Numerical Simulation for Casting Defect Prediction of Steel Casting -A Case Study

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ABSTRACT: Solidification of metal is the process phase transformation of the liquid phase to solid phase with the liberationism of latent heat of fusion. Metal solidification phenomenon is the great interest to casting engineers, metallurgist and software developers. It influences directly the quality of casting, production cycle time and utilization of materials (yield of casting). During this phase transformation process, it developed casting defects like shrinkage, hot tears, and porosity. To minimize these defects, the accuracy of proper design of casting and gating system is the basic necessity. We can predict those defects with casting design by means of numerical optimization (simulation) of casting solidification. In this paper, by using Autocast –X simulation software we made modification in gating system and develop casting free from defect, in particular, shrinkage defect. The product taken for simulation study was subjected to shrinkage defects which were the major cause for the rejection in the foundry industry. The yield of this casting is 58.84 % as per foundry data. The product under research study of master pinion gear with steel material, because of more thickness in the part has multiple hot spots. Therefore, optimum size and location of riser have been identified by using computer simulation trials. A simulation-based approach has helped in the improving yield of casting and quality of casting.

KEYWORDS: Casting Simulation, Gating system, Casting Defects, Casting Yield.

1. INTRODUCTION:

Metal casting is a versatile manufacturing process in which liquefied metal is poured into a mould cavity and allowed to solidify. Subsequently, the product is taken out of mould cavity, trimmed it and cleaned further proceed to finishing operations. Casting component can produce from few grams to several hundred tons and from simple shapes like a metal plate to most complex parts which have an intricate shape like engine blocks. The casting process is also called as a near net shape manufacturing process involving minimum or no further operations. Almost any type of metal or alloy which can be easily melted is cartable.

Casting has many process variations depending upon the casting material, the type of pattern, mould and the pouring technique like co2 moulding, sand casting, investment casting, die casting, squeeze casting and lost foam casting. Sand casting and co2 moulding is the most widely used process which can be used to produce heavy and intricate parts in almost every metal and alloy that can be melted. According to the worldwide census of casting production over 75 million metric tons of castings are produced annually. India is the third largest producer of castings. [1]

For a better production of castings everyone needs knowledge in the following operations:

i. Preparation of mould and patterns
ii. Melting and pouring of liquefied metal
iii. Solidification and further cooling to room temperature
iv. Inspection and quality control

Defects in the casting process are influenced by various parameters with their different levels. For any type of casting defect has several causes with their different category which are listed below such as defect arises due improper gating, moulding, pouring or melting related parameters. Proper gating design is one type of plumbing network through which molten metal is introduced into a previously prepaid mould cavity, fill completely and solidify t form desired casting shape.

2. LITERATURE REVIEW:

Tawele et al. [2] discussed the defect of metal casting i.e. warpage can be minimized. These will more valuable to quality control department of foundries for analysis of casting defects. Also, the casting numerical simulation technology has become an essential powerful tool for casting defect troubleshot and design modification. This will reduce the lead time for the sample casting improved productivity. In general, warpage can be eliminated by improper designing methoding and by referring methods which help in analysis of casting defects may minimize the rejection of casting

.Renukananda et al. [3] have studied in this work that flow of water and LM6 aluminium alloy through a multi-gate gating system have been compared using numerical simulation. As water, whose kinematic viscosity is of the same order as common molten metals, so can be used for experiments.

Shinde et al. [4] have suggested a methodology to optimize mould yield by selecting the correct combination of the mould box size and the number of cavities based on solidification time and mould temperature. The simulation results were verified by melting and pouring ductile iron in green sand moulds instrumented with thermocouples and recording the temperature in the mould at predetermined locations.

Gondkar and Inamdar [5] suggested that, numerical simulation which helps to visualize mold filling and casting solidification; predict related defects like cold shut, shrinkage porosity and hard spots; and optimize the casting design to achieve the desired quality with high yield. Flow and solidification of molten metals is, however, a very complex phenomenon that is difficult to simulate correctly by conventional computational technique. Use of simulation software, shrinkage defects optimized.

Sadekar et al. [6] yield is the ability of a foundry to manufacture acceptable casting in an effective manner. Improving yield offers many commercial as well as financial benefits to the foundry. Along with direct cost control, high yield is also associated with better process control and therefore improved cost control. By using computer simulation, an optimum gating system can be designed to improve the acceptability of the casting.

3. METHODOLOGY :

The experimental work carried out at medium scale foundry, which manufactures steel casting and ductile iron casting. When casting defect inspection was completed on casting major shrinkage defect and cold shuts was found. Due shrinkage defect, the casting was failed during ultrasonic testing. Simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program.

In casting numerical simulation the activity like, filling of molten metal into the mould and solidification process analysis is done with the help of algorithm or program based on vector element based, the simulation used to identify the hot spots and defects like shrinkage porosities, hot tears, cracks, etc. The casting solid 3D model has to be created using a solid modeling system e.g. catia or solid works and imported into the simulation software, further analysis. B.ravi [7] has suggested casting simulation and optimization methodology as shown in Fig. 1

Fig: 1 Flowchart of the Simulation Process.

3.1 Data collection:

In this paper entire study has been carried out in various section first casting design of “master pinion gear” with casting material is steel EN19 grade .calculation as per foundry information and drawing data, numerical simulation by using the Autocast-X simulation software. Next part simulation trials to predict the defect in gating system. To performed simulation data for gating system and feeding systems like the dimension of sprue, runner, riser, and ingates taken from development department. The actual drawing of master pinion gear with the 3D model as shown in fig 2.

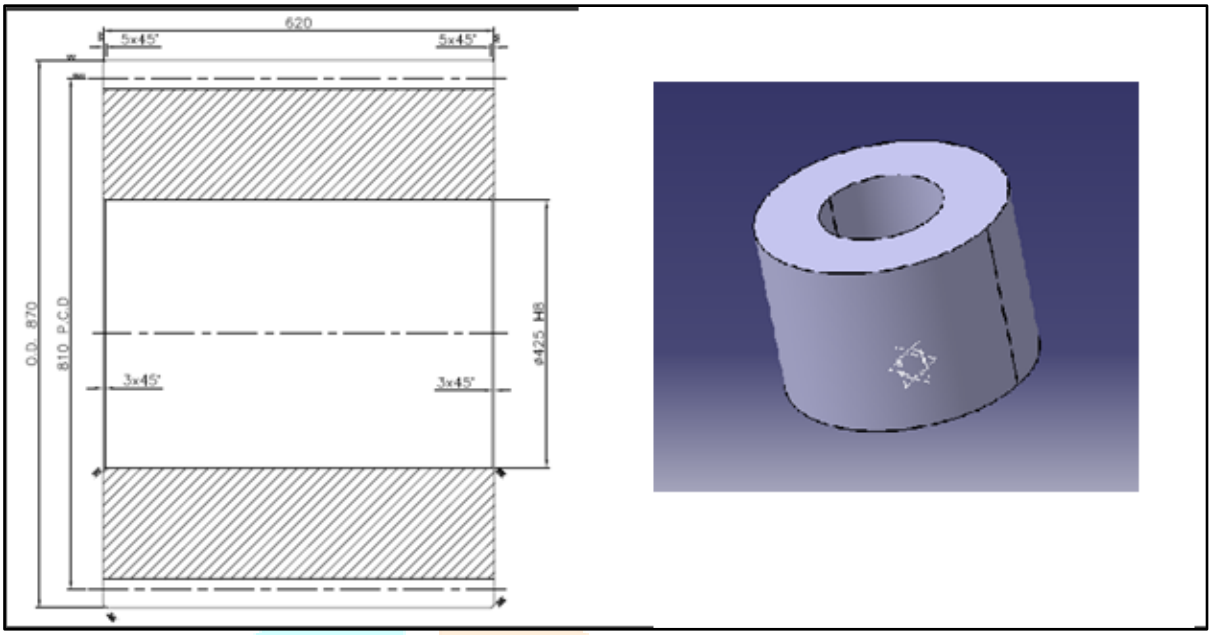

Fig: 2 Part Drawing and 3D model.

3.2 Simulation Results for Gating System:

Existing gating system is as shown in following figure 3. In this design, the sprue is connected to casting with four runners and four ingates. There are three blind risers and one open riser at the top surface of casting with two side riser are connected to opposite site of gating system. Exothermic sleeves are used for every riser to increase the efficiency and solidification time of casting for compensation shrinkage. table 1 shows the process details for existing gating system.

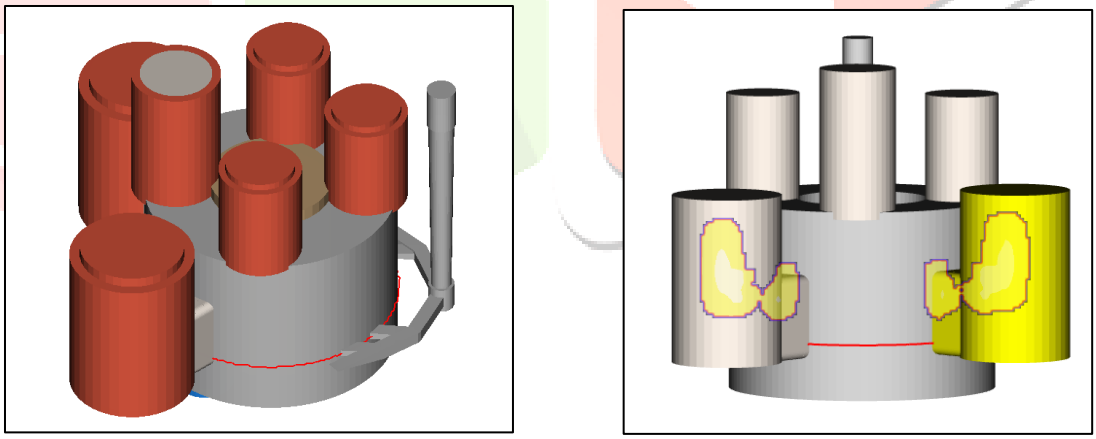

Fig: 3 3D model of gating system with simulation result.

Table 1: Casting Process Details.

No	Title	Details
1	Mould material	Co2 sand
2	Height of casting	620 mm
3	Tapping temperature (Tp)	1640-1625 ^{0}C
4	Pouring Temperature	1565-1550 ^{0}C
5	Pouring time	135-170 sec
6	Density of material	7880 kg/m3

7	Part weight of casting in mould box	2290 kg
8	Number of cavities in mould box	1No.
9	Total dimensions of mould box	1500 mm X 1400mm X 1200mm
10	Shape of mould box	Rectangle
11	Type gating system	Parting line gating system
12	Existing Yield of casting = $\frac{\text{Total weight of good casting}}{\text{Total weight of metal poured}}$	Yield = $\frac{2290 * 100}{3885}$ = 58.94 %

4. CHANCES OF DEFECTS:

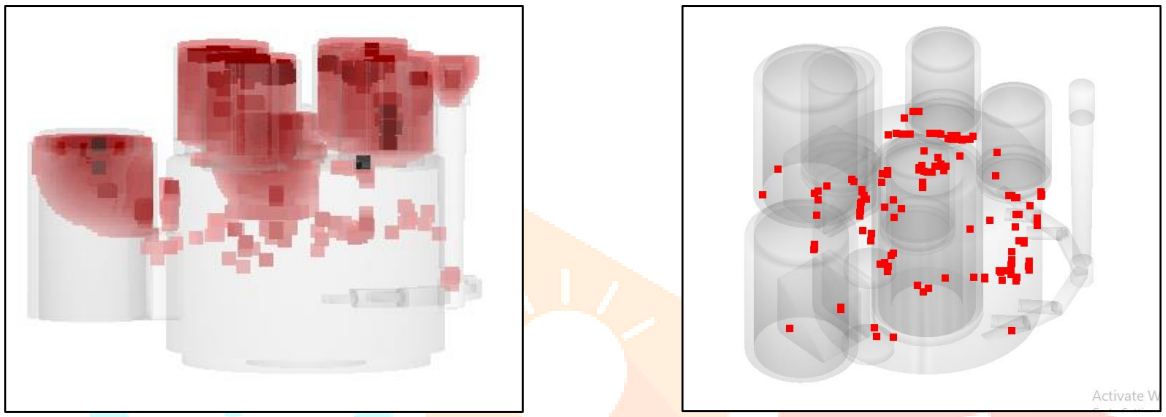

Fig: 4 (a) Chances of Shrinkage-Porosity in Casting (b) Chances of cold shuts

The simulation results show Fig 4 (a) and (b) that the hot spots are absorbed by the feeder. On another hand, microporosity has been found at an outer surface area of the whole part surface which is the influence of maximum casting thickness at that section which takes more time to solidify the molten metal and gets defected, the second image shows the cold shuts defect is identified the minor range in casting. To eliminate these defects certain modification in the gating system and design riser size, gating system as per gating ratio for steel material. Volumetric concentration is an important factor in the design of riser and gating system.value of material volumetric contraction is dependent on the material used for casting. We can also use chills for directional solidification of this component and to minimize the shrinkage area.

5. CONCLUSION:

Optimization of gating system helps minimize the defect and improves the quality or yield of casting. Casting simulation is used for the reduces shop flore trial also for new product development. Numerical simulation helps to identify the defects and their locations. With this simulation technique, the Feeding ability of casting process can be analyzed and optimized. A good design gating system provides smooth and laminar flow, with minimum turbulence to avoid entrapment of air, metal oxidation, and mold erosion.

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