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In-line Degassing Treatment of A356 Alloy using the Electromagnetic Melt Transferring Pump

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The dissolution of hydrogen gas in liquid aluminum has been assumed to be a significant issue for the production of high quality aluminum castings. It is well known that the dissolved hydrogen in melts is the major cause of porosity in aluminum castings and accordingly degrades the properties of the aluminum castings. The dissolved hydrogen gas can be removed from the melt successfully by means of inert gas purging method using such as lance, porous plug and rotary impeller. Recently, new techniques for transferring of the molten metal into the casting mold directly by means of the electromagnetic force have been developed. The electromagnetic melt transferring pump is consisted of the channel, crucible and electromagnet. The molten metal is circulated continuously in the channel and crucible by the electromagnetic force during the process. Therefore, new degassing techniques are required for the electromagnetic melt transferring pump. The position of the gas purging equipment, the shape of impeller and the mode of melt circulation can affect the effectiveness of the removal of the dissolved gas in the melt. In this paper, the degassing treatments have been performed under the various parameters and the results have been examined.

Keywords: *casting, A356, electromagnetic pump, degassing, hydrogen content*

1. Introduction

It is widely accepted that hydrogen gas dissolution in liquid aluminum is the most significant problems facing aluminum foundry industries. The dissolved hydrogen in melts is the major cause of porosity in aluminum castings and accordingly degrades the properties of the aluminum castings [1, 2]. Thus, the removal of the dissolved hydrogen in the molten aluminum alloy is critical for the production of high quality castings. The dissolved hydrogen gas can be removed from the melt by means of inert gas such as argon and nitrogen gas purging method using lance, porous plug and rotary impeller. Among them, rotary impeller is most successful since the size of inert gas bubble is small and the distribution of the bubbles is uniform in the melt.

Recently, new techniques for transferring of the molten metal into the casting mold directly by means of the electromagnetic force have been developed. The electromagnetic melt transferring pump (EMTP) has an induction channel consisting of three branches (Fig.1). In the bottom, these branches are connected with each other; in the top, they are connected with crucible comprising liquid metal bath. In the windows of channels, there are located inductors with windings. The place of crossing the lower horizontal area with a vertical branch is located between the poles of electromagnet. Such design makes possible to create some variants of melt circulation. It is achieved by different variants of switching on the electromagnetic systems (two inductors and electromagnet). At any variant, the melt transferring speed can be regulated in wide limits. *Pumping mode* is realized when melt moves from bath (crucible) to the mouths of lateral branches of induction channel and flows out through the mouth of central branch of channel as the submerged jet (Fig.2). Vice versa, in the *in-taking mode*, melt moves from bath to the mouth of central branch of induction channel, and flows out in bath through the mouths of lateral branches of channel as two submerged jets. Lateral stirring of melt (*holding mode*) is realized when liquid metal moves from bath both to the mouth of one of lateral branches and mouth of central branch, and flows out as the submerged jet through the mouth of other lateral branch. These modes are symmetric, and they are arrived by the connecting of inductors in the anti-phased mode. At that, directions of created electric currents in the central branch of channel are coincided. Direction of melt circulation is changed by the reverse of the electric phases supplying electromagnet. Thus, the EMTP can be used for mixing, holding and pouring of the alloy directly to various types of casting such as gravity, die, pressure and continuous castings.

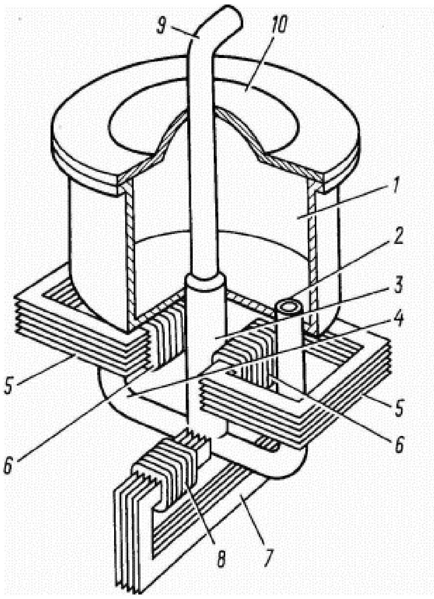

Fig. 1 Schematic drawings for the electromagnetic melt transferring pump. (1 crucible; 2, 3, 4 induction channels; 5 magnetic core of inductor; 6 winding of inductor; 7 magnetic core of electromagnet; 8 winding of electromagnet; 9 metal duct; 10 cover)

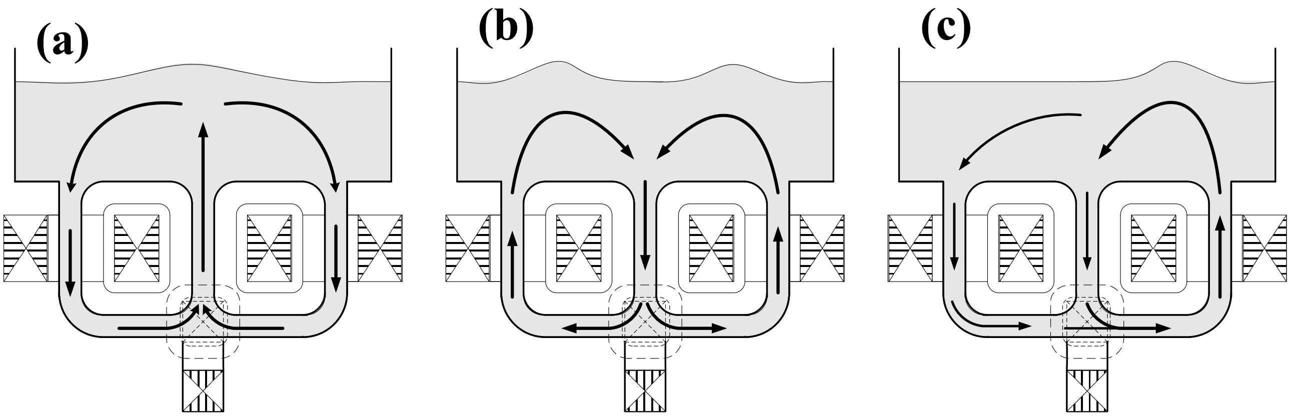

Fig. 2 Mode of melt circulation in the EMTP.
(a) pumping mode (b) in-taking mode (c) holding mode

In the EMTP the molten metal is circulated continuously in the channel and crucible by the electromagnetic force during the process. Therefore, new degassing techniques are required for that installation. The position of the gas purging equipment, the shape of impeller and the mode of melt circulation can affect the effectiveness of the removal of the dissolved gas in the melt. In this paper, the degassing treatments have been performed under the various parameters and the results have been examined.

2. Experimental

2.1 Degassing treatment

Several schemes of the degassing treatment (Table 1) were performed for A356 alloy in the EMTP installed in Dongsan Tech., Co. Ltd. The capacity of the installation is 630kg of aluminum melt and the maximum melt transferring speed is ~10kg/sec. When the temperature of the molten aluminum reached to 730°C, degassing treatment was performed for 15~20minutes using gas purging apparatus. After finishing the degassing treatment, the melt was held for more than 60 minutes and the reduced pressure test (RPT) was performed every 20 minutes.

Table1. Schemes for degassing treatment in EMPT.

Scheme	Mode of circulation	shape	position	remarks
A	-	-	-	holding of degassed melt
B	pumping/in-taking	tube	central mouth	
C	holding	tube	lateral mouth	
D	pumping	rotary impeller	central mouth	
E	pumping	special shape impeller	central mouth	

2.2 Measurement of the hydrogen content

The RPT was used to determine the hydrogen level of the melts. Thin-walled iron cup was used to sample the molten alloy. The RPT test was performed under a reduced pressure of 50mm Hg. The densities of the RPT samples were measured.

It is well known that the true hydrogen content of A356 alloy is always significantly higher than that calculated from the density of RPT samples [3-5]. In the experiment, hydrogen content was evaluated using a calibration curve for converting the density data into hydrogen content data. Fig.3 shows the correlation between the density of RPT samples and the hydrogen content measured by Telegas method using Alscan-F manufactured by ABB Bomem. In the figure other researcher's results were replotted and the results of Xu et al [6] and Gruzleski et al [3] are well coincided with that of this investigation for the density more than 2.5g/cm^3.

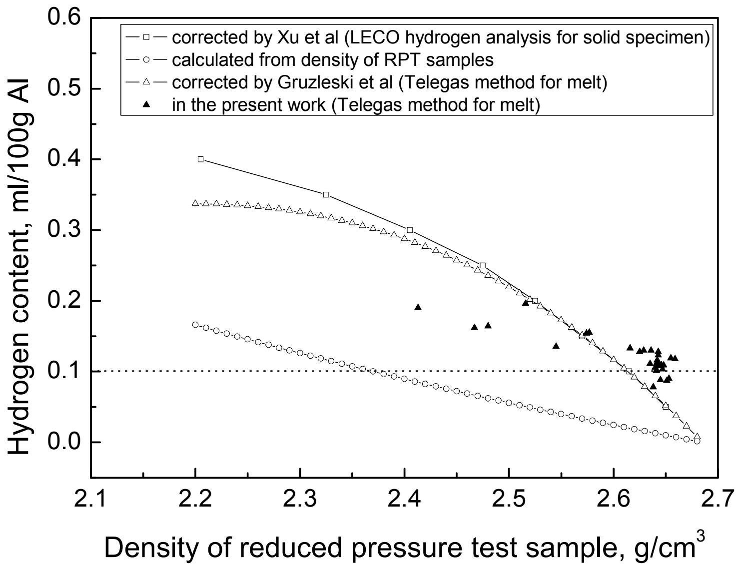

Fig. 3 Correlation between hydrogen content and the density of RPT samples.

3. Results and discussion

3.1 Holding of the degassed melt

In the first scheme the degassed melt was poured into the EMTP and the variation of hydrogen content was examined with the melt holding time. Fig. 4 shows the variation of the density of the RPT samples with holding time of the melt in the EMTP. It can be shown that the degassing effect is well maintained during holding the melt in the EMTP for more than 1 hour.

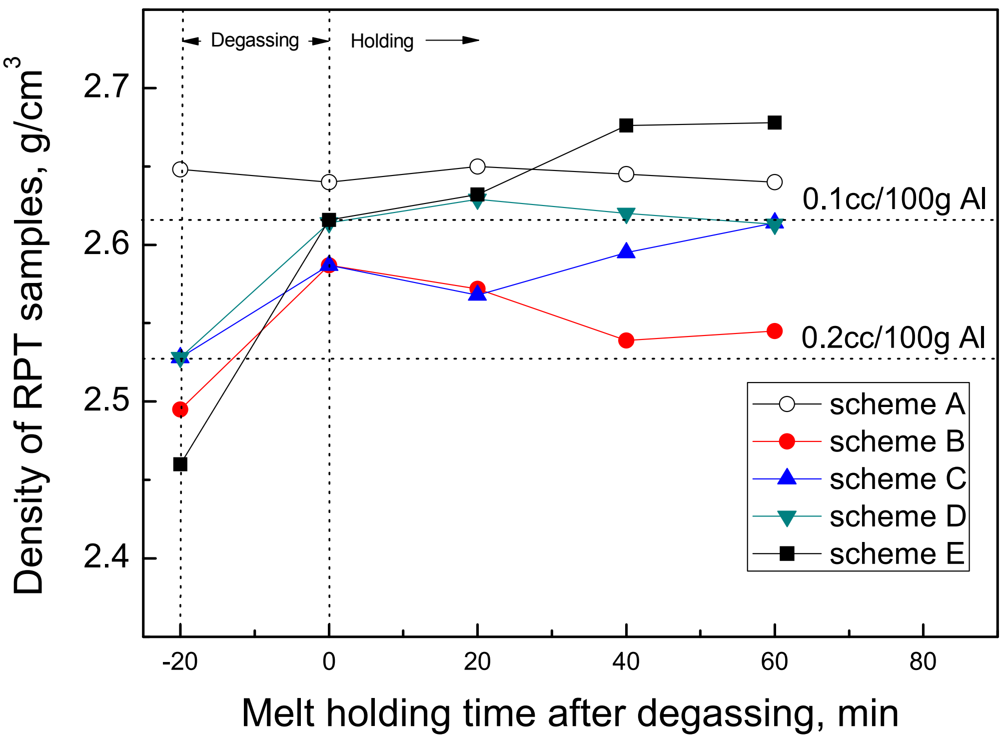

Fig. 4 Variation of density of RPT samples with melting holding time before and after degassing treatment for various schemes.

3.2 Effect of melt circulation

It is well known that the effectiveness of hydrogen removal from the melt depends on the size and distribution of inert gas bubbles in the melt. In the EMTP the melt is circulated continuously in the channel and crucible by the electromagnetic force during the process. The circulation mode of the melt can affect the size and distribution of gas bubbles. At purging of gas under the in-taking or holding mode of the melt it was not succeeded to get shallow bubbles on the surface of liquid metal. It was confirmed that the distribution of the bubble was not uniform throughout the melt. In addition, the sound of gurgle was audible and the pointer of ampere meter was oscillating during the process (Fig.5 a). This is due to the pinch-effect of bubble under the magnetic field in the channel. When electromagnetic power was turn off, the large bubbles were emerged in the surface of the melt.

While gas was purged under the pumping mode the distribution of bubble became uniform throughout the melt and the pinch-effect did not occur. Thus, the effectiveness of the hydrogen removal becomes better than other circulation mode (Fig. 4).

3.3 Effect of shape of gas purging apparatus

The finer the size of bubble, the surface area increases and accordingly the efficiency of hydrogen removal increases. For more than decades the researches have been focused on the refining of the bubble through improvement of the shape of gas purging apparatus. In this experiment three types of gas purging apparatus - simple tube, rotary impeller and special shape impeller – were used under the pumping mode of the melt circulation. In the case of simple tube, the size of the purging gas is so big thus the resultant bubbles did not refine in the melt and the effect of hydrogen removal did not reveal. We performed the same experiment with rotary impeller which is widely used in the casting industry. The rotary impeller has 8 radial grooves on the bottom. During the degassing treatment the impeller was fixed on the central mouth of channel without rotation. On the surface of melt the evenly distributed bubbles were popped up during the process, however, the size of bubble was somewhat bigger in the range of 15-20 mm by visual estimation (Fig 5 b). The effectiveness of hydrogen removal became similar to that of holding the degassed melt (Fig.4). To refine the size of bubble more, we made special impeller which is suitable for EMPT. When the melt was degassed with the special shape impeller putting in the mouth of channel, the size of bubble became much finer less than 1mm (Fig. 6) and the effectiveness of hydrogen removal became better than that of holding the degassed melt in the EMPT.

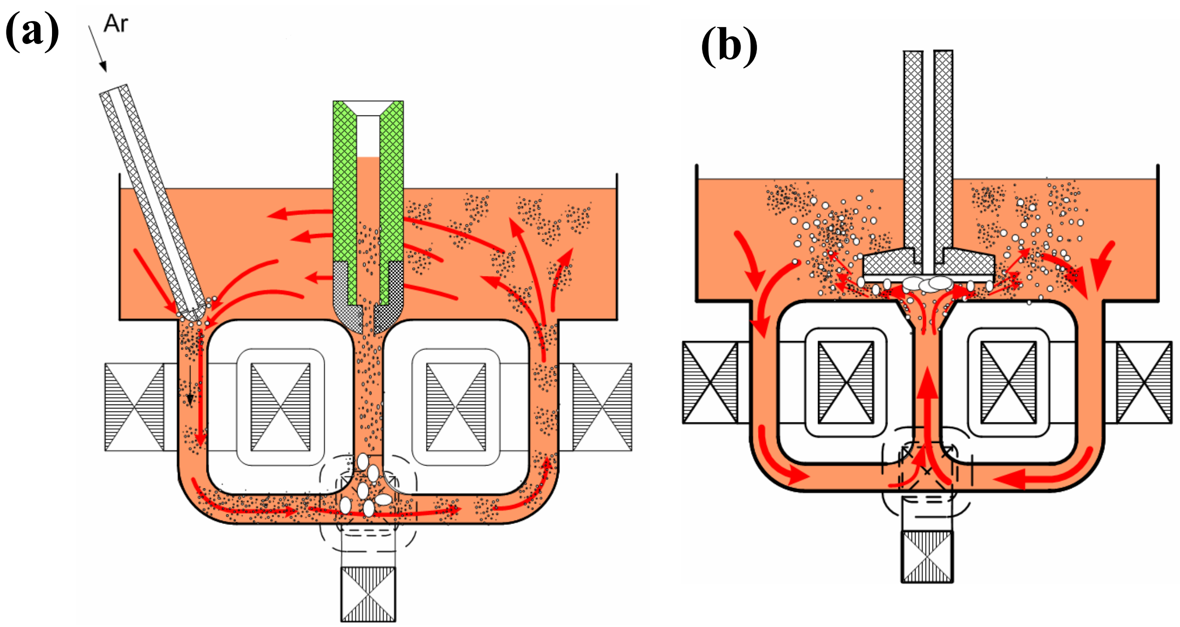

Fig. 5 Schematics of argon gas blowing by (a) simple tube under holding mode of melt circulation (scheme C) and (b) rotary impeller under pumping mode of melt circulation (scheme D)

4. Summary

New degassing techniques which are suitable for the electromagnetic melt transferring pump are developed. The mode of melt circulation and the position and the shape of the gas purging apparatus affected the size and distribution of gas bubbles, and accordingly the effectiveness of the removal of the dissolved gas in the melt. Successful degassing effect was obtained using special shape impeller suitable for the electromagnetic melt transferring pump.

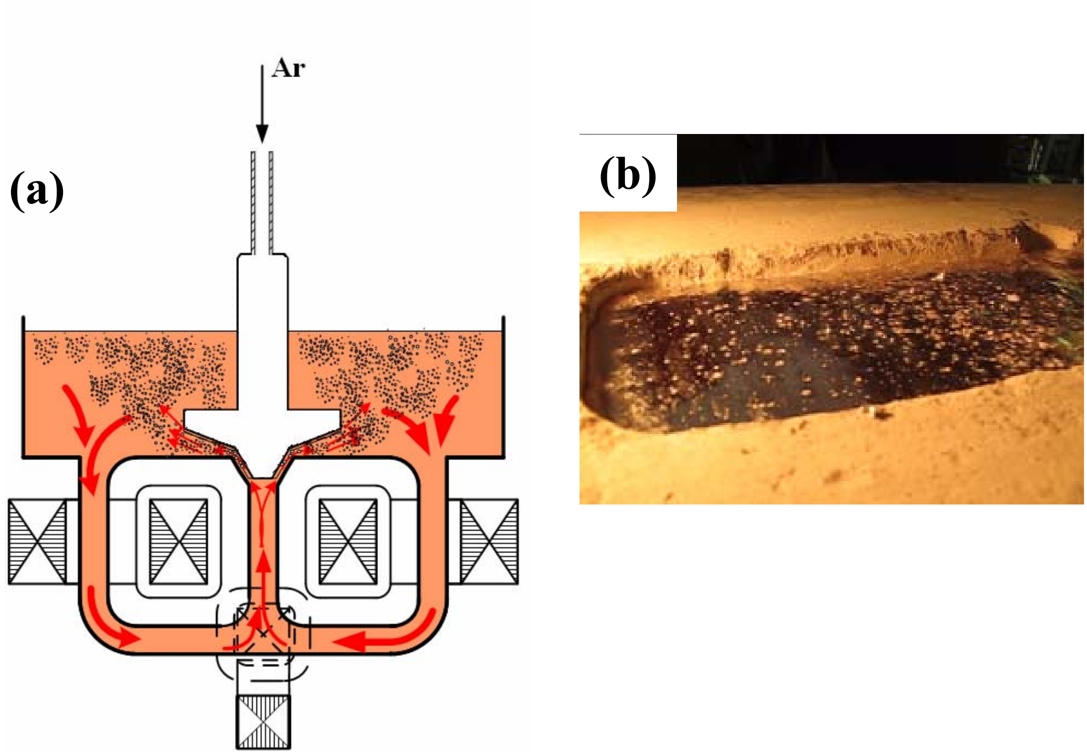

Fig. 6 Schematics (a) and photo (b) of argon gas blowing by special shape impeller under the pumping mode of melt circulation (scheme E)

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