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Experimental Investigation on Solidification Rate and Grain Size for Centrifugal Casting

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Abstract— In the case of centrifugal casting the molten metal occupies into the cavity by virtue of the centrifugal force. Horizontal centrifugal casting is the process of production of cylindrical components and in the same casting with different mechanical properties through the section [1]. The experiment set up is designed and this set up consists of a stainless steel cylindrical mold which is fixed both sides by a driving flange. This driving flange connected to the mold in a temporary manner with the help of nut and bolt. The DC motor can be varied up to 1400 RPM. For this analysis lead is used as molten metal because lead melted at very low temperature. Numerical simulations are carried out using the ABAQUS program which treated as an attractive and useful tool for modeling centrifugal casting process. There are numerous procedure constraints impact the appearances of the centrifugal castings such as pouring temperature of the molten metal, die wall temperature, rotational speed of the die, centrifugal force these processes. By means of the centrifugal force and rapid solidification rate the finer equiaxed grain structures are formed to obtain homogeneous and isotropic mechanical properties [1].

Index Terms— Abaqus Program, Cooling Rate, D C Motor, Experimental Set up, Horizontal centrifugal casting, Lead Material, Pouring Temperature.

Introduction

The aim of the current study is to analyze on the solidification rate of molten metal of horizontal centrifugal casting process. Mechanical property of any casting significantly depends on the solidification rate of the casting and microstructure also effects on the solidification rate.

Centrifugal castings are from time to time mentioned to equally liquid forgings. The centrifugal casting process is contrasting additional foundry processes in that it necessitates special knowledge, practices and skills not usually found in other types of foundry operations. Centrifugal casting is one of the prime casting branches in the casting industry, accounting for rough 15% of the overall casting output of the domain in terms of tonnage. The centrifugal casting technique uses the centrifugal force generated by a spinning cylindrical mold to throw molten metal against a mold wall to form the desired outline. Consequently, a centrifugal casting must be able to rotation a mold, receive molten metal, and let the metal solidify and cool in the mold in a carefully controlled manner. Not only solidification rate there are many other parameter which are affect in centrifugal casting like pouring temperature of the molten metal, initial temperature of the mold, rotating speed of the mold, size of the mold, cooling rate of molten metal, flow rate of molten metal and many others. Here solidification rate taken in major consideration and other parameter kept negligible.

Literature Review

Solidification in centrifugal castings is a similar process to that occurring in castings i.e. is a change of state phenomena, the rate of which is governed by heat transfer, but there are super imposed effects of the mechanical action [Howson, 1969]. The ideal representation of solidification behavior in a horizontal centrifugal casting is to assume that crystal growth commences with the liquid metal in contact with the mold wall, and then proceeds right across the section until the last remaining liquid freezes uniformly at the inner surface, to leave a smooth bore free from shrinkage cavities [Cumberland, 1963]. T. P. D. Rajan et al. discussed on developments in solidification processing of functionally graded Aluminum alloys and composites by centrifugal casting technique. With the help of centrifugal casting method different types of component easily manufactured as well as

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structures of FGM manufactured that's why centrifugal casting also called as very versatile casting. The present paper gives an overview on the influence of various process and solidification parameters on microstructure and properties of graded alloys and composites are described. Functionally gradient composites are formed by centrifugal casting technique through segregation of particles due to centrifugal force, either at the inner or the outer periphery of the casting, depending on the relative densities of the particles and the melt. Various investigations have been carried on processing FGMs through centrifugal casting mainly on aluminum based systems. Madhusudhan et al. discussed that experimental study on rate of solidification of centrifugal casting. Centrifugal casting is a process of producing casting by causing molten metal to solidify in rotating molds. The final casting quality is depending on the several parameter like flow pattern of the molten metal and rate of solidification, rotational speeds of the mold. Experiments have been conducted by rotating a horizontal axis cylinder at different rotational speeds and also at different fluid temperatures. At different rotational speeds cooling rates of the liquids were observed, which also depend upon the relative movement between the inner surface of the rotating mold and the fluid. This study gives the effect of rotational speed on solidification rate of centrifugal casting. Yikun Luan et al. investigated on effect of solidification rate on the morphology and distribution of eutectic carbides in centrifugal casting high-speed steel rolls. High speed steel (HSS) rolls properties greatly influenced by the morphology and distribution of eutectic carbides. The morphology and distribution of the carbides has been studied for investigation the effect of solidification rate on the eutectic carbides and also find a process to refine them. All this performed by using different molds with several initial temperatures. The morphology and distribution of the eutectic carbides was assessed by optical microscopy and scanning electron microscopy as well as by X ray diffraction and x ray energy dispersive spectrum. It has been carried out as solidification rate increases; the eutectic carbides became finer and more uniformly dispersed. To improve the wear resistance and thermal fatigue properties of high speed steel rolls take the high value of solidification rate

EXPERIMENTATION AND DESIGN SET UP

The experimental set up of horizontal centrifugal casting consists of a stainless steel cylindrical mold which is fixed both sides by a driving flange. This driving flange connected to the mold in a temporary manner with the help of nut bolt. This flange connected to the shaft of a DC motor where the speed can be varied from 0 RPM to 1400 RPM. The experiment is conducted with different speeds like 200 RPM, 400 RPM, 600 RPM and 800 RPM.

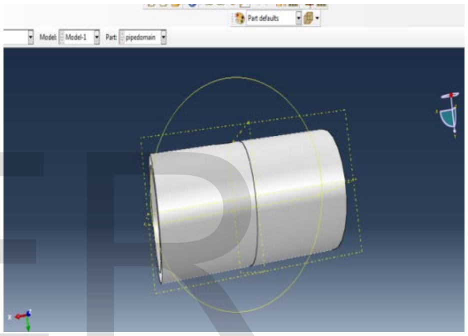

Fig. 1. Cylindrical Mold

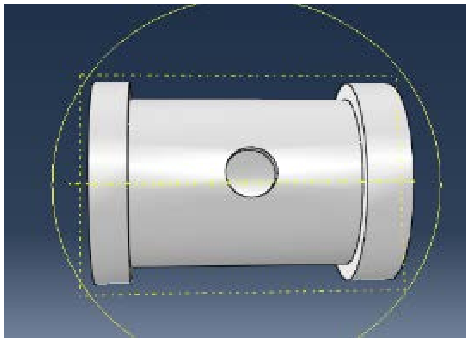

Fig. 2. Cylindrical Mold with flange

The flow of molten metal into the mold is confined in the horizontally oriented, axially rotating cylindrical mold. The rotational speed of the mold is increased from zero to optimum speed of rotation where the fluid forms a uniform thick layer inside the rotating mold.

Firstly cylindrical mold is kept at room temperature. Lead is used as a molten metal at around 800 C. In centrifugal casting

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required metal is used just above the melting point. As the rotational speed of the mold is gradually increased the thick film is pulled out from the pool and the lump of molten tin oscillates. The molten metal entered through a narrow passage to fill the entire pattern. This passage was intentionally designed to be narrow to allow us to differentiate the mold-filling capability of metals with different amounts of fluidity to fill a mold.

For designing this permanent mold used ABAQUS CFD software. First of all design this mold on the software after that by using the same dimension made a physical model of this mold.

TABLE 1

Design and Operating Parameters

S. No.	Parameters	Dimension(mm)
1	Inner Diameter of the Mold	100
2	Outer Diameter of the Mold	128
3	Length of the Mold	236
4	Length of the Shaft	280
5	Diameter of the Shaft	18
6	Diameter of the Flange Plate	150
7	Diameter of the Hole for pouring molten metal	25.4
8	Frame	700*350

Fig. 3. Actual mold

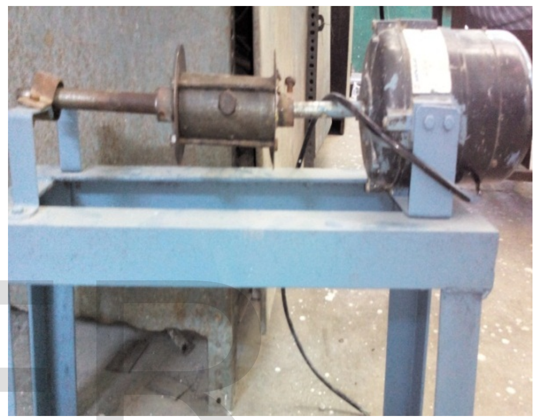

Fig. 4. Experimental Set Up

Observation Drawn from Experimental and Software Study

The aim of the paper is presentation of the centrifugal casting method and investigations on different parameter of centrifugal casting such as solidification rate and grain size. Investigations were done with use of experimental set up.

Fluid pours delivery with the help of Abaqus CFD software

The fluid pour delivery has been studied for different fluid transfer methods. From pouring the fluid into a cylinder from

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a central pour to projecting the molten metal onto the cylinder wall rotating at 400 rpm. Since the centrifugal casting process is most rapid process and mold being opaque it is not possible to visualize the flow patterns [4]. For the visualization of the flow pattern of molten metal used Abaqus CFD software. And also during solidification the density of the liquid metal continuously increases. Also there is a rich assortment of stationary and temporally varying spatial patterns inside a horizontally rotating cylinder for one single particle size and one particular size of the cylinder [2]. As can be detected from Figure 6 the central pour generates a vast amount of bubbles (from the figure 5, the red color in first and second cylinder shows these bubbles) and would require a complex mold design to ensure that the air entrained during the pour escaped and was not transported to the critical regions of the mold. A number of varying inlet conditions were examined experimentally and simulations performed to access the models ability to accurately predict air and bubble entrainment. From the figure 5, the green color in first cylinder represents the molten metal in liquid form which is obtained directly from Abaqus software. Other cylinder represents the molten metal until it completely solidified. Last one which is shown by blue color represents the completely solidified cast. Rotational speed of the mold is one of the important process variables which affect the rate of cooling of the molten metal. As the rotational speed is increased the centrifugal force is increased by a square proportion, which may create a strong convection in the liquid pool and then producing a homogenization of temperature in the bulk liquid [3]. So it is required to review and focus on the fluid flow phenomena in the centrifugal casting. The fluid exhibits different flow patterns when it is rotated at different speeds, like Ekmann flow, Coutte flow and Taylor flow which are disturbed flows [4].

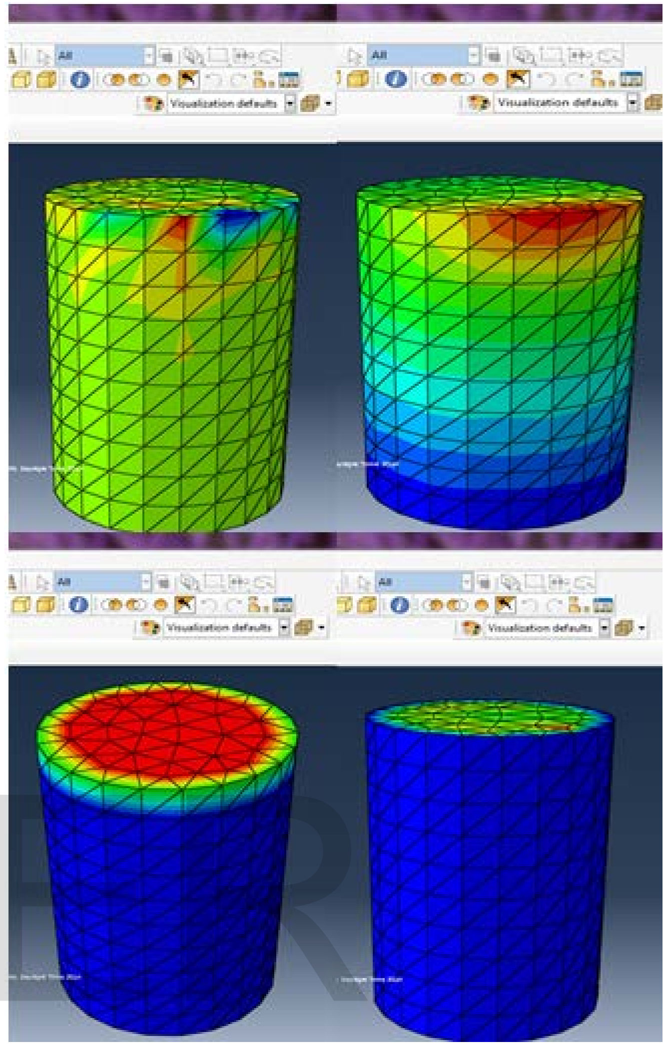

Fig. 5. Fluid Pours

RELATIONSHIP BETWEEN SOLIDIFICATION RATE AND GRAIN SIZE

By measuring the slope of the cooling curve solidification rate versus grain size has been plotted as shown in the Figure 7. This graph can be used to measure the rate of solidification of centrifugal castings which are obtained by varying the various process variables based on the grain size. Since grain size of the centrifugal casting are finer in size, the left portion of the curve is more important to analyze the centrifugal casting.

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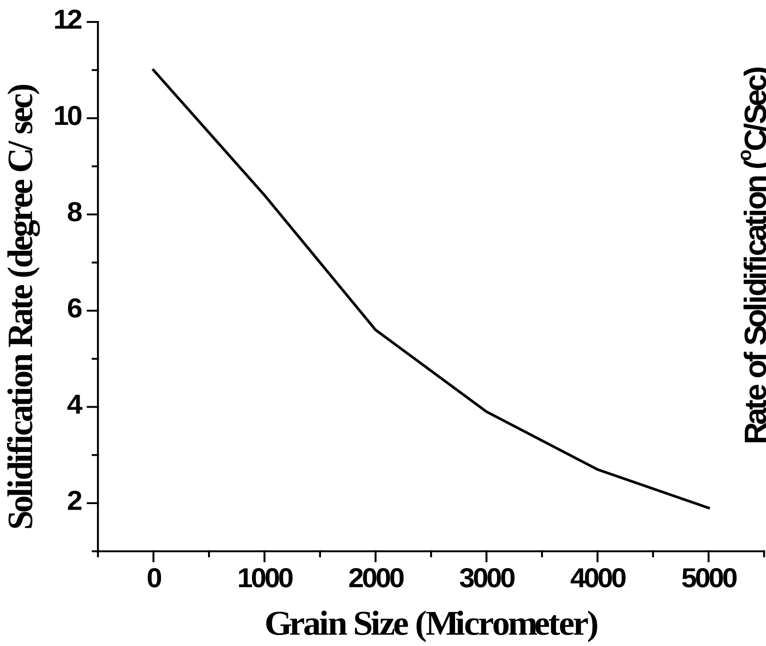

Fig. 6. Relationship between solidification rate and grain size

Fig. 7. Rate of solidification vs. rotational speed of the die

Rate of Solidification vs. Rotational Speed of the Die

By referring the figure 8 rate of solidification can be determined as it shows the grain since formed at different rate of solidifications. The grain size of the casting obtained at 400 RPM is 1220μm and corresponding solidification rate is 7.3oC/Sec, and rate of solidifications for the castings obtained at 600 RPM and 800 RPM are 7.6oC/Sec and 8.0 oC/Sec respectively. It is observed that the rotational speed had very strong influence on the microstructure of the specimen. With increase in rotational speed to 800 RPM, the molten metal gets lifted immediately after it is being poured onto the mold. In case of continuous liquids the relative movement between the rotating mold and the liquid cylinder is negligible hence rate of cooling is less, but in case of casting since viscosity is increasing as well as continuously metal forming layers and gets solidified, hence rate of solidification is faster.

Conclusion

The design and development of a horizontal centrifugal casting machine to produce defect less cast has been presented and discussed throughout this work based on different parametric analysis. The main merit of this project is its mold design based on the ABAQUS software, and using lead as a molten metal performs casting operation. Different parameter of horizontal centrifugal casting has been studied. The centrifugal cast sample shows a fine to coarse microstructure from the outer to inner casting surface. Solidification rate is one of the parameter which affects the final cast. The study of rate of solidification of centrifugal casting is highly impossible by direct measurement; based on grain size the solidification rate can be easily determined. The slow rate of solidification gives coarse grains and faster rate of solidification gives fine equi axed grains. At around 400 rpm due to turbulence the rate of solidification is faster and hence the fine grains are formed and at very low and around 800 rpm the rate of solidification is slightly slower and hence coarse grains are formed.

Future Prospect

The present model has been developed for only one dimension, but longitudinal temperature distribution also has significant effect on the mechanical properties of centrifugal casting, so for more realistic simulation above developed model should be solved in two dimensions. In the present model the heat transfer due to conduction in various regions is only considered, the consideration of convective heat transfer in liquid region can significantly increase the accuracy of results. Such a transient heat transfer model can also be exploited further to predict the time temperature information which if correlated with the time temperature transformation diagram of a specific alloy system may lead to significant information about the microstructure of the developed casting.

REFERENCES

[1] *Amy Q Shen "Granular fingering patterns in horizontal rotating cylinders", Physics of Fluids, Vol 14, No 2, Feb 2002, 462-470.*

[2] *A Halvaee, et al, "Effect of process variables on Microstructure and segregation in Centrifugal casting of C92200 allo", Journal of Materials Processing Technology, 118 (2001) 123-127.*

[3] *Evans P L, et.al "Steady and unsteady solutions for coating flow on a rotating horizontal cylinder: Two- dimensional theoretical and numerical modeling", Physics of Fluids, Vol 16, No8, 2742-2756, 2004.*

[4] *Madhusudhan, "Experimental Study on Rate of Solidification of Centrifugal Casting", International Journal of Mechanical and Materials Engineering (IJMME), Vol. 5 (2010), No. 1, 101-105.*

[5] *Yikun Luan, "Effect of solidification rate on the morphology and distribution of eutectic carbides in centrifugal casting high-speed steel rolls", Journal of Materials Processing Technology 210 (2010) 536–541.*