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Hydrogen Degasification performance analysis of Aluminum Alloy Melt and Impact Assessment on Quality of Gravity Die Cast Products

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Abstract –

In any casting plant the melt treatment is the most important process because the effectiveness of the treatment determines the quality of cast product. Effective handling of the molten metal is key to successful casting of the alloy. The amount of an alloying element present in alloy and how the melt is treated, have a considerable impact on the mechanical properties and, consequently, the quality of the castings. The properties of these alloys are dependent on the degree of refinement of the microstructure and melt treatment Generally the molten casting alloy is contaminated with inclusions, oxides, slag, insoluble materials and dissolved gases. For effective treatment various process like fluxing, grain refinement and degasification are performed. The degasification is a process to remove the dissolved gases from the molten material. In this paper influence of various degasification process variables for the removal of hydrogen gas from molten aluminum alloy are investigated through experimental work and the impact of degasification on quality of cast products is examined.

1. Introduction-

In any casting plant, the melting and alloying units are crucial because it marks the beginning of the casting production process.. If the defective melt is used for casting, it results in the form of large number of faults, heavy scrap and significant financial losses for the casting industry. As a result, the most crucial factor in determining the quality of a product in foundries is the monitoring of the chemical composition of melt, the melting process, and melt quality control. Before pouring into the mould, various contaminants like slag, inclusions, oxides, and dissolved gases are eliminated by the process of melt treatment. Dieter et.al [1]explained that fluxing, grain refining, and degasification are the three most significant treatment procedures. Fluxing is done to get unwanted oxides and impurities out of the molten alloy as well as to separate the dross from it.Clark et.al[2].described that homogeneous structure of extremely tiny grain size is required for a smooth surface and good casting appearance. Therefore The objectives of the grain refinement are to refine grain size of primary silicon and homogenize the distribution of Si. Alloys made of aluminium absorb hydrogen from their surroundings. The main sources of hydrogen are –moisture present in atmosphere, oxides of aluminium, Salt fluxes Furnace atmosphere, increase holding temperature. Due to all these sources the high levels of hydrogen are found in aluminum alloys, which lead to flaws such porosity, pinholes, and micro porosity. Degasification is the process of eliminating these dissolved gases.Davis[3] proposed that in order to get rid of the dissolved hydrogen, the melt of the casting alloy is degasified[3] Molten alluminium is extremely reactive , so when it comes in contact with moist air the water decomposes to released hydrogen in the melts which has detrimental effect on the cast product , to control the entrapment of hydrogen gas one should

1. Prevent and minimize introduction hydrogen in the melt
2. Remove the hydrogen before poring

2. Degasification Techniques-

Gas Bubble Filtration (GBF) process is used for removal of hydrogen gas from aluminium alloys. The GBF process removes not only hydrogen gas but also non metallic inclusions such as oxides from the melt by diffusing argon gas bubbles through a rotary diffuser. The hydrogen dissolve in molten material diffuses inside the inert Gas bubble, which floats up to the metal surface at the same time the non metallic inclusions present in the melt are observes into the inert gas bubbles, they are then transfer to the melt surface through this gas bubbles to remove inclusion most effectively. It is essential to diffuse very fin bubbles or to have turbulent mixing of melt GBF treatment forms the finest gas bubble of maximum 4 mm in size. Due to it is finer size of bubbles, this technique is more effective. Because of the pressure of dissolved gas with in inert gas bubble is zero so due to difference in pressure the dissolved gas migrates to the bubbles, collect them and it is fluxed from the melt

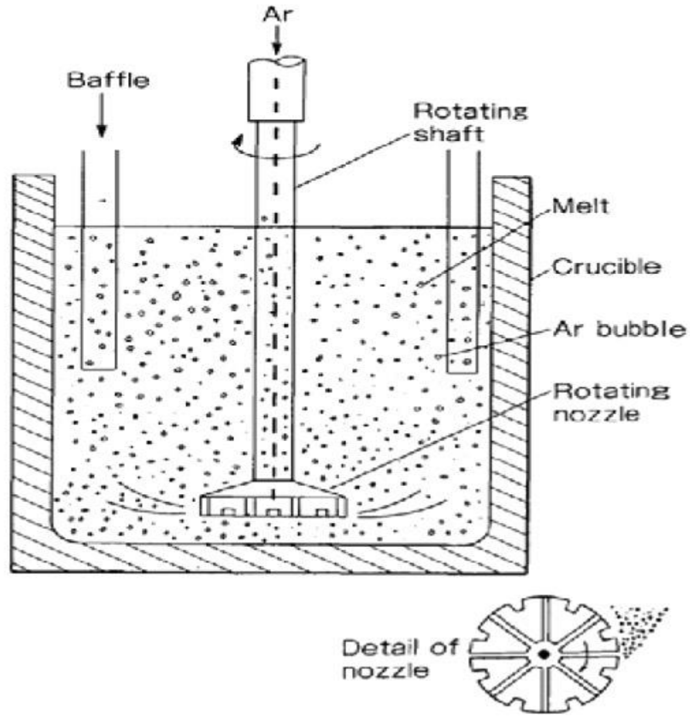


Fig. No 1 GBF Technology

Teng et.al[4] investigated that small purging bubbles are very much effective in removing gases due to larger surface area for a given volume purging gas Mitrasinovic et.al[5] proposed model for online prediction of melt hydrogen and casting porosity level in 319 alluminium alloy Mile et.al [6] concluded that modified structured of silicon from blocky ,acicular and needle like silicon face to a fine fibrous silicon structure, improve the casting properties of alluminim silicon alloy. Ren et.al[7] proposed concept of electromagnetic direction solidification to degasified alluminium alloy .Kotus et.al[8] concluded that casting quality is affected by the chemical composition of melt , casting mold quality and casting production quality . Maneilla E et at[9] studied performance of rotor in water in respect of degasification.

3. Experimental Setup-

3.1 Mobile Degassing Unit

Mobile Degassing unit is used for degassing the molten alloy, the gases are bubbled slowly through the melt. The inert gas is pass through in rotating impeller .The best shaft location is slightly off the center line (50mm - 10mm) of the crucible value to avoid vortex formation. due to its circular location. Hydrogen dissolved in aluminum melt, diffuses into gas bubbles and is carried away towards the top surface. Degassing carried out by skimming of surface drosses and then bubbling the inert gag (argon) through the melt for 6 min. at the rate of 4 to 6 L.P.M. for 225 to 300 Kg. melt at a pressure of 2Kgf/cm²[10].In this arrangement rotor disperse insert gas and discharges as gas mixture in the form of very fine gas bubbles, hydrogen dissolved in the aluminum alloys diffuses into gas bubbles and is carried away. Some mobile degassing units have mixing panel units mixing

95% argon and 5% chlorine. Chlorine reacts with chemical to from chlorides, which changes the wetting characteristics of melt. These chlorides can be removed .The removal of chlorine of these chemicals is done to separate unit to reduce its harmful effect. The mobile degassing unit is as show in figure number 2.

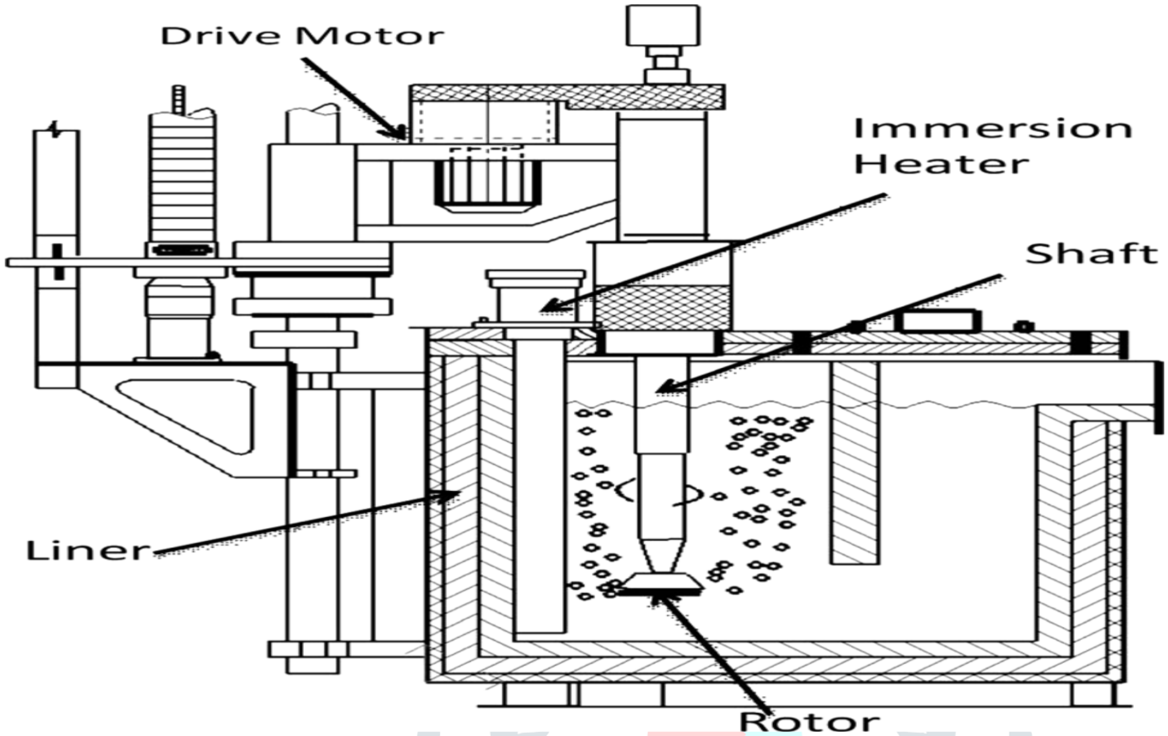


Fig. No 2 Mobile Degassing Unit

For this unit chlorine gas is received from main line and argon is taken from argon gas cylinder. Flow meters are used to measure flow of gasses. FM; FM2 are the flow meters used for chlorine and argon gases respectively. The range of flow rate for chlorine varies from 0 to 5 L.P.M. and that of argon ranges from 0 to 15 L.P.M. In the diffuser the gases are mixed with each other and then they are passed to graphite tube. This tube rotates at fixed r.p.m. Due to rotations the bubbles of mix, of argon and chlorine pushes the hydrogen gas through the melt section uniformly. The degassing is done at following test conditions [10] As per Piston Foundry Operation Manual, pressure of argon gas 2.4 Kgf/cm², rate of flow or argon 4 to 6 1.p.m, and duration of treatment 6 min.

The mobile degassing unit has certain advantages like, It is very efficient method of removal of hydrogen gas and oxides, rotor and shaft are attached by coupling so it can be changed very quickly and this method requires shorter treatment time as compare to other degassing process. From this technique homogeneous melt quality is obtained and minimum operating space is required.

3.2 VAC Test apparatus

VAC test gives indication about extent of degasification of molten alloy in terms of density index. In this test two samples from molten alloy are solidified in different sets of conditions. One test sample is solidified under atmospheric pressure and other one in vacuum chamber. The specimen solidified in vacuum chamber will have different density as compare to that which is solidified in open atmosphere. Density of specimen solidified at atmospheric pressure will be more as compare to other specimen due to hydrogen entrapped in it. The relative change in density is represented by density index. The relatively lower value of density index is the indication of presence of less hydrogen in solidified samples [10].The VAC test consists of vacuum chamber, in which vacuum is created by exhausting the air from this chamber. The vacuum pressure is displayed on pressure gauge (ranging from 0 to 100 m bar). A open platform is provided for solidification of sample under atmospheric conditions. A timer is used to display the solidification time. On the base of stand, a water tank is provided to cool the solidified hot samples. The density index display unit is a computerized unit which indicates density index automatically. This unit consists of a platform on which the solidified samples are tested by dipping in water contained in glass container. This unit is controlled by microprocessor to obtain highest accuracy. It has sliding arrangement for rapid position control. The Vacuum pressure is set at 80 mili bar. The casting spoon preheated and one crucible is placed in vacuum chamber while other ne in open atmosphere. Molten alloy is poured in both crucibles up to 3/4 of its level. The vacuum pump is switched on. When the solidification is over the top lid of vacuum chamber is removed. Cast samples are removed and quenched in water and then they are dried with a clean cloth. Water filled glass beaker is placed on the weighing device. The TARE switch of weighing device is pressed. One of the samples is placed on weighing platform but outside the water filled beaker. The Red D switch is pressed until liquid is displaced on the display board. Pick up the sample, held it into water with wire hanger and press RED switch. Density is displayed on board and memorized by computer of weighing device. The same procedure is repeated for second sample. Density Index is automatically displayed on the display board.

4. Experimental work and Test Procedure-

4.1 Influence of process variables

Hydrogen present in the atmosphere exhibits appreciable solubility in molten aluminium alloy. To remove this amount of hydrogen from molten alloy the molten alloy is degassified. The extent of degasification (removal of hydrogen) is measured very precisely with the help of vacuum test. To perform this test two samples, from same melt, are solidified at different conditions one in controlled conditions in vacuum chamber vacuum pressure and another at atmospheric conditions. The both samples are dipped in water and there density difference is calculated with the help of computarised attachment. This density index provides information about hydrogen contents. Lesser the value of density index means lesser amount of hydrogen is contained by melt. In the degasification the mixture of argon and chlorine gas is passed through melt which has to degasify.) Hydrogen dissolved in molten aluminium alloy diffuses into the inert gas bubbles, which floats up to melt surface. In the mobile degassing units rotor rotates at fixed rpm and thus it disperse inert gas bubbles throughout the melt in the form of very fine bubbles. This treatment is performed for a fixed duration. There are two process variables which affects the extent of degasification (i.e. density index).

(1) Treatment time. **(2)** Rotor speed

In the present experiment the effect of these variables is evaluated. To know the effect of these variables on density index. The degasification is performed at different rotor speeds. Three ranges of rotor speed, selected for this test are 100, 200 and 400 rpm. At these different rotor speeds during degasification the samples are taken from melt at the interval of fixed after duration and tested for VAC test.

(1) Pour the ungassified molten alloy in to crucible and solidify them in different atmospheric of conditions, one at under 80m bar vacuum pressure and another under atmospheric pressure.

(2) These untreated alloysamples are tested for vacuum test and the value of density index is known.

(3) Rotor speed is set at 100 rpm and degasification is started by passing chlorine and argon gases with the help of mobile degassing unit. At the interval of two minutes duration the molten alloy is taken and is poured it in crucible to, solidify. This samples are checked for vacuum test and different values of density index are tabulated as in Table 1.

(4) The step 3 is repeated for different rotor speeds at 200 and 400 rpm. The density index for each sample is checked by VAC test.

Table Number-1 Test Results

Sr No	Degasification Duration	Density index		
		At Rotor speed 100rpm	At Rotor speed 200rpm	At Rotor speed 400 rpm
1	0	3.00	3.00	3.00
2	2	2.30	2.00	1.50
3	4	1.70	1.40	0.98
4	6	1.32	1.05	0.90
5	8	1.20	0.90	0.80
6	10	1.06	0.82	0.75
7	12	0.95	0.80	0.75
8	14	0.90	0.80	0.75
9	16	0.90	0.80	0.75

4.2 Impact assessment of degasification on quality of cast product

The melt before degasification and the melt sample after degasification are casted by gravity dicasting method the defect presents on both casting analysed For the quality control department

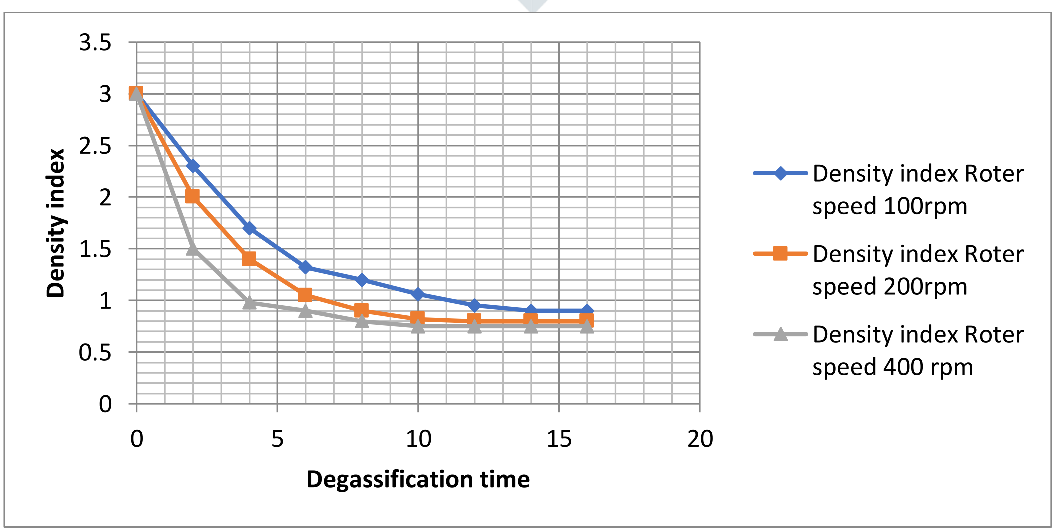
Table Number-2 Observations of experimental work

S.NO.	Types of Defects	No. of Defect (Before Treatment)	No. of Defect (After Treatment)
1	Large Size Defects	6	2
2	Medium size Defects	26	4
3	Small Size Defects	150	8

5-Results and Discussions-

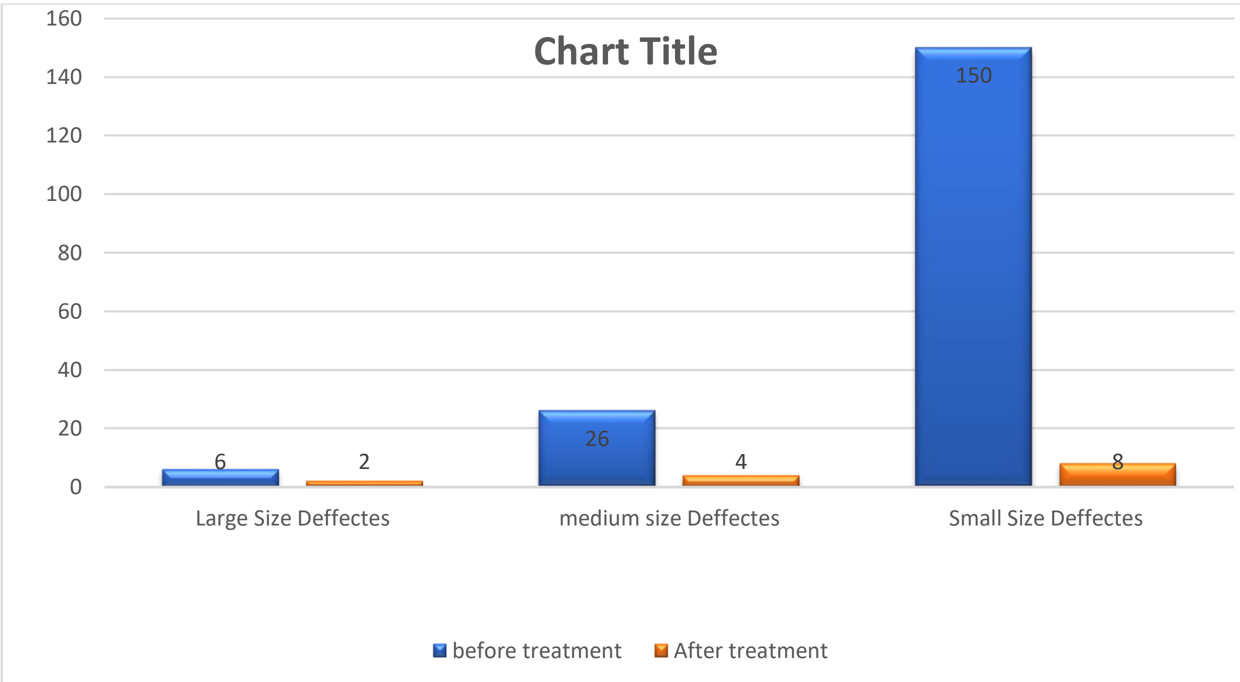
The results thus obtained are plotted against degasification treatment time at different rotor speeds and are shown in fig. The variation of density index with treatment time is inversely related. As the treatment time is increased the value of density index reduces. At a constant rotor speed during initial stages of degasification the density index reduces sharply and as the process advances the density index reduces at comparatively slower rate and after certain duration the density index does not reduces further. The value of density index for melt before degasification treatment was 3.0. As the degasification process advances density index varies with treatment time in exponentially reducing order. To evaluate the effect of rotor RPM on extent of degasification the readings are taken for different rotor speed for particular treatment time. The value of density index reduces as rotor speed is increased. Results can be summarized in table Number 1.We get minimum value of density index 0.75 (for 244 alloy) which is equivalent to 0.75cc/kg Al and minimum treatment time at 400 rpm after treatment duration of 6 minutes.

Figure 3: Degasification process variables



The figur 4 shows the influence of degasification on quality of casting product.

Figure 4: Influence of degasification on quality of casting product



7. CONCLUSION-

The optimal combination of degasification time and rotor speed is investigated in this research paper. The process parameters are optimized to get optimum results. From experimental work it is conclude that the removal efficiency of both hydrogen and inclusions depends upon following factors

1- Bubble Size- finer is the bubble size greater with the hydrogen removal

2- Flow rate- maximizing the no of bubble will lead to better quality

3- Extent of turbulence- gentle bubbling and ensuring the minimum turbulence on melt surface will lead to quality products.

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