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Design Optimization of Gating System by Fluid Flow and Solidification Simulation for Pump Casing by Sand Casting.

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Abstract

Casting is a major manufacturing process, which requires an understanding of a wide range of geometrical, material and process parameters. In today's market of intense competition, where the need of the hour is to develop quality products at low cost and short lead time, innovative and cost effective designs are the means to success. During the casting process it includes casting defects like shrinkage, porosity and hot tears. To eradicate and eliminate these problems, accurate casting design and proper design of gating system is necessary.

This paper discusses a newly developed simulation tool and its application to a pump casing that is manufactured by using a sand casting route. The simulation software called ADDSTEFEN was used to design optimization of riser system by fluid flow and solidification for pump housing through several simulation iteration, it was concluded that defect free casting could be obtained by modifying the initial riser system i.e.by location of riser from outer circumference to inner side which is prone to formation of shrinkage porosity And lead to emlimation of shrinkage porosity.

Keywords**:** *Pump Housing, Casting Simulation, Riser Design Optimization, Fluid flow and solidification Simulation, Shrinkage Porosity.*

1. Introduction

Casting is a manufacturing process by which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of mould to complete the process. Inspite of conventional knowledge of gating and riser system design and suggestions by experienced foundry engineers pump casing showed the presence of shrinkage cavity. Producing defect free casting is a challenge in manufacturing environment. The formation of various casting defects is directly related to fluid flow phenomena during the mould filling stage and in the cast metal. The rate of solidification greatly affects the mechanical properties such as strength, hardness, machineability etc. One of the critical elements that has to be considered for producing a high quality sanding casting product is the gating system design and risering system design. 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 system for improved yield of defect free casting.

Casting design is primarily done on a shop floor by trial and error basis. Conventionally experimental routes are often used for design and development of product with optimum process parameters. But the process is costly, time consuming and may be impossible in some cases. Hence with conventional approach, finding an acceptable gating system design proves to be an expensive and arduous process. Presently use of casting simulation software is increasing, as it essentially replace or minimizes the shop floor trails to achieve sound casting. With the availability of modern numerical software and good hardware capabilities, simulation has become an important tool for design, analysis and optimization of casting processes. Use of casting process simulation software can significantly reduce the casting cost and in turn cost benefit can be passed over to the customer. It also provides reduced research and development lead time, better first time casting and higher quality of casting.

Adstefen is three dimensional solidification and fluid flow packing developed to perform numerical simulation of molten metal flow and solidification phenomena in various casting processes, primarily die casting (gravity, low pressure and high pressure die casting) and sand casting. It is particularly helpful for foundry application to visualize and predict the casting results so as to provide guidelines for improving product as well as mould design in order to achieve the desired casting qualities. Prior to applying the adstefen extensively to create sand casting and die casting models for the simulation of molten metal flow(mould filling) and solidification(crystallization in the process of cooling).The cast and mold design of the experiment is transformed into a 3D model and imported into adstefen to conduct the sand casting process simulation. Many software use finite element method(FEM) to simulate casting process, which needs manual meshing and are prone to human errors. The casting simulation software used in the present work uses Finite Difference method (FDM) using cubes as the basic elements and has a major advantage over FEM. It meshes automatically eliminates the need to recheck the meshing connectivity there by speeding up analysis. In the present riser system has been designed and optimized by iterative process through fluid flow and solidification simulation for a pump casing to produce defect free casting.

2. Methodology

Figure 1 shows the drawing of a typical pump casing and Table 1 shows its specification. The pump casing 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.

Table1: specification of pump casing

Parameters	Value
Material Density	7.2kg/cm2
Material Grade	SG400/15
Weight	650kgs
No of Cavities	1Nos

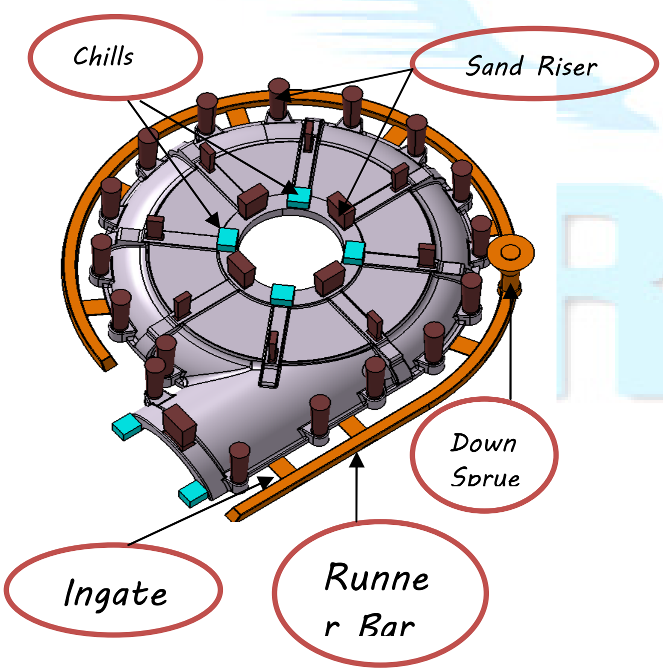

Fig.1: Drawing with Gating and Riser System

A. Design Of Riser System
Calcuation for Riser Design.

1)Sand Riser Size(Round):φ2”/3”x10”-15Nos - 07Kgx15-105 KG.
2)Sand Riser Size(rectanglar):3.5”/2”x1.5”/1”x8”ht-05 Nos -8Kgx05-40 KG.
3) Weight of Downsprue+Runnerbar+Ingate:80 KG
4)Liquid metal Weight :640+105+40+80=865KG

Figure 2: shows the shrinkage defect obtained due to improper riser design.

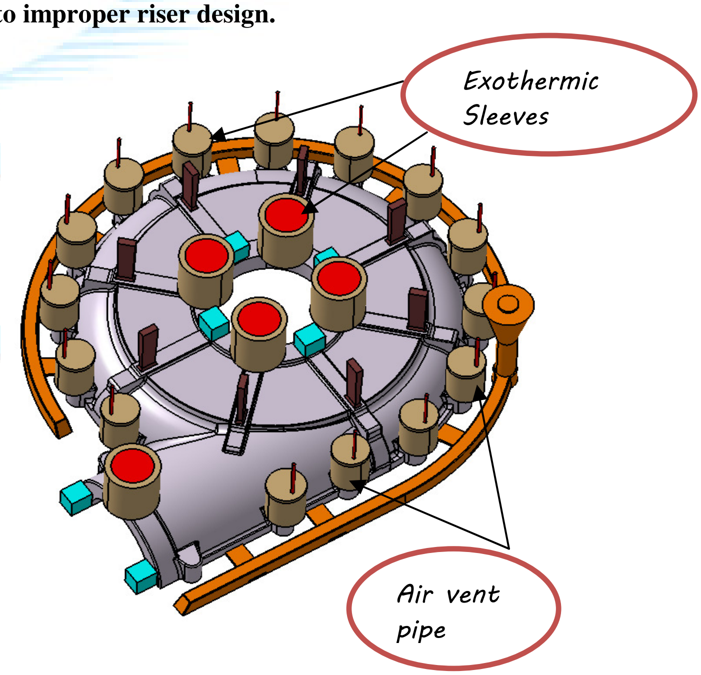

Fig 3: Shows the Changes in Riser Design in CAD model.

Calcuation for New Riser Design.

1)Riser Size(bigger) :φ3"x5"-15 Nos -04 Kgx15 – 60 KG.
2)Riser Size(samller) :φ5"x6"-05 Nos -14 Kg-70 KG.
3)Liquid metal Weight:640+60+70+80(gating system)=850

C.Simulation process.

ADSTEFEN is casting simulation software developed by Hitachi Corporation Ltd Japan.This was used to simulate fluid flow and soldification process for two riser designs. Casting simulation and result analysis was done to predict the molten metal solidification behavior inside the mould. The casting component with riser 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 casting is taken as 5mm. The structural boundary conditions are automatically taken care by the software. Assignment of material properties,fluid flow and soldification 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 SG Iron and other input parameters of fluid flow and solidification conditionss like pouring time, pouring type,direction of gravity etc. were assigned. Table 2&3 show the material propertirs, fluid flow & solidification parameters. After the assignment of material properties and simulation conditions,predicationb 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 perdict defects after the sucessful execution.

Table.3: Input material properties and conditions

Parameter	Type of Mould	Conditions
Material	Silica sand	
Density	7200kg/m3	Liquid
Initial Temperature	1400°c	Liquid
Liquidus Temperature	1150°c	
Solidus Temperature	1151°c	

Table.4: Input fluid flow and solidification parameters.

Parameter	Input Condition
Fill Time	32 secs
Pouring type	Bottom pouring
Output files	1)Air Entrapment 2)Filling temperature 3)Solidification pattern 4)Shrinkage&gas porosity
Riser Type	Open type
Riser Material	1)Iteration1-sand riser 2)Iteration2-Exothermic riser

3. Results & discussion

a) Air Entrapment.

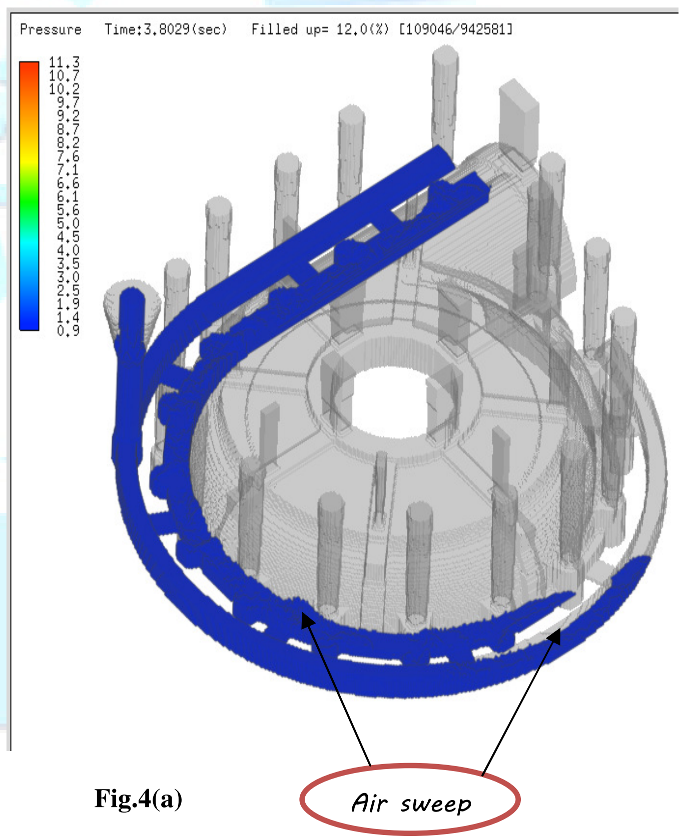

Fig.4(a)

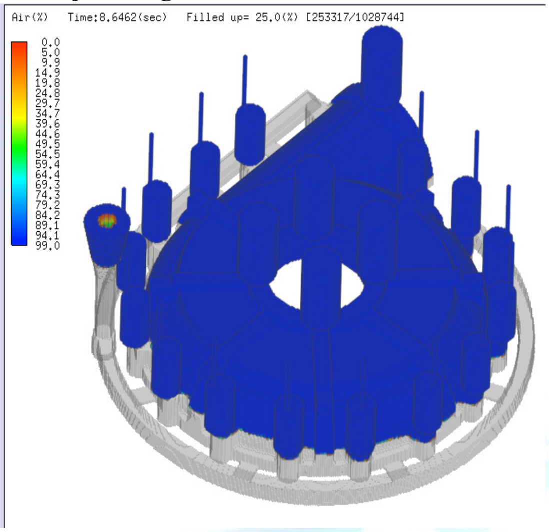

Fig. 4(b)

Fig.4(a)&(b):Air sweeping from mould cavity.

Figure 4(a) & (b) shows the molten metal (grey colour) at the bottom portion and air sweeping(blue colour) from the top portion of mould cavity. From the simulation results it is clear that as the mould is filled with molten metal, air escapes through the top of the housing. The metal enters through the gating system into the mould cavity in first iteration shown in figure 4(a). In the second iterations as shown in fig 4(b). The ingates and runner bars are placed symmetrically due to which even flow of melt makes the air gently to rise above, as the metal starts filling from the bottom fo cavity. This allows all the air and gases to escape from the mould cavity. There is no air entrapped zone in the casting component and gating system in any of the iterations.

B) Temperature Distribution.

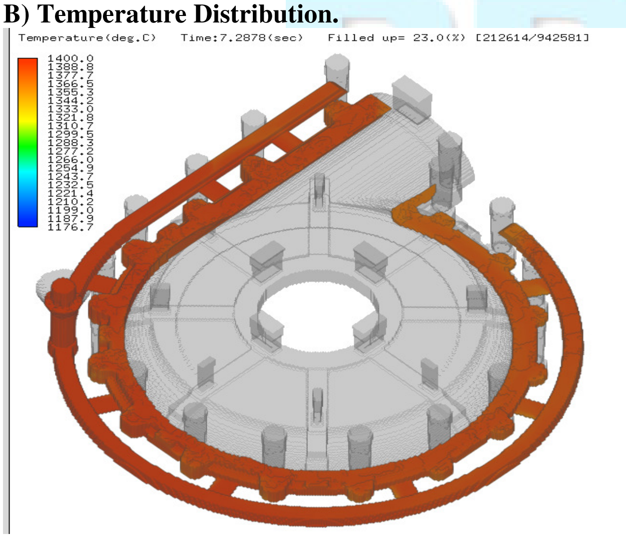

Fig5(a)

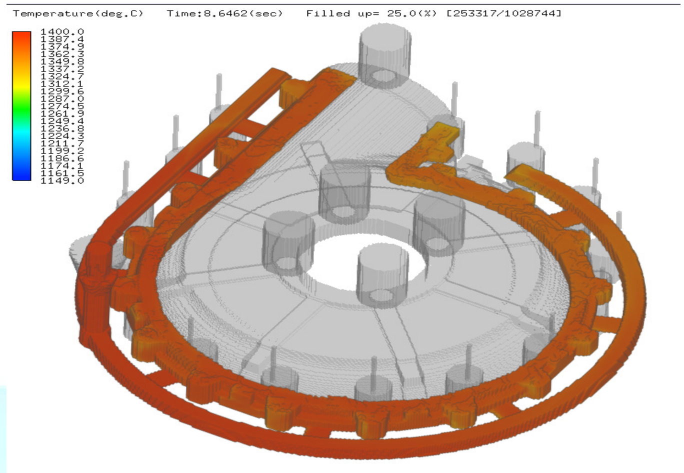

Fig. 5(b)

Fig. 5(a)&(b) Temperature Distribution in casting component.

The actual solidification of metal begins at liquidus temperature of 1150°c (reddish yellow colour). The solidification of metal ends at solidus temperature 1090°c (yellow colour). Figure 49(a) shows the temperature distribution of the molten metal in first iteration of riser system. At no part of the melt, did the temperature fall below the liquidus temperature. In second iteration as shown in figure 5(b) the ingates and runner bars and ingates have temperature distribution within the limit i.e. above liquidus temperature. Any fall in temperature within the gating elements would have resulted in formation of cold shuts and blockage of further entry of molten metal which has not been observed in simulation.

C) Shrinkage porosity.

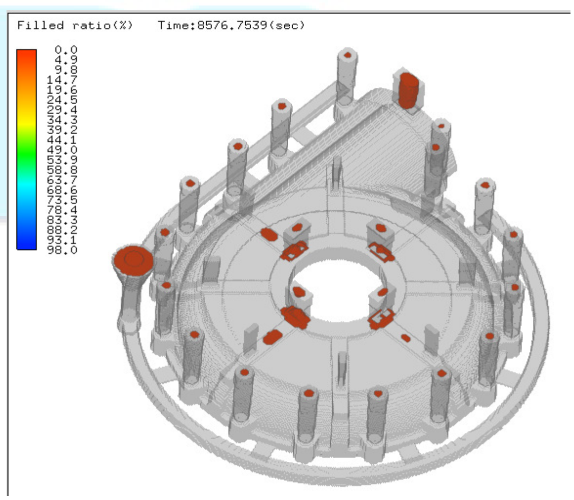

Fig. 6(a)

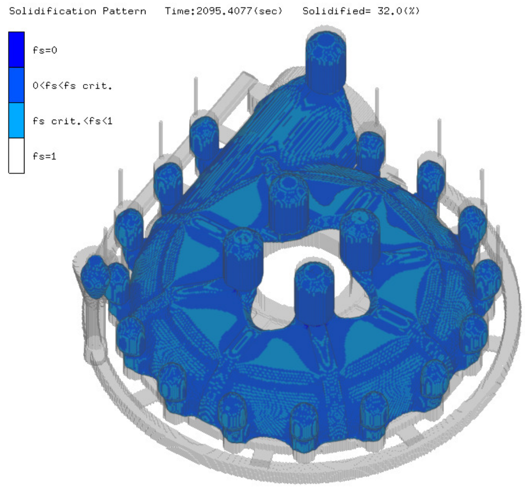

Fig. 6(b)

Figure.6: Shows the solidification pattern

Figure 6(a) shows the shrinkage porosity in casting component for first & second iteration riser system. It is observed that is first iteration riser system simulation showed shrinkage porosities at one place in bigger size with total volume of 1.545 cm3 and in second iteration riser system the solidification process led to elimination of shrinkages porosities.

In final iteration the shrinkage porosity was not found due to the changes done in the riser system. Also porosities were found in sprue and riser which are removable parts from components and also the reduced size of riser have increased the yield by 2%. These studies thus helped in arriving at an optimum riser system.

4. CONCLUSION

In present work a 3D component model was developed using casting simulation software ADSTEFEN to evaluate possible casting defects under various riser system designs for sand casting of pump casing. Two riser system were examined through simulation and an optimized design was choosen through this process.

- By adopting the parting line and 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 cold shut was observed.
- In first iteration due to the improper size of riser system led to formation of shrinkage porosities whereas in the second iteration due to sufficient size and location of riser system helped to provide the required directional solidification in shrinkage area which inturn led to defect free casting.
- In second iteration due to reduction the riser system the yield increased by 2%.
- It is apparent that theoretical methods used for simple components would result in defect free casting but for complex shapes like pump casing verification of process with casting simulation would yield better product at lesser time.

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