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Gating System Optimization for Reducing Shrinkage Defect in Large Size Steel Casting

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ABSTRACT: Every foundry there is always compromise between the cost of casting product and the quality of product requirement. The metals solidification is to be a phenomenon of great interest to metallurgists, casting engineers and software developers. It directly affects the production cycle time, internal quality of castings and material utilization (yield). Besides, it is desired that the yield of casting is required maximum with the respective volume of feeder for shrinkage reduction having directional solidification. In this paper, an attempt has been made to redesign and develop a casting free from defects, in particular, shrinkage defect. The framework is presented based on cad model and simulation tool using catia and Auto-Cast software's. The component takes for methods and simulation study is master pinion gear having a high amount of shrinkage defect it causes continuously rejection. In this article experimentally observed that hotspots area is completely shifted towards feeder region. Whereas its remains at the center of non-feeder part of casting. Hence by using casting simulation to help us to locate optimum feeder size and location of feeder required. It is concluded that optimal size of feeder and gating system affect the quality of casting. Simulation of steel casting is performed by Autocast software and minimizes the defect by selecting proper size of feeder and gating system.

KEYWORDS: Simulation, solidification, design, Gating System.

I. INTRODUCTION

The metal casting is one of the basic manufacturing processes. It is the most primary process of manufacturing from last many centuries and even today it is observed that it is a most important manufacturing process. Casting application includes many auto parts, machinery parts, domestic used appliances, etc. The manufacturing a casting predicts preparing mould cavity of required shapes to be made for that liquefied metal is allowed to enter into the mould cavity of desired shape and size and it is allowed to solidify. Process development and methoding are designed to enhance the quality characteristics of process parameters which will greatly minimize the defects. [1, 2] Casting process is used for mass production of the items, which are large in size, with intricate shapes. The major steps required to be followed manufacturing of castings are moulding of sand, melting of metal, pouring of molten metal, solidification of molten metal, cooling of casting, fettling of casting, cleaning of casting, quality check of casting and elimination of defective casting. For a production of sound castings, a user should have the knowledge related to metallurgical, metal filling, solidification and casting quality inspection. Improper gating system leads to the casting defects. A casting defect is an irregularity in the metal casting that is undesired. Some defects can be tolerated while other can be repaired otherwise they must be eliminated. Those defects eliminated by modification in gating system and predicted the new gating system by virtual trial in simulation tool. Casting defects are classified into five main categories: gas porosity, shrinkage defects, mould material defects, pouring metal defects and metallurgical defects [3].

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II. LITERATURE REVIEW

Choudhari et al. [4] in this study, the component suffered from shrinkage porosity defect leading to premature failure. It also was subjected to incomplete fill due to sudden variation in thickness. Hence, it was necessary to redesign and redevelop the component. Component geometry has been modified without affecting its functionality by providing sufficient draft and radius at the junction. An attempt has been made to carry out the entire methoding, simulation and optimization in Autocast software. Reis et al. [5] concluded that the process modeling of shape casting is geometrically complex as well as computationally very challenging. Previously the methoding and defect prediction are modeled through empirical relations applied to the results obtained by simulation, which was not much reliable. Shang et al. [6] concluded that micro-porosity in Al-Si castings is the most detrimental defects leads to high scrap loss in the production of commercial castings and severely prevents their widespread uses in many critical load-bearing conditions. The effectiveness of the prediction of single solidification parameter and existing criteria functions was evaluated by correlating thermal data of simulation which was studied to experimentally obtained micro-porosity values. Svensson and T. Sjogren [7] concluded that models for microstructure and mechanical property prediction have been implemented into casting simulation software. The presently simulated casting is a ductile iron material and the critical parts of the simulation are a cooling rate, nucleation of graphite and the restriction of ferrite by the chemical composition. Su-Ling lu et al. [8] have observed the casting defects inside the surface of a wet-type cylinder liner such as macro segregation and shrinkage porosities and coarse-grained zone. Performing the simulation pro-cast analyze filling stage, casting temperature, mould temperature, simulation and Comparison of the simulated results and those of defects observation indicates that casting defects occur nearly at the same location.

III. PROBLEM IDENTIFICATION

The problem is identified by the industry i.e. Phoenix Ferrous Private Limited M.I.D.C Miraj Sangli. It produces castings catering to the needs of heavy engineering sector including integrated steel plants and also produces refractory items for steel and agricultural parts. Figure 1 shows the Master pinion Gear which is subjected to a high amount of Shrinkage. The ultimate objective is to reduce this shrinkage defect by changing the existing gating system. Find out new optimum gating system by virtual trial without wastage of material energy. A material used for this casting is steel EN19 and the actual weight of this component is 2250 kg.



Fig: 1: Shrinkage occurs at the center of casting

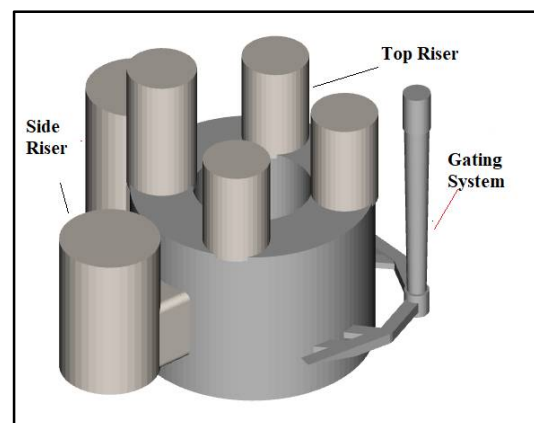


Fig: 2 Existing Gating System

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Figure 2 shows a model of existing gating system, which is used in the foundry. Existing gating system contains sprue, runner, ingate, and riser. In this gating system, four top risers are used on the top surface of the casting, three riser from which are a blind riser and one is open type riser is used. Whereas two large sizes of blind side riser are used at the side surface of the casting. The details about existing system are shown in following table 1.

Table 1: Existing gating system details

No	Title	Details	No	Title	Details
1	Mould material	Green sand	7	A part weight of the casting	2290 kg
2	Height of casting	620 mm	8	Number of cavities in a mould box	1No.
3	Tapping temperature (	1640-1625 °C	9	A shape of a mould box	Rectangle
4	Pouring Temperature	1565-1550 °C	10	Type gating system	Parting line gating system
5	Pouring time	135-170 sec	11	Size of box	1500 mm X 1400mm
6	Density of material (L)	6980 kg/m ³	12	Existing Yield of casting =	Yield = $\frac{2290 * 100}{3885}$ = 58.84 %

As per details are given for existing gating system from a foundry, take as an input parameter in numerical simulation (Autocast-X simulation software).simulation is performed. The simulation does prediction of the stages of filling, solidification, and important one shrinkage defect their size and location in cast component. Figure 3 shows that red colour area is shrinkage in casting. Here we can see riser is insufficient to remove or eliminate shrinkage from casting. it is usually difficult to eliminate porosity completely from metal castings while reducing it or moving it to an unimportant area can be a choice. For moving this we have to do some modification in this system by calculation method find out the riser and gating system dimension which are sufficient for moving this defect into an unimportant area. Below design of riser and gating system calculation is completed and get new dimension for new methoding for this cast component.



Fig: 3 Shrinkage Defect predictions by simulation

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III. DESIGN FOR NEW RISER AND GATING SYSTEM

a) DESIGN OF RISER:

Design of riser by Modulus method:

A volume of the casting = $0.29 \times 10^6 \text{ mm}^3$

A surface area of the casting = $3.02 \times 10^6 \text{ mm}^2$

A volume of the riser = $\pi D^3/4$

A surface area of the cylindrical riser = $\pi D^2 + \pi D L/4$
= $1.25\pi D^2$

Where D is the riser diameter.

Modulus of the casting = volume of the casting/surface area of the casting
= $0.29 \times 10^6 / 3.02 \times 10^6$
= 96.02

According to the formula

Modulus of the riser = 1.2 * Modulus of casting

= 1.2×96.02

= 115.231.....Eq. 1

Now,

Modulus of riser = $(\pi D^3/4) / (1.25\pi D^2)$

D/5.....Eq.2

Comparing eq.1 & 2

A diameter of riser 576.15mm and height of the riser is 460 mm.

b) DESIGN OF GATING SYSTEM:

Pouring time- The time for complete filling of mould termed as pouring time.

Pouring time 't' = $1.012 \times \sqrt{W}$ sec.....For steel casting

Where,

W = mass of the casting, kg

t = $1.012 \times \sqrt{8500} = 93.30 \text{ sec}$

Choke area/ sprue bottom area A = $W/dt\sqrt{2gh}$

Where,

W = casting mass, kg

d = density of molten metal kg/mm³

H = effective height of metal head (sprue height) in mm

C = efficiency factor for gating system

t = pouring time (sec)

$$\frac{3750}{6.981 \times 10^{-6} \times 93.30 \times 0.9 \times \sqrt{2 \times 9810 \times 1000}} = 1444.24 \text{ mm}^2$$

So
$$= \frac{\pi d^2}{4} = 1444.24$$

d = 42.88 mm

Sprue top area = 2 * sprue bottom area

$$= \frac{\pi D^2}{4} = 2 \times 1444.24$$

D = 60.64mm

For steel we have taken gating ratio = 1: 2: 2 Using this gating ration we can find out the all the dimension of gating system such as runner and ingates.

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c) Modified Gating System and Simulation Results

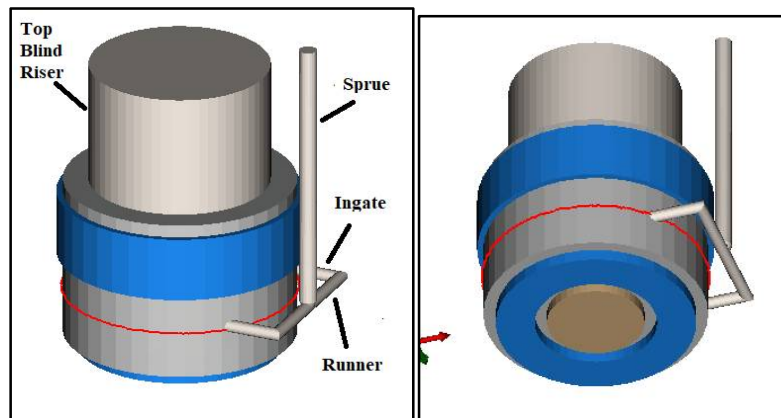


Fig: 4 New Modified Gating System

As per the above design calculation dimension of riser and gating system is calculated. Here we can see cylindrical riser is kept at the above surface of casting with considering assumption. Our part is in symmetric in nature so we take cylindrical riser at the top surface of the casting. Gating system is connected through the sprue, runner, and two ingates. In figure 4 shows we use two hollow circular chills (blue color parts), to get a chilling effect and optimum directional solidification. 3D model is created in CATIA software. AutoCast-X simulation software is used to perform virtual trial casting. Simulation results are predicted.

IV. RESULT AND DISCUSSION



Fig 5: Shrinkage Defect

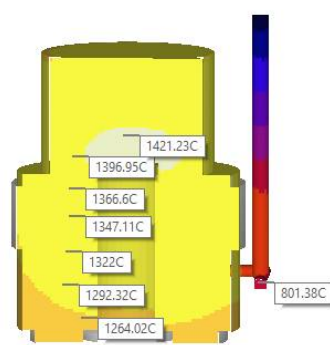


Fig: 6 Directional Solidification

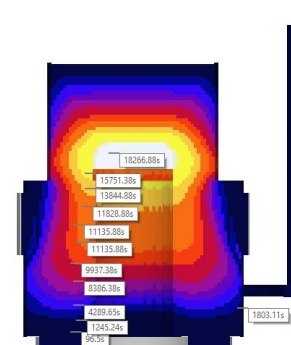


Fig: 7 Solidification Time

In this section we can see after performing the virtual trial, results are predicted by simulation numerical tool. In first existing virtual trial result fig 3 shows shrinkage defect is at center, after modification of this gating system. Fig 5

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shows the shrinkage defects moving into the unimportant area i.e. feeder because feeder size is sufficient to move this defect. As well as directional solidification is achieved fig 6 shows cut section of casting temperature is noted down. Temperature goes 1264.02^o C to 1421.23^oC increases towards the direction of feeder that means sound solidification is done. Fig 7 shows time required for solidification is predicted by this simulation tool which equals to 18266 sec approx 5 hrs and 7 min. 6.04% yield improvement of this modified gating system is done after modification in dimension in feeder size and gating system. The yield of casting is calculated.

$$\text{Modified Yield of casting} = \frac{2290 \times 100}{3571} = 64.12 \%$$

V. CONCLUSION

- Casting Simulation is very important and powerful tool which is used to predict the correct location of gating system and riser so as to reduce defect.
- Using simulation tool we can easily perform a virtual trial of casting without wastage of material, money, man power, and energy.
- After doing the simulation of gating system by AutoCast software it is found that the hotspot is exactly at the center of the cast component and after modify system and using chill hot spot is move into the riser in next simulation.
- This facilitated the optimized placement and design of feeders with improvement in yield by 6.12 % while ensuring casting soundness without expensive and time-consuming trial runs

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