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Impact Assessment of Humidity and Pouring Temperature on Aluminum alloy Melt Quality

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Abstract –

Casting is a process of melting the material and then pouring it into mould to produce the components of required shape and size. The alloy composition and process variables have significant impact on product quality and mechanical properties of cast components. The quality of the melt and, ultimately, the quality of the finished product is affected by some process variables as pouring temperature, pouring rate and some meteorological variables as humidity of air. In the present investigation the effects of pouring temperature and air humidity on hyper-eutectic aluminum-silicon alloy are examined through experimental work. The pouring temperature ranges from 680°C to 760°C.The optimum value of parameters for producing high quality products are investigated thorough experiments.

Keywords- Aluminum alloy, Gravity dies casting, Degasification, Pouring temperature, Humidity

1. Introduction-

Aluminum alloys are very widely used for manufacturing light weight components. The casting properties and quality of cast components depend upon amount of alloying elements and process variable of casting. In the gravity die casting process the molten alloy is poured into mold cavity under the force of gravity. A metal die is designed, usually in two parts, to form a mould cavity and molten metal is poured into this mould cavity. After solidification of the molten metal the die is opened and the cast components are removed. Finally excess material including the gate, runners, riser and flash are removed from the cast components to get the desired shape of castings. Gravity die casting produces excellent dimensional accuracy and smooth cast surfaces.

The composition of alloying elements has great impact on quality of cast products. Alloying element as Si, Mg and Ni are added to get alloy of desired mechanical and metallurgical properties. In cast aluminum alloy when silicon is added, it provides the benefits of increasing fluidity, reducing cracking and improving feeding rate to minimize shrinkage and porosity [1]. Al-Si alloy is one of the most widely used materials for casting of automobile components. Alloy having silicon percentage less than 11.6% (by weight) is called hypoeutectic and having silicon more than 11.6 %, is called hyper-eutectic alloy. [2] In aluminum - silicon alloy other element like nickel and copper are also added to improve mechanical properties. Addition of copper decreases shrinkage and provide basis for age hardening, which further improves hardness of the cast component after a certain time. The addition of Nickel increases the strength of alloy at elevated temperature [3]. In aluminum-silicon alloy the course sized silicon crystals create harmful effects to the casting .Silicon crystals are hard and brittle, thus provide poor surface finish. Thus the elimination of large size silicon are very essential to get good quality castings, which is done through refinement process. The presence of Mn in Al-Si alloys may increase slightly the high temperature properties of alloy and enhances its fatigue resistance, and reduces its solidification shrinkage [4].

The quality of cast components also depends up on melt refinement and casting process variables Pius et.al [5] observed that melting and pouring parameters directly and indirectly affects the mechanical properties like hardness , percentage elongation and percentage reduction J.H Lee et al. [6] find the relation between turbulence of melt in holding furnace before pouring and degasification duration and concluded that the design of degassing rotor have a huge impact on the generation of turbulence in the holding furnace before pouring. With the increase in the turbulence inside the furnace the duration required for degassing is reduced. Onarwanna et.al [7], while investigating the effect of various parameters on quality of cast components concluded that the most important parameter which affects the quality of casting is heat transfer coefficient of molten alloy. Ager et.al [8] investigated the influence of alloying magnesium in aluminum on mechanical properties of alloy and concluded that as percentage of magnesium increased there is improvement in hardness and compressive strengths. Diego et.al [9] highlighted through their researches that casting of aluminum alloys have been a challenging task due to maximum shrinkage which occurs in this material. Therefore, the parameters that significantly affect the casting quality are rotation of impeller of degassing unit, maximum temperature of the aluminum alloy, the speed of pouring the molten metal in the mould cavity and pre-heating of the dies. The optimum value of parameters for producing high quality products are investigated thorough experiments in the present work.

2 Melt Treatments and Experimental Work-

2.1 Refinement and Degasification of Hydrogen from Melt-

The aluminum silicon alloy having composition (Si-23-26%, Cu-0.8-1.5%, Ni-0.8-1.3%, Mg-0.8-1.3%, Al-remaining) is melted in induction furnaces up to its melting points and then refinement is done as per following specification [10]

Table No.1-Refinement process variables

S NO.	Variables	Specifications
1	Taping Temperature	780°C±20
2	Addition of Phosphorus	200 PPM
3	Treatment Time	10 Minutes

The hydrogen gas naturally diffuses at elevated temperature in molten aluminum alloy. The entrapped hydrogen produces various defects like porosity, blow holes and pin holes, which finally leads to deterioration of mechanical properties. To produce the casting of good quality the degasification is done by using gas bubble filtration technique (GBFT). In this the argon gas is passed through melt with the combination of chlorine gas (Ar-95% and Cl-5%). The bubbles of these gases carry away the entrapped hydrogen with them, and thus removable of hydrogen takes place. Flowing process parameters are followed to get the optimum results. [10]

Table No.2-Degasification process variables

S NO.	Variables	Specifications
1	Degasification Technique	GBF
2	Gases used	(Ar-95% and cl-5%)
3	Rate of flow of gases	6 LPM
4	Rotor Speed	400 RPM
5	Duration of degasification	6 minutes

The normal pattern of relative humidity, temperature and absolute humidity was studied for previous year and it was decided to perform experiments in three time slots to get the test results in different sets of ambient conditions. It was planned to perform the experimental work in three slots (in the month of Jan, March and August) the Meteorological observations on the day of performing experimental work are tabulated in table no 3

Table No.3- Meteorological observations

S No.	Readings at different time slots	Average ambient temperature °C	Relative humidity %	Humidity gm/kg
1	Slot-1 (Jan)	13.0	77	7.0
2	Slot-2 (Mar)	33.5	37	11.5
3	Slot-3 (Aug)	30.0	73	19.5

2.2 Experiment Work-

From Table no. 3 it is clear that the humidity is maximum in the month of August and minimum in month of January .To get the proper variations of density index it was decided to take observations in the month of March also. In each round of experiment work test samples were solidified (after proper refinement and degasification) at different pouring temperature ranging from 680 °C – 760 °C at the interval of 10 °C. The VAC test was perform on each and every sample as per recommended guidelines[10].Vacuum 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 environmental conditions. In each round of experimental work 18 samples were solidified from the molten metal taking at nine different pouring temperatures ranging from 680 °C – 760 °C. (Two samples for each pouring temperature).Out of this two, one test sample is solidified under atmospheric pressure and other another in vacuum chamber at 80 mili-bars pressure to standardizes the test results. [10]. The relative change in density is represented by density index.

The VAC test apparatus consists of vacuum chamber, in which vacuum in created by exhausting the air from this chamber. The vacuum pressure is displayed on pressure gauge (ranging from 0 to 100 mili-bars. 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 mounted to cool the solidified hot samples. The display panel is a computerized unit which indicates density index automatically. This unit consists of a platform on which the solidified samples are tested for density index by dipping in water contained in glass container.. To study the variation of these parameters with pouring temp the data are recorded from VAC test at different pouring temperatures and at different humidity. The test result are tabulated in table no 4

Table No- 4 Test Observations

S.No.	Pouring Temp.	Density Index At humidity 7gm/kg-	Density Index At humidity-11.5gm/kg	Density Index At humidity-19.5gm/kg
1	680 .°C	0.60	0.70	0.90
2	690.°C	0.65	0.75	0.98
3	700.°C	0.70	0.83	1.08
4	710.°C	0.75	0.89	1.16
5	720.°C	0.80	0.96	1.25
6	730.°C	0.85	1.01	1.34
7	740.°C	0.90	1.09	1.42
8	750.°C	0.95	1.14	1.51
9	760.°C	1.00	1.20	1.60

3. Results and Discussions-

The test samples solidified in vacuum chamber will have different density as compare to that which is solidified in open atmosphere. The relatively lower value of density index is the indication of presence of less hydrogen in solidified samples. The variation of ambient conditions is as shown in fig no.1

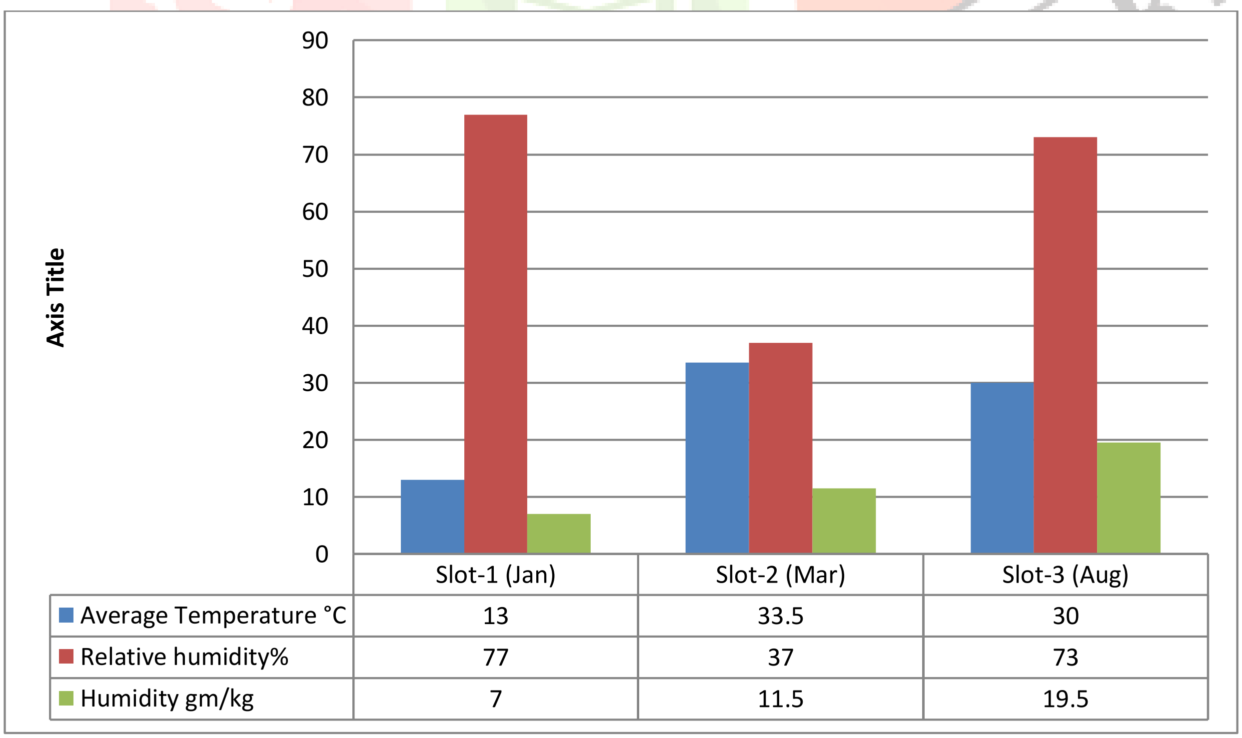

Figure No.1- Variation of Ambient conditions

The observations are plotted in a graph between pouring temperature and density index at different value of humidity as shown in figure 2

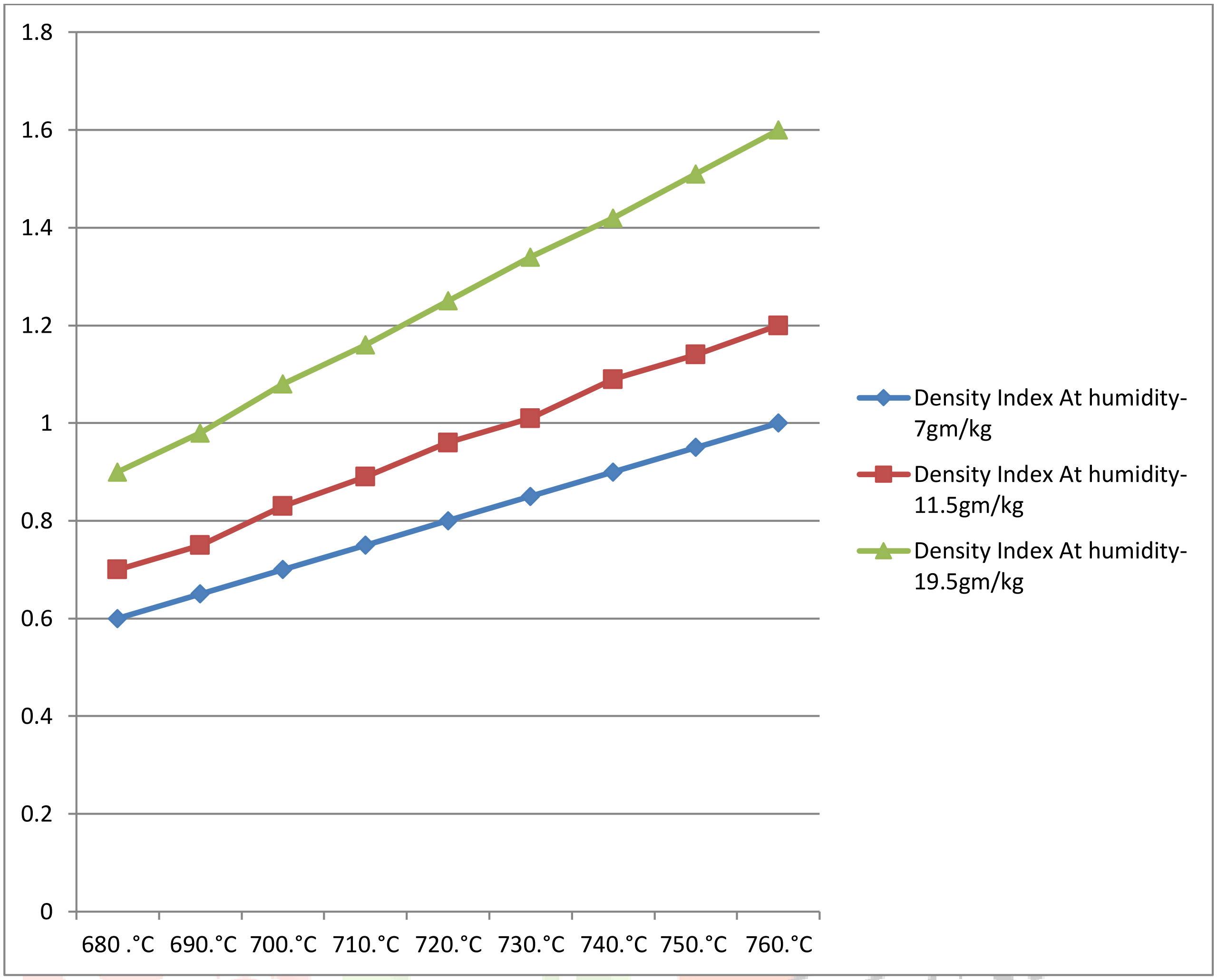

Figure No 2- Variation of Density Index with Pouring temperatures and Humidity

Form the Fig-2 it is clear that if pouring temperature is increased for particular value of humidity the density index also increases and is directly proportional to the pouring temperatures. The minimum value of density index (after degasification of 6 min) is obtained at humidity 7.0 gm/Kg and as the value of pouring temperature increases the density index also increases .Which shows that aluminum have a tendency to absorb higher amount of hydrogen at elevated temperature. The variation of density index at different values of humidity is also shown in Fig 2. The density index increases as humidity increases for a particular pouring temperature. Test result of density index is higher at high value of humidity. Thus it is concluded that the optimum conditions are at pouring temperature at pouring temperature 640°C, at humidity at 7.0 gm/Kg. of the melt which have been degasified for 6 minutes at rotor speed 400 RPM.

4. Conclusion-

The experimental results indicate that Aluminum- silicon alloy has a intense property to absorb more hydrogen at elevated temperature of the liquid melt. The optimum conditions of pouring temperature and relative humidity have been investigated in this work. If pouring temperature is lower than the optimum value of temperature then mould cavity will not be filled properly and will solidified very rapidly ,as result of this the directional solidification will be obstructed. If pouring temperature is excessively high it will cause more hydrogen entrapment, leading to various defects.

The humidity also displays the same impact on density index. Higher humidity results in a higher density index value leading to low quality castings .It is recommended that low humidity and optimum pouring temperatures are most suitable conditions to produce high quality cast components. During manufacturing of cast components the pouring temperature of melt and humidity of air etc are some variables, which need to control properly to get high quality castings which are free from defects due to hydrogen entrapment.

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