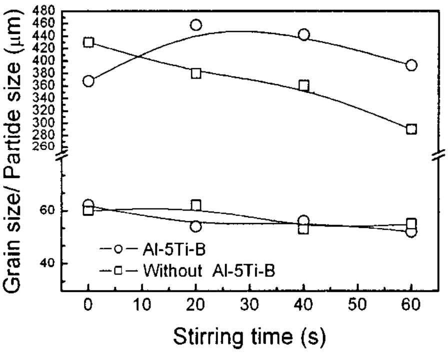

Fig. 4 Grain size and particle size of the primary phase of semisolid slurry stirred cast using A356 molten alloy with and without inoculation.

Fig. 4 shows statistical data of the grain size and particle size as a function of stirring time. It can be seen that the grain size completely differs from particle size. Because grain size is inversely proportional to nuclei number, it is greatly influenced by stirring time and dendrite fragmentation. However, particle size is the size of the disfigured dendrite arm. It is mainly influenced by interception length of the dendrite arms. Therefore, particle size is usually inversely proportional to cooling rate. Because the cooling rate in this experimental is nearly the same, the particle size in Fig. 4 is nearly the same. However, as the stirring time increased the grain size of the primary phase decreased. These semisolid slurries with similar particle size, but different grain size give us an opportunity to distinguish the effects of grain size and particle size.

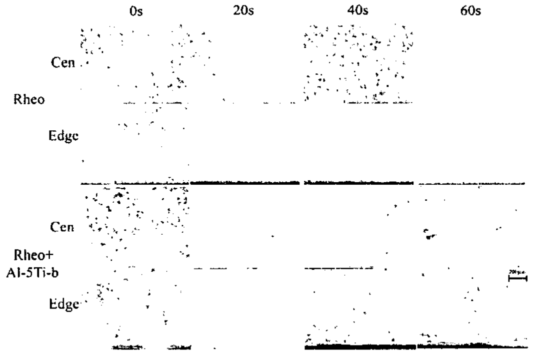

Fig.5 Microstructures of the rheocast structure injected using different semisolid slurries at an injection velocity of 1.2 m/s.

Fig. 5 and 6 show the microstructure of the parts rheocast by the Buhler 42 horizontal die-casting machine using the semisolid slurries illustrated in Fig.2 and 3. Fig. 5 shows the rheocasting structure injected at 0.3 m/s using the semisolid slurries stirred for different times, it can be seen that the thickness of the liquid segregation on the surface of the sample changes as the stirring time changes. If carefully compared with Fig. 4, it can be found that the large the grain size of the primary phase, the thicker the liquid segregation. In Fig. 4, the maximum grain size occurs in the semisolid slurry inoculated by Al-5Ti-B and stirred for 20s. The greatest liquid segregation also occurs in that condition. This means that large grain size results in a thicker liquid segregation.

Fig. 6 shows the microstructure of the rheocasting structure injected at different velocities using the semisolid slurries stirred in a rotating magnetic field of 0.075 T for 60s. It can be seen that the thickness of the liquid segregation on the surface of the sample increased as the injection velocity was increased.

It can be found that die filling process did not change the morphology of the primary phase in the center of the die casting parts. However, microstructure at the surface of the sample changed greatly as the grain size changed.

Fig. 7 shows the surface quality of the samples injected at a velocity of 1.2 m/s using the semisolid

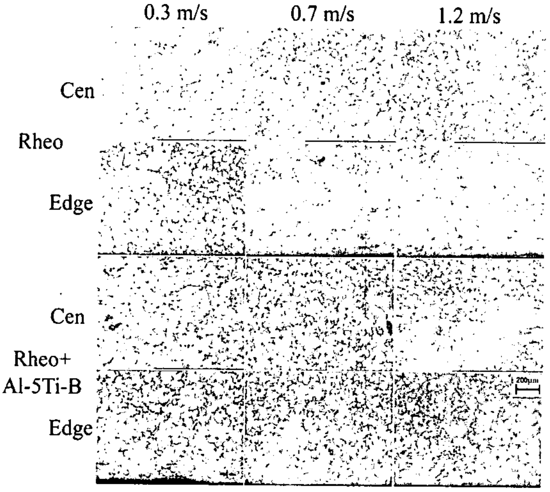

Fig. 6 Microstructures of the rheocast structure injected at different injection velocity using the semisolid slurry stirred under the magnetic field of 0.075 T for 60 s.

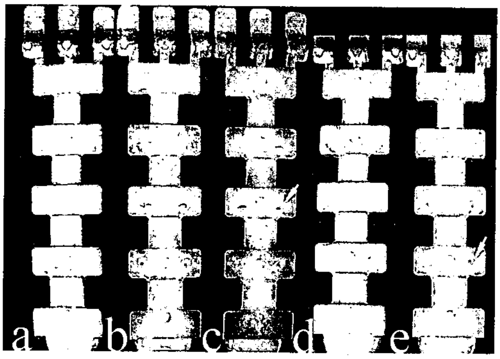

Fig. 7 The surface quality of the rheocast part using the semisolid slurry stirred for (a) 0 s, (b) 10 s, (c) 20 s, (d) 40 s, (e) 60 s. The A356 alloy was inoculated by Al-5Ti-B

slurry inoculated by Al-5Ti-B and stirred for different times. The samples with 0s and 60s stirring have a better quality than the other samples. By comparison between Fig. 4 and Fig. 7, it can be found that that finer primary phase has a better die filling character. This phenomenon can be explained as that the small primary phase has a better fluidity. In the high velocity injection, turbulent flow usually cause infilling. If the fluidity of the semisolid slurry is good, the flaw will be sealed as the case in Fig.7a and Fig. 7e. If the primary phase is coarse and the fluidity of the semisolid slurry is bad, the flaw will remain.

4. Discusuion

It is found that grain size of the primary phase of the semisolid slurry was decreased by long time stirring. However, it is found that the combination of short time stirring and addition of Al-5Ti-B leads to a abnormally coarse primary phase. Through the experiment of rheocast in a Buhler horizontal die casting machine, it was found that the finer the equiaxed primary dendrites, the smoother the die filling and better cast quality. Small equiaxed primary dendrite also results in less liquid segregation on the surface.

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