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Casting Simulation for Sand Casting of Flywheel

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Abstract: *Sand casting technologies have now emerged as practical and commercial ways of manufacturing high integrity near net shape castings. A variety of castings have found their way into general engineering applications. Castings that serve these specific applications have to achieve the quality requirements of superior mechanical properties and zero-porosity. To achieve these objectives within a limited time frame in a product development process, CAD technologies combined with process simulation tools are increasingly used to optimize form filling and solidification of the cast parts. This project describes the newly developed simulation of flywheel component that was prototyped via sand casting route. Results of casting trials showed a high level of confidence in the simulation tools*

Keywords: *Casting simulation, Fluid flow, Flywheel, Shrinkage, Solidification.*

I. Introduction

The formation of various casting defects is directly related to fluid flow phenomena during the mold filling stage and in the cast metal [1]. The rate of solidification greatly affects the mechanical properties such as strength, hardness, machinability etc [2]. One of the critical elements that has to be considered for producing a high quality sand casting product is the gating system design and risering system design [3-4]. Any improper designing of gating system and risering system results in cold shut and shrinkage porosities. Therefore adequate care is necessary in designing gating and risering systems for improved yield of defect free castings

Casting simulation essentially replaces or minimises shop floor trials to achieve the desired internal quality at the highest possible yield. A number of casting simulation programs are available today, such as ADSTEFAN, CastCAE, MAGMA, Novacast, ProCAST, and SolidCAST. Most of them use Finite Element Method to discretise the domain and solve the heat transfer and/or fluid flow equations [5]. The main inputs include the geometry of the mould cavity (including the part cavity, feeders, and gating channels), thermo-physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mould material, as a function of temperature), boundary conditions (such as the metal-mould heat transfer coefficient, for normal mould as well as feed-aids including chills, insulation and exothermic materials), and process parameters ((such as pouring rate, time and temperature). The results of solidification simulation include color-coded freezing contours at different instants of time starting from beginning to end of solidification. This provides a much better insight into the phenomenon compared to shop-floor trials (real moulds being opaque). The user can verify if the location and size of feeders are adequate, and carry out iterations of design modification and simulation until satisfactory results are obtained. Sometimes, it is not possible to achieve the desired quality by changes to method (mainly feeding and gating) alone. In such an event, it may become necessary to modify the part design.

For example, the wall thickness of the part can be increased (referred to as padding) at locations that choke the flow of feed metal. Another typical modification is adding or increasing taper to promote directional solidification. These modifications however, imply additional machining cost. If feedability analysis is carried out at the product design stage itself in a systematic manner, it can potentially lead to superior product-process compatibility. This implies foundry-friendly‟ castings, making it easier to achieve the desired quality with high yield [6]. Shamasunder [7] discussed the steps involved, possible sources of errors and care to be taken during the casting process simulation. According to him the designer needs to have full confidence in the casting simulation tool. This can come only by experience and usage of the tool to mimic effect of various process parameters. With the advances in technology and proper care in modeling, it is possible to simulate the defects generated during casting before the casting is practically produced. They presented different case studies using ADSTEFAN software

The location and size of the feeders and ingates is an important input for solidification simulation. This decision requires considerable methoding experience from the user. Further, the engineer has to create or modify the solid model of the feeder, attach it to the casting model using a CAD program, and import it into the casting simulation program for each iteration. These tasks require computer skills. The accuracy of results (such as solidification time and location of shrinkage defects) is influenced by metallurgical models and availability of temperature dependent material property database. The simulation of intricate castings may involve more time and cost than shop-floor trials, and any error in program inputs implies further delay and expenses.

Casting simulation programs can be used by foundry engineers for quality assurance and yield optimization without shop-floor trials, as well as by product engineers for analysing and optimizing the feedability of a casting during design phase itself. For widespread application, the simulation programs should require little domain experience, and they should be fast, reliable, easy-to-use, and economical. These goals can be achieved by automating some of the tasks involved: identifying the location of a feeder, calculating its minimum size, creating its solid model, attaching the feeder model to the casting, carrying out solidification simulation, predicting quality and estimating the yield. The sand Casting (Green Sand) molding process utilizes a cope (top half) and drag (bottom half) flask of sand, (usually silica), clay and water. When the water is added it develops the bonding characteristics of the clay, which binds the sand grains together. When applying pressure to the mold material it can be compacted around a pattern, which is either made of metal or wood, to produce a mold having sufficient rigidity to enable metal to be poured into it to produce a casting. The process also uses coring to create cavities inside the casting. After the casting is poured and has cooled the core is removed. The material costs for the process are low and the sand casting process is exceptionally flexible.In this work simulation is carried out for manufacturing of STEEL flywheel and the results were presented

II. Casting Simulation

This includes mould filling, solidification, grain structure, stresses and distortion. It requires solid models of product and tooling (parting, cores, mould layout, feeders, feedaids and gates), temperature-dependent properties of part and mould materials, and process parameters (pouring temperature, rate, etc.). The simulation results can be interpreted to predict casting defects such as shrinkage porosity, hard spots, blowholes, cold shuts, cracks and distortion. The inputs however, require considerable expertise and may not be easily available to product designers. One solution is to involve tooling and foundry engineers in the product design stage, and evolve the product, tooling and process designs simultaneously, ensuring their mutual compatibility with each other. This approach is referred to as concurrent engineering.

III. Material And Methodology

Flywheels are typically made of steel and rotate on conventional bearings; these are generally limited to a revolution rate of a few thousand RPM. Chemical analysis of steel material is as shown below.

Element	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V
Wt %	0.25	0.60	1.50	0.040	0.035	0.35	0.40	0.15	0.40	0.05

Table I: Chemical Properties of STEEL

Figure shows drawing of a typical flywheel. The flywheel casting model with essential elements of the gating system like In-gate, runner, sprue and risering system were generated in CATIA V5 CAD modeling software. Four ingates are provided at the first model (fig 1), after the completion of first iteration the shrinkage defect is occurred. In order to obtain sound cast the model has to be modified in such a way that two ingates are provided at the thicker section of inner rib of flywheel and on which the risers are provided to achieve the directional solidification (fig 2).

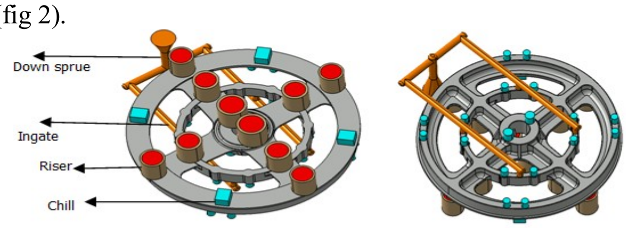

Fig: 1 Top & bottom view of f Flywheel

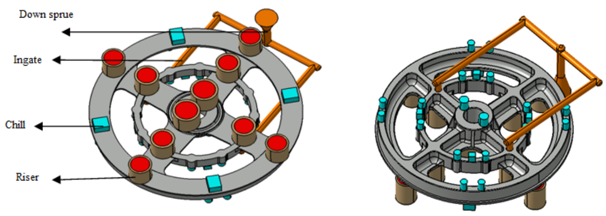

Fig: 2 Top & bottom view of f Flywheel (modified model)

Simulation Process

ADSTEFAN is casting simulation software developed by Hitachi Corporation Ltd, Japan. This was used to simulate fluid flow and solidification of sand casting of flywheel. Casting simulation and result analysis was done to predict the molten metal solidification behavior inside the mold. The casting component with gating system was imported in STL (Stereo lithography) format to the ADSTEFAN software and meshing of the model was done in the pre-processor mesh generator module. The mesh size of the casting was taken 5 and the structural boundary conditions are automatically taken care by the software.

Assignment of material properties, fluid flow and solidification parameters: The meshed model was taken into the precast environment of the software, where the number of materials, type of mold used, density of cast material, liquidus and solidus temperatures of STEEL and other input parameters of fluid flow and solidification conditions like pouring time, pouring type, direction of gravity etc. were assigned. Table & 5 show the material properties, fluid flow & solidification parameters. After the assignment of material properties and simulation conditions, prediction of air entrapment, temperature distribution and shrinkage porosity are carried out. Casting simulation program provides output files in the form of graphical images and video files which are analyzed to predict defects after the successful execution.

Table II: Input material properties and conditions

Parameter	Type of Mould	Conditions
Material	Green Sand	STEEL(IS 1030)
Density	1.5 gm/cm^3	7.6 gm/cm^3
Initial Temperature	20°C	1580
Liquidus temperature	--	1505
Solidus temperature	--	1450

Table III: Input fluid flow and solidification parameters

Parameter	Input condition
Velocity of fluid flow	19.8 cm/s
Fill time	38 sec
Critical solid fraction	0.8 (maximum 1)
Pouring type	Gravity Pouring
Output files	1) Fluid flow 2) Solidification pattern 3)Shrinkage and porosity
Riser type	Open

IV. Results & Discussion

A. Fluid flow

Figure 3(a) (b) shows metal filling in mould cavity, that ensure the smooth flow of Liquid metal and the cold metal is not entering in the mould cavity. The pouring temperature for steel is 1580°C to 1600°C. The estimated pouring time for complete filling of mould cavity is 38 seconds. From the iteration 1&2 we can easily predict that the cavity is filling smoothly, uniformly without any turbulence and temperature differences
we can see. The Yellow colour highlights the temperature drop due to chill provided. But this temperature drop is in safer side there are no possibilities of cold metal or cold shut. In any of the iteration there is no defect associated with fluid flow, in casting component and gating system.

a) **b)**

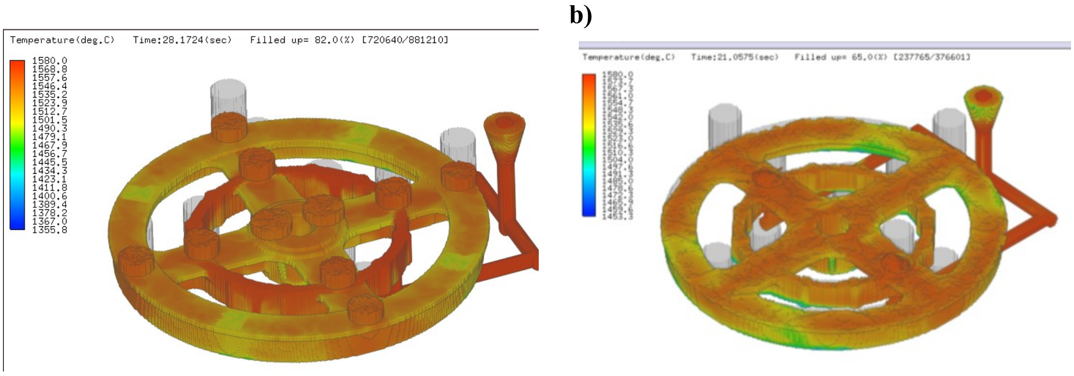

Fig: 3 Fluid flow in the casting component.

B. Solidifaction

It is necessary to provide the directional solidification in order to achieve the sound casting .The directional solidification starts from thinnest section to thickest section and which ends at riser. The actual solidification of metal begins at liquidus temperature of 1505°C. The solidification of metal ends at solidus temperature 1450°C.

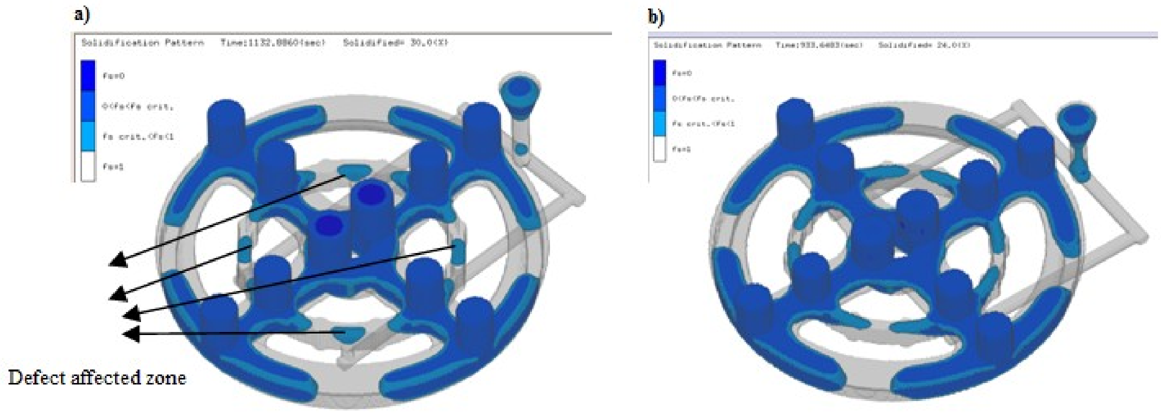

Fig: 4 Solidification of the casting component.

In figure 4(a) 1st iteration the inner rib of the flywheel section is also chilled but the section thickness is small at ingate area, so the hot spot is increased at ingate area so isolation is formed in that section so that isolation prone to defective area. Thus in orders to eliminate these defective areas, the ingates are provided at the thicker section of the inner rib of flywheel component and simulation is carried out. In 2nd iteration only two ingates are provided on which the risers are provided to achieve the directional solidification and fig 4(b) shows the directional solidification of the casting component.

C. Shrinkage Porosity

Figure 5 shows shrinkage porosity in the casting component for first iteration of simulation. It is observed that in first iteration gating system simulation showed shrinkage porosities at four different locations.

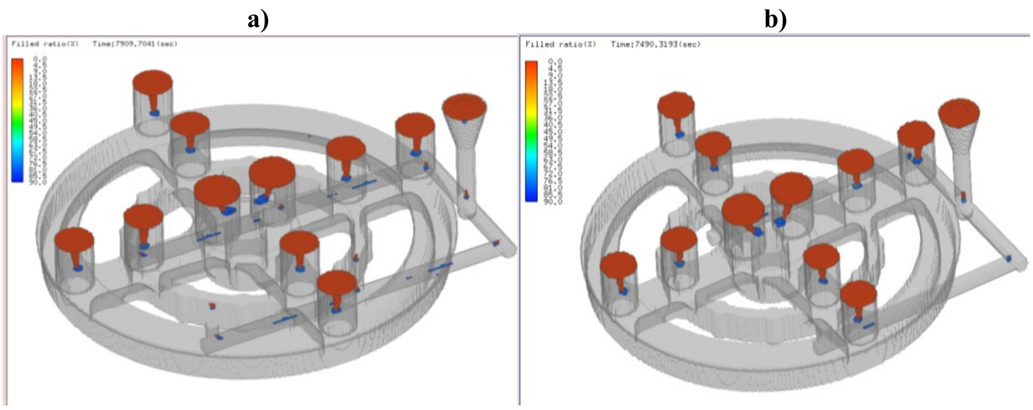

Fig: 5 Shrinkage porosity in the casting component.

But in the 2nd iteration fig 5(b) these shrinkage porosity are at the different locations of the component are eliminated by providing ingates at the proper location, and also the diameter of ingate are increased from 50 to 60mm and on which the risers are provided. Thus shrinkage porosity decreased significantly by 98%. These studies thus helped in arriving at an optimum gating system.

V. Conclusions

In the present work a 3D component model was developed using casting simulation software ADSTEFAN to evaluate possible casting defects for sand casting of flywheel. Notable conclusions from this study are:

- By adopting the pressurized gating system, the fluid flow was smooth and air was expelled without any entrapment inside the mould cavity. Simulation showed that the molten metal was able to fill the mould within the desired time. Therefore fluid heat distribution was good and no cold shut was observed.
- In first iteration improper location of ingates led to formation of shrinkage porosities where in the second iteration only two ingates are located at the thicker section of the inner rib of the flywheel, on which risers are located in order to achieve directional solidification.
- The second iteration resulted in reducing the shrinkages by 98% and the defect associated with the cast is eliminated and the sound cast is achieved.

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References

[1]. Mohd Rizuan Mohammed Shafiee, "Effects of gating design on the mechanical strength of thin section castings", ELSEVIER: Journal of Materials Processing Technology, Vol-105, Pg. 128-133, 2009.

[2]. T.Nandi, "Optimization of Riser size of Aluminium alloy (LM6) castings by using conventional method and computer simulation technique", International Journal of Scientific & Engineering Research, Vol-2, 2011, ISSN 2229-5518. 2011

[3]. Lee, P.D, Chirazi, A and see, D (2001). Modelling micro porosity in aluminium -silicon alloys: a review. Journal of light metals. Vol.1 Pg 15-30

[4]. Katzarov, I.H (2003). Finite element modelling of the porosity formation in casting. International Journal of Heat and Mass Transfer. Vol 46. Pg. 1545-1552.

[5]. . Ravi, Metal Casting: Computer-Aided Design and Analysis, Prentice-Hall India, New Delhi, 2005.

[6]. B. Ravi, R.C. Creese and D. Ramesh, "Design for Casting – A New Paradigm to Prevent Potential Problems," Transactions of the AFS, 107, 1999.

[7]. Shamasunder S., ―To believe or not to believe results of casting simulation software,‖ ALUCAST, pp. 62-67, 2012.