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A Bubble Flotation Process for Purification of A356 Cast Alloy

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ABSTRACT

According to the principle of bubble floatation, purification of A356 aluminum casting alloy has been studied by purging nitrogen gas into the A356 alloy melt through the porous plug which is immerged in the molten aluminum and can generate a large quantity of dispersed micro bubbles to absorb and sweep hydrogen and nonmetallic inclusions to the surface of the melt. 5 samples have been taken at 0 min, 2 min, 4 min, 6 min, 8 min and 10 min, respectively, to measure the hydrogen content through HYSCAN Ⅱ hydrogen tester. The experiments results show that the removing effect of hydrogen is remarkable. The hydrogen contents reach the minimum when purging lasts 10, 8 and 4 minutes for the 280kg, 160kg and 40kg. The inclusions are also removed along with the removal of hydrogen.

Keywords: aluminum cast alloy, purification, bubble floatation

1. INTRODUCTION

Aluminum melt reacts with water vapor and oxygen in the air to form aluminum oxide and hydrogen during the melting and casting process. Defects such as micro pores, pinholes and dross in the casting will be formed because of the inclusions and hydrogen. Mechanical properties of materials will also been seriously deteriorated due to stress concentration around the pinholes and inclusions in the casting. The purpose of purification is to decrease the harmful inclusions and hydrogen to an acceptable level and improve the mechanical performance of the casting. Basically there are two industrial techniques used to perform melt purification in molten aluminum alloys: flotation and filtration. Flotation techniques have been widely used in the metalcasting industry due to this process was effective in reducing hydrogen and inclusion contents in the melt. Bubble floatation is a very efficient purification technology of aluminum melt, in which a hundred and thousand of bubbles were purged into the aluminum melt, the flush of inert gas bubbles brings the inclusions in suspension to the melt top surface. In the present paper, a porous ceramic sprayer was employed to eject dispersed bubbles in order to provide a great number of micro bubbles in the melt. The relationship between purging time and hydrogen contents, along with removal of oxide inclusion, has been investigated with different capacity of the A357 melt.

2. EXPETIMENTS

A356 aluminum cast alloy was employed for experiment material. The chemical compositions of alloy are 7.5% Si, 0.53% Mg and 0.05% Be with aluminum being balance. A burden of 40Kg, 160kg and 280kg was melted respectively in the electric resistance furnace and the temperature of the melt was maintained as 720C for use. The sprayer device comprises a nitrogen gas tank A, a relief valve B, a manometer C, an air filter D, a molecular sieve E, a gas flow-meter F, a porous plug P and some solenoid valves V, as shown in figure 1.

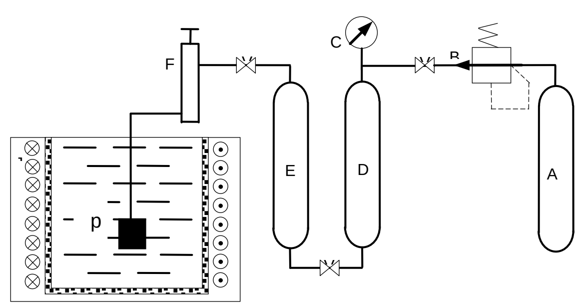


***Figure 1**. The schematic diagram of flotation equipment*

The nitrogen gas in the tank A enters into tank D and E for drying and filtrating to remove water after decreasing the pressure through the relief valve B. The dried nitrogen gas then enters into the porous sprayer via the flow-meter. In this way, the flow rate of the gas can be adjusted accurately. In the experiment, the flow rate was set to $0.2m^3/h$. The samples were taken respectively at 0 min, 2 min, 4 min, 6 min, 8 min and 10 min for measuring hydrogen contents in the melt and 5 tests were performed. The device at our pilot workshop was seen in figure 2. The pressure of nitrogen gas was set to 0.2MPa. Figure 3 showed an immerged sprayer was working with A356 melt in a cast iron crucible. The bubbles can be seen on the surface of the melt.

Figure 2. *Flotation equipment at our pilot workshop*

Figure 3. *An immerged sprayer was working*

Hyscan II hydrogen analyzer by BNF Metals Technology Centre for the UK Light Metal Founders Association was used for measuring hydrogen concentration. A constant mass of the melt (approximately 100 grams) was placed in a chamber and the pressure was reduced rapidly to a predetermined value by a vacuum pump. The chamber and associated vacuum system was then isolated from the pump and the sample was allowed to solidify. As the melt cooled hydrogen was released and its partial pressure was measured by a calibrated Pirani gauge whose output was converted continuously to a digital display of hydrogen contents.

3. RERULTS AND ANALYSIS

The relationship between nitrogen purging time and hydrogen content in A357 melt was shown (a), (b) and (c) in figure 4. It can be seen that hydrogen contents decrease as the purging time increases. The times for minimum hydrogen concentration were about 10 min, 8 min and 4 min for the aluminum melts of 280kg, 160kg and 40kg, respectively. The degassing efficiency was remarkable. The hydrogen contents were decreased by approximately 60% on average for the three capacity of melt.

According to the diffusion theory, the hydrogen removing efficient can be expressed by the mass transfer coefficient K:

$$K=2\cdot\sqrt{\frac{Du}{\pi D_e}} \qquad (1)$$

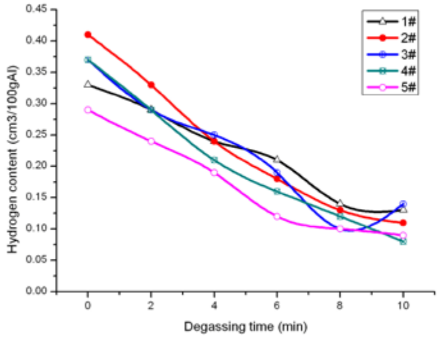
where, D is the diffusion coefficient; u is the rising speed of the bubble and D_e is the equivalent diameter of the bubbles. The hydrogen in the melt will diffuse into the bubble under the partial pressure difference until the hydrogen partial pressure reached balance. During the flotation, the bubbles float, taking with the inclusions to the liquid surface so as to purify the melt.

It can be seen from the equation (1) that hydrogen removing efficient depends mainly on the diameter of the bubble. The small the bubble is, the higher hydrogen removing efficient is.

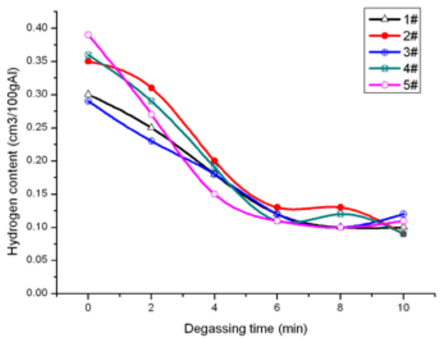
As the hydrogen concentration difference between the melt and the bubble was so tremendous that the degassing speed was fast in the beginning period. With the increasing of the purging time, the hydrogen content continue to decrease but the speed was slow down due to the less hydrogen concentration difference between the melt and the bubble. From the figure 4, the hydrogen content reaches the minimum value at 10 min, 8 min and 4 min for the capacity of 280kg, 160kg and 40kg melt, respectively, with the hydrogen being near to 0.1ml/100gAl.

Under ordinary melting conditions a wide variety of inclusions can be found in an aluminum melt. However, most inclusion is aluminum oxide which is usually present among the interdendritic as flake and flocculent, as shown in figure 5. In castings, pore nucleation can be possible to occur primarily at heterogeneous sites which are linked with inclusions.

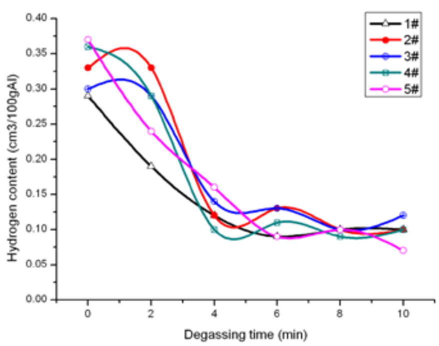
Microstructures before and after melt treatment can be compared in figure 6 in which (a) is before purification and (b) is after purification for the case of 40kg melt. It can be seen that the oxide inclusion (the black) is also decreased drastically.



(a)



(b)



(c)

***Figure** 4 The relationship between degassing time and hydrogen content in A356 melt*

(a) 280kg melt, (b) 160kg melt and (c) 40kg melt

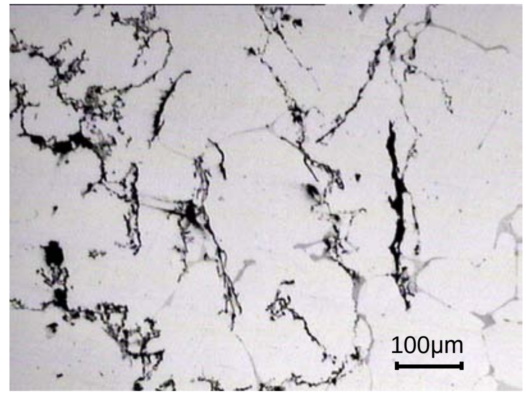
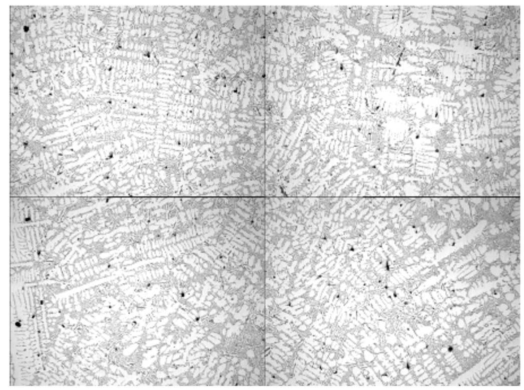
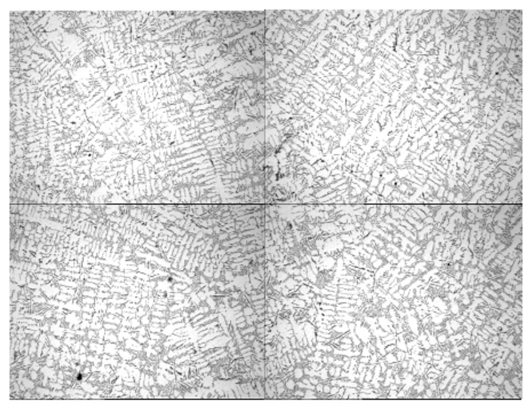


Figure 5. Oxide inclusion in A356 cast alloy



(a)



(b)

***Figure 6** The microscopic image of A356 alloy before and after treatment*

CONCLUSION

A simple method of purification has been proposed. In which, a porous ceramic prayer is immerged into the aluminum melt and nitrogen gas is ejected from the micro holes, dispersed in the melt. Hydrogen contents decrease with the increasing of purging time. At 10,8 and 4 minutes, the hydrogen content get to the minimum for 280kg, 160kg and 40kg melt, respectively. The aluminum oxide inclusion is also decreased drastically.

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