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REMOVAL OF INCLUSIONS IN MOLTEN ALUMINUM BY FLUX INJECTION UNDER COUNTER-GRAVITY

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Abstract

A new process for removal of oxide inclusions in molten aluminum, namely flux injection under counter-gravity, has been presented in this paper. The molten aluminum to be purified is in the lower holding furnace and is covered with the liquid flux. The molten aluminum is first forced to flow upwards into the crucible which is placed in the upper holding furnace through a feeder tube, followed by the molten flux injecting into the molten aluminum by increasing the pressure in the lower holding furnace. In this way, the flux and the molten aluminum are mixed fully to contact each other, resulting in the transfer of inclusions in the molten aluminum towards the flux because of the absorption of the flux to the inclusions. As the result, the molten aluminum is purified. The injection-backflow procedures can be repeated two or three times to acquire better effectiveness. The experiments were carried out for ADC12 die casting aluminum alloy with the flux (40% NaCl，30% KCl，10% NaF and 20% Na3AlF6). The results show that the inclusion and hydrogen concentration can be decrease significantly after two injection-backflow cycles.

Introduction

Nonmetallic inclusions are one of the major defects in aluminum alloy castings. The presence of inclusions can be detrimental to the mechanical properties and corrosion resistance of the castings. Therefore, the inclusions must be removed before the molten aluminum is poured into the mold cavity. Purification of molten aluminum is an important way to improve product metallurgy qualities. Several methods are currently in use to purifying the molten aluminum. These methods include the use of nitrogen or argon or mixture of either of these with chlorine as a purge gas. There are also other techniques such as tablet degassing by using hexachloroethane (C_2Cl_6) or other chloride tablets, vacuum degassing, electromagnetic refining, filtration and ultrasonic degassing, etc [1-6]. Fluxing method was one of the traditional techniques that were first used in purification of aluminum [7]. The principle is the molten aluminum is covered with flux, and the smelting process is under the protection of the flux to protect the melt from oxidation. On the other hand, the inclusions in the aluminum melt will transfer spontaneously into the flux due to the drive of the chemical potential. However, Inclusion removal depends on the number of collisions between inclusions, gas bubbles and the flux, and whether the collisions are successful. Purifying effects are usually weakened greatly by the too little contact or collision between the flux and aluminum melt. Aiming at the limitations for currently used flux methods, a new process for removal of inclusions in molten aluminum, namely flux injection under counter-gravity, is developed

Experiment methods

The apparatus for flux injection is shown in Fig. 1. Where, 1 is the lower holding furnace; 2 and 14 are the heating elements; 3 is the lower crucible; 4 is the molten aluminum; 5 is the liquid flux; 6 is the feeder tube; 7 is the charging door; 8 is the separating plate; 9 is the clamping device; 10 is upper holding furnace; 11 and 12 are inlet and outlet, respectively; 13 is the upper crucible; 15 is the sealing gasket; 16 is the sealing ring; 17 and 20 are solenoid valve, respectively; 18 is the vacuum pump and 19 is the pneumatic pipe.

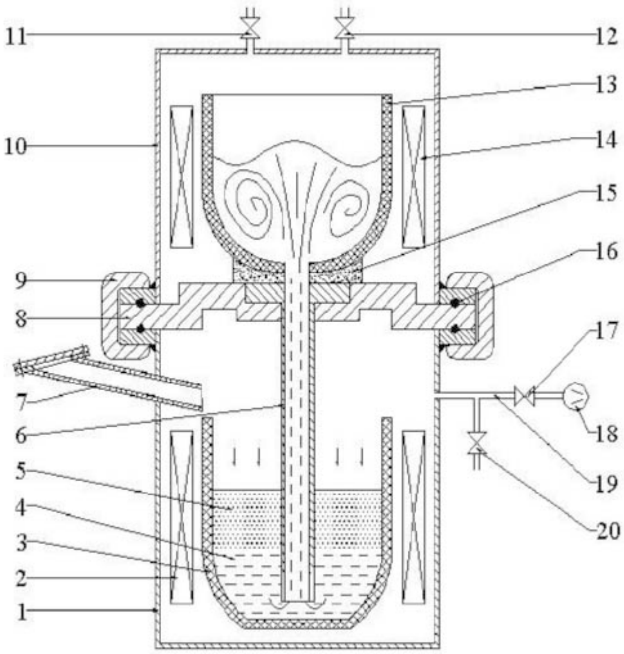


Fig 1. Schematic of flux jet apparatus

The molten aluminum to be purified (4) is in the lower holding furnace (1), and is covered by the molten flux (5). Switch valve (17) on to increase the pressure in the lower holding furnace. The molten aluminum is first forced to flow upwards from the feed tube (6) into the crucible (3) which is placed in the upper holding furnace (10), and then the molten flux injects into the molten aluminum from below and is mixed with the molten aluminum. When the pressure reaches the set value in the lower holding furnace, the valve (17) is switched off and the valve (20) is switched on, the pressure in the lower holding furnace decreases to the same as that in the upper holding furnace. Thus the molten aluminum and flux in the upper crucible will flow back under gravity to return to the lower holding furnace, completing a full cycle. The molten aluminum can be protected from oxidation by inert argon which enters from the inlet (11) and discharged from the outlet (12) at a determined flow rate.
The flux consist of NaCl 40 wt%, KCl 30 wt%, NaF 10 wt% and Na_3AlF_6 20 wt%. ADC12 die casting aluminum was employed for the experimental material. The alloy was fabricated with 100%

secondary aluminum. The alloy contains 3.2 wt% Cu, 11.3 wt% Si, 0.22 wt% Fe, 0.43 wt% Mn, 0.24 wt% Mg and Al as balance. The alloy was smelted at an induction furnace and then was transferred into the lower holding furnace to adjust the temperature to 700℃.

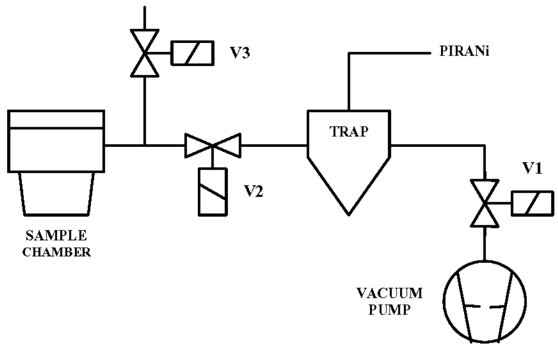


Fig 2. Schematic of hydrogen content tester

HyscanII hydrogen analyzer by BNF Metals Technology Centre for the UK Light Metal Founders Association was used for measurement of hydrogen concentration, as shown in Fig. 2. A constant mass of the melt (approximately 100g) is placed in a chamber and the pressure reduced rapidly to a predetermined value by a vacuum pump. The chamber and associated vacuum system is then isolated from the pump and the sample allowed to solidify. As the melt cools hydrogen is released and its partial pressure is measured by a calibrated Pirani gauge whose output is converted continuously to a digital display of hydrogen contents
Vacuum test was conducted on vac-test-system made by IDECO, Germany. Using the ladle take approximately 200g of liquid aluminum and pour into the crucible that has been placed in the vacuum chamber. The pressure is reduced to 80 mbar and lasts 3 minutes. Metallographic microstructures were used to evaluate the porosity and cleanliness of the sample casting before and after purifying of the molten aluminum.

The results and discussions

Purifying treatments were carried out at 700℃. The samples were taken from the crucible to measure contents of hydrogen and to inspect inclusions after each injection-backflow cycle. The measurements were repeated five times for one injection-backflow cycle. Four injection-backflow cycles were carried out and 20 measurements were done altogether. The hydrogen test results were shown in Fig. 3. It can be seen from Fig. 3 that the hydrogen contents decrease dramatically as the injection-backflow cycles increases. The hydrogen concentration decreased from 0.33ml/100gAl to 0.12ml/100gAl after two cycles, with hydrogen removal rate being 64%.
The previous researches have indicated that hydrogen content has a close correlation with the oxide inclusions in molten aluminum [8]. Hydrogen bubble formation is strongly resisted by surface tension forces; however, oxide is usually nucleation site for hydrogen precipitation. In generally, the oxide inclusion has a rough surface and can't be wet by the molten aluminum. Therefore some existing cavities are present on the surface of the oxide inclusion, which is beneficial to hydrogen bubbles formation heterogeneously.

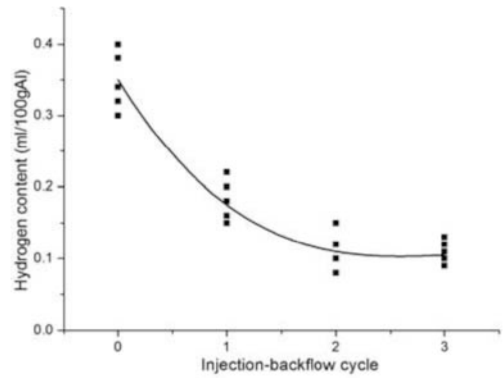
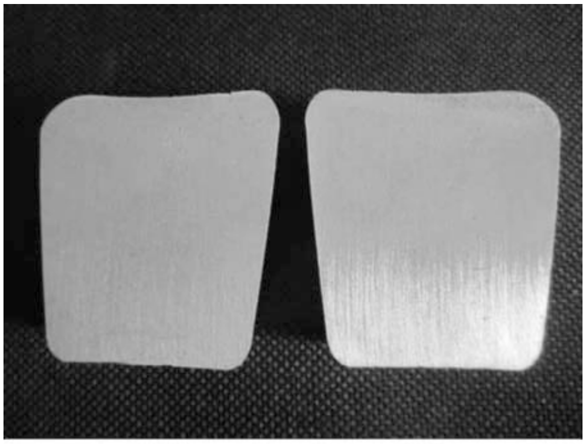


Fig 3. hydrogen content vs injection-backflow cycles

The morphology of samples solidified under vacuum was shown from a to c in Fig. 4. The porous honeycomb-like morphology indicates higher hydrogen content due to precipitation of the hydrogen during solidification of the samples, as shown in Fig.3 (a). As the injection-backflow cycles increase, the porosities of the sample decrease, as shown in Fig.4 (b) and Fig.4 (c).

(a)

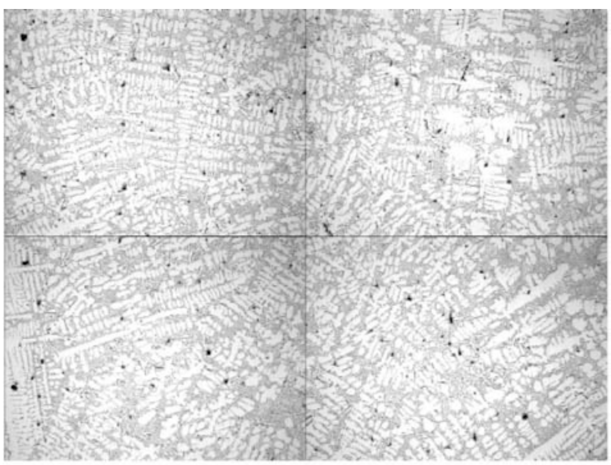
(b)



(c)

Fig 4. The section of samples before and after refining: (a) before treatment; (b) after one treatment and (c) after two treatments

The metallographic images before and after the treatments were shown in Fig. 5. It can be seen that inclusions, mainly in the form of floccules, gathered on the grain boundary, as seen in Fig. 5 (a). By comparison few inclusions were seen in Fig. 5 (b) which was sampled after two injection-backflow cycles).



(a) 100X

(b) 100X

Fig 5. The microstructure of alloy: (a) before treatment; (b) after treatment

Conclusions

A new process for removal of inclusions in molten aluminum, namely flux injection under counter-gravity, has been presented in this paper. The basic principle of this method is that the molten flux is forced to inject into the molten aluminum under counter-gravity, creating strong vortex. The flux and the molten aluminum will be mixed fully to contact each other. In this way, the inclusions in the aluminum will transfer into the flux because of the absorption of the flux to the inclusions. As the result, the molten aluminum will be purified. The experiments were carried out for ADC12 die casting aluminum alloy fabricated from 100% second aluminum (recycled aluminum). The experimental results have shown that after two injection-backflow cycles, the inclusion and hydrogen contents have reduced to a normal level of the die casting.

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