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CASTING METHODS DESIGN, SIMULATION AND OPTIMIZATION OF CIRCULAR PLATE

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Abstract: Casting simulation helps designers to see how their designs will be resulted after casting process without needing to do the casting process. The use of simulation programs saves time and reduces the costs of the casting system design .Casting design simulation holds an important role in analyzing the outcome of the design. Casting solidification is actually the transformation of liquid phase to solid phase with the liberation of latent heat of fusion. During this metallurgical process, it induces 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 can be predicted and designed by means of computer simulation of casting solidification. In this paper casting of circular disc is analyzed and studied to solve the problem frequent rejections due to shrinkage observed at machining stage. Initially feeder system is designed using past experience and judgment of patternmaker. .A well-designed feeding system is very important to secure good quality and optimal yield. The feed system is analyzed using theoretical knowledge and casting simulation. There after the feeder system for disc is redesigned based on feeding rules, conventional method and casting simulation. All the designs were simulated with Auto-Cast-X [Viewer Mode] to ensure the completion of filling process and to see the manner of solidification of Cast Iron castings. The various models are made, then 3D CAD model of casting with these modified feeder system are simulated to analyze effectiveness of modified feeder system. Results from simulation are used to evaluate the possibility of defects and minimize them .Analyzing the various modified feeder system and the most suitable design is selected so as it will give the improved quality of casting to achieve defect free casting.

Keywords: 3d Cad Modeling, Metal casting, Casting simulation, Solidification simulation, Quality, Defects, Mold filling

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INTRODUCTION

Traditionally, casting process development is an inherent trial and error workflow. Design and engineering departments develop the guidelines for building a component mainly based on previous experiences. Although the foundry aims to manufacture the components in the desired quality, the initial casting trials of new prototypes often fail due to design mistakes. Therefore, modern casting engineering demands a stronger interlocking of the design and casting process.

This is because the later changes are made in this process chain, the more expensive they become. With the emergence of computer technology, Computer Aided Design (CAD) has also entered the area of casting engineering. Since the computer aided simulation of casting and solidification processes has become a necessity in founding industry.

Computer Aided Casting Simulation

Nowadays, Computer Aided Design is not limited to sketching and drafting, but also helps to create analyzable models as needed for computer based process simulation. Since industrial process simulation supports the identification of process issues and thus aids in the formulation of new design rules, it has become an inevitable part of the development chain. Therefore, also the simulation of casting and solidification processes has become a necessity in founding industry. A prior simulation of the entire manufacturing process makes potential castability problems already become apparent in the earlier design stages. Thus, modelling and simulating the casting process by a capable software tool helps to reduce manufacturing costs and to increase yield and casting quality.

Casting process modeling

An engineer designing the particular production technology of a casting has certain possibilities of interfering with the process of solidification and cooling – among others through proper designing of technological allowances, internal and external chills, distribution and magnitude of riser heads, assuming optimum temperature of pouring and chemical analysis of the alloy, and finally through a suitable selection of sand mix. The process of designing the technology of a casting production can be expanded, modernized and improved through utilization of the possibilities offered by the introduction of numerical methods in the calculation of solidification and cooling of metal in a mould. Autocast is a three dimensional solidification and fluid flow package developed to perform numerical simulation of molten metal flow and solidification phenomena in various casting processes and sand casting. It is particularly helpful for foundry applications to visualize and predict the casting results so as to provide guidelines for improving product as well as mold design in order to achieve the desired casting qualities .Prior to applying the Autocast extensively to create sand casting models for the simulation of molten metal flow (mold filling) and solidification).. Sand casting is the casting process that has the longest history (Ravi et al, 2005). Sand casting still accounts for the largest tonnage of production of shaped castings. This is due to the fact that sand casting is economical and possesses the flexibility to produce castings of any material and the weight of castings can be range from tens of grams to hundreds of tons. Conventional sand casting is not a precision process and requires after-cast machining processes and surface finishing producing the required dimensions and surface quality.

A. Problem definition:

A Circular plate as a weight component is manufactured by sand casting Its overall size is 150*150*20 mm and its weighs 2.5kg. The casting is exhibited a large shrinkage defects next to feeder .It suffered frequent rejections due to shrinkage, observed at machining stage .

Cast Metal	Cast Iron - CI 4.0 CE	Casting Process	Sand Casting
Density	7200 kg/m³	Liquidus	1176 ºC
Part Dimensions	150 mm X 150 mm X 20 mm	Part Surface Area	450.88 cm²
Min. Thickness	8.87 mm	Max. Thickness	8.87 mm
Part Weight	2.49 kg	Part Volume	332.57 cm³
Mold Material	Green Sand	Density	1550 kg/m³
Mold Dimensions	345mm X 345 mm X 130 mm	Parting Orientation	Horizontal
Number of Cavities	2 x 2		
Min. Cavity-Wall Gap	80.03 mm	Metal / Sand (weight)	49.94%
Min. Cavity-Cavity Gap	14.44 mm	Metal / Sand (Volume)	10.36%

II. METHODOLOGY

In conventional optimization process includes actual shop floor trials in which pattern, feeder size, shape and location cores, mould layout, gating etc are required to be changed in each iteration which is associated with machining cost, tooling cost, modification cost, melting cost, fettling and transportation cost as well as energy, materials, time are wasted in each trial until and unless the required results are obtained. hence optimization using conventional process is costly , complex and time consuming.In computer aided casting optimization , designs are made using feeding rules and theoreticalknowledge and according to the design the 3D CAD model of casting with each riser is made and further simulated to check for defects, if desired results are not obtained then riser design is modified based on feeding rules and previous simulation results . The required modifications are made in 3D CAD model of casting with riser and again simulated to check defects; the procedure is carried out until the required results are obtained. After analyzing the simulation results of the various modified feeder designs the best design is selected so as to obtain the defect free casting with the optimal casting yield.

A. Analysis of casting: For the analysis purpose of the casting of circular disc, the 3D model of the casting is made with modeling software and further it is simulated using e-foundry simulation

lab. Previos methoding included a cylindrical feeder of height 70 mm and 16 mm bottom diameter. From the result of simulation the size and location of hot spot is known, which match the casting defects in location and shape . The revised method design included a large feeder 75mm height and 35 mm bottom diameter. Simulation now shows better directional solidification with hot spot shifting entirely to feeder ,and leding to defect free casting.The results will appear as 3D colour image of temperatures inside casting at the end ofsolidification. From the image idea regarding temperatures inside casting can be achieved. The various colours for the analysis of state of metal and temperatures used are as follows: Blue indicates Early freezing region, red – In phase of solidification, white – Hot region, yellow – Hot spot. From the simulation result it is clear that hot spot is occurring in the part of circular disc hence defects such as porosity, cavity, surface sinks occurs.

STEPS

1. Solid model a cast part and save it as a .STL file.
2. Browse and upload the casting model
3. Wait till the simulation results are displayed.
4. Identify hot spots. Decide feeder size and location.
5. Model the part with feeder and save as a .STL file.

6. Simulate again and check the location of hot spots.

7. If hot spots are not shifted inside feeders, repeat 4-6.

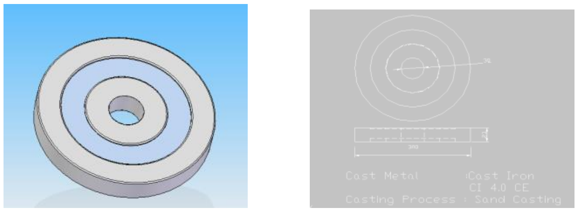


Fig 1 .3D CAD model of circular disc

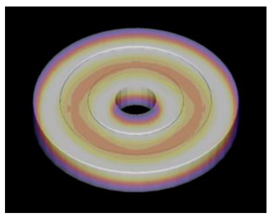


Fig2.defect in circular disc casting **Fig 3 . 3D CAD and simulation result of disc without feeder system**

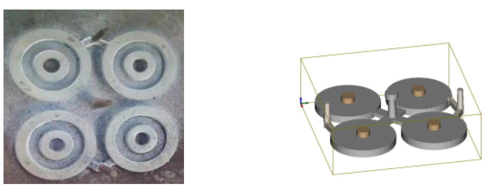
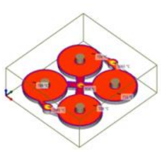


Fig4 .3D CAD model of circular disc with feeder system



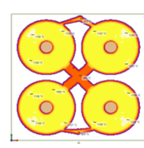


Fig.6.temperature in part and feeder sides in improved design **Fig.5.temperature in part and feeder side in old design**

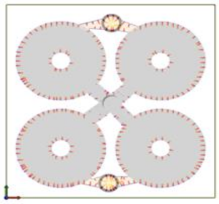


Fig. 06 Feed path in

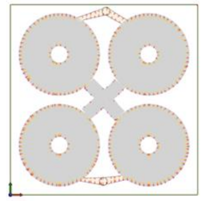


Fig . 07 Feed path in improved method old

Fig. 09 Shrinkage in old design

Fig. 09 Shrinkage in improved design

RESULT AND DISCUSSION:

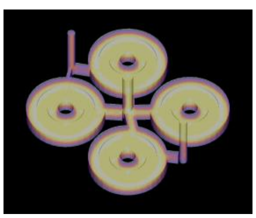


Fig 10. Hot spot locations old method

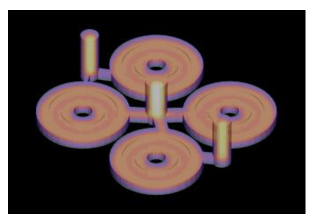


Fig 10. Hot spot locations in improved method

The comparison of the initial and modified casting designs on the various parameters are given below,

1.) Considering initial design for a disc, simulation results showing hot region in casting hence the its is not working properly and efficiently. Temperature observed at part side is 1106 max and Temperature in feeder side is 709 max.

2.) For the modified design simulation results showing hot spot shifted completely inside the feeder and no hot spot or hot region are shown in casting hence it’s working properly and efficiently. Temperature in feeder side is 1063 max and Temperature at part side is 865 max.

Simulation Result

Feed F	old Design	Improved design
Feeder		
Feeding Yield	96.36%	90.37%
Orientation	Side	Side
Shape	Cylindrical	Cylindrical
Weight	173.14 g	522.76 g
Volume	23.17 cm^3	69.94 cm^3
Diameter Top	13 mm	25 mm
Diameter Bottom	16 mm	35mm
Height	70 mm	75mm
Number ofNecks	2	2
Gating		
Pouring Temperature	1326 ºC	1326 ºC
Total Metal Head	75 mm	75 mm
Gating System Weight	398.8 g	509.57 g
Total Poured Weight	10.72 kg	11.51 kg
Gating Yield	96.14%	95.12%
Number of Gates	4	4
Total Gating Weight	115.83 g	60.44 g
Total Gate Area	10 cm^2	15 cm^2
Total Gating Volume	15.5 cm^3	8.09 cm^3
solidification time	2.57 min old	5.26 min
Temp in part side	1106 max	709 max
Temp in feeder side	865 max	1063 max
cavity filling time	3.49 sec	2.52 sec
Yield	92.77%	86.37%
Hot Spot	In part side	Shifted in Feeder side

Casting simulation clearly showed a hot spot region in part side, matching the casting defect in location & shape. The revised methoding was stimulated and analyzed for casting quality. From figure., we can see "Hot Spots" and the largest of them is being present at the feeder side. Therefore we could come to a conclusion that the above design of gating system for the circular plate is correct

Simulation now shows better directional solidification with hot spot shifting entirely to feeder, and leding to defect free casting. Sectional solidification and feed path and analysis at the critical section analysis shows improved temperature and gradient contours ,assuring the metal flow from the feeder to the casting.

The cause of the defect was correctly identified as an undersized feeder, used in simulation and this was corrected and verified by simulation again to achieve defect free casting . The revised methoding with modified feeding & getting system produce defect free casting with optimal yield. The rejection will eliminated by revised methoding.

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