Minimization of Gas Porosity through Casting Simulation Tool for Sand Casting

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Abstract— Porosity is the one of the defects most frequently encountered in ductile iron casting. Porosity formation cause costly scrap loss and limits the use of cast parts in critical high strength applications. The amount of porosity is closely related to sand casting processes parameters. A considerable reduction in porosity formation can be obtained using optimization technique in the sand casting process. Casting is a manufacturing process to make complex shapes of metal materials in mass production may experience many different defects such as gas porosity, pin holes, blow holes, shrinkages and incomplete filling. The Gating/riser system design play very important role for improving casting quality. Due to the lack of scientific procedures the design process is normally carried on a trial-and-error basis. The main objective of this paper is to redesign the components using Auto-CAST X1 simulation software and increases the product life. Many researchers reported that 90% of the defects in casting are obtained only because of wrong design of gating and feeding system and only 10% due to manufacturing problems. In this paper to study the solidification behavior of material, detection of hot spots, blow holes and removed such defects in the casting with the help of mentioned casting simulation software. The simulated results also compared with experimental results.

Key words: Gas Porosity, Casting Simulation Tool, Sand Casting

I. INTRODUCTION

Gating and Feeding system plays very important role for any casting. Risers are used for compensating for the solidification shrinkage which occurs during the process of solidification [1]. Generally this can be visualized as if these sections feed thinner sections; so, thick sections experience deficiency of molten metal at last and that location contains no metal resulting in defects such as shrinkage cavity. For any newer casting, the development of gating and feeding system takes huge amount of time, cost as well as man power for the manual trial and error method. Sometimes, existing method of castings does not serve its purpose and need modification. All these problems can be effectively handled by Casting Simulation technique [2-3]. Simulation involves construction of mathematical models for any physical process and performing repetitive iterations on those models so as to predict the behaviour or growth of the process. In case of castings, the simulation software is already developed to provide artificial environment of foundry for performing experiments virtually. Web resources are also available now to run basic simulation which eliminates need of expensive software. Casting simulation comprises of three modules namely Solidification, Flow and Coupled simulations. Out of these three, Solidification simulation can be used to detect locations of hot spots and show the feed-paths; hence it can be used for designing and modifying the feeding systems [4]. Flow simulation can give the idea about velocity of molten metal during mold filling, filling time and solidification time, which in turn helps to locate flow related defects such as cold shut, misrun, etc [5]. Till date several researches have used casting simulation software for design optimization of gating and feeding system. the well-designed runner and gating system is very important to secure good quality die castings. Two types of runner and gating systems were designed and analysed. A preliminary design with a split gating system led to a swirling filling pattern and insufficient central flow, which spontaneously closed the edges and left the last filled areas falling into the inner portion of the part. After that, a high possibility of air entrapment was found in the casted part and then examined the suggested gating system was not proper and improved by using a continuous gating system and a large size runner. After that change was made by increased the gate area and the gating speed reduced slightly. Numerical simulation showed that this new design provided a homogenous mold filling Pattern and the last filled area was located at the upper edge of the part, where overflows and the vents were conveniently attached. Bhatt H. and Barot R.[7] has suggested that the design optimization of feeding system and simulation of cast iron in foundries can reduced the casting defects which were arise during solidification and filling process. Time to changed riser and feeding system dimensions and simulate with the help of Auto-CAST software and validate it and found reduction in hot spot and shrinkage porosity and cracks in gear box of automobile components. Zhizhong s et al. [8], suggested that the numerical optimization of gating system parameters for a magnesium alloy casting with multiple performance characteristics in magnesium alloy base casting to analyzed the effect of various gating system design on cavity filling and casting quality using simulation results indicated that gating system design affects the quality of casting, four gating system parameters were changed namely ingate height, ingate width, height of runner and width of runner for casting model of magnesium alloy, designed and simulated mold filling and solidification processes through MAGMASOFT software and satisfactory results obtained with high yield and reduced shrinkage porosity. The casting design and simulation of cover plate using autocast-x software for defect minimization with experimental validation studied Chaudhari C.M and Narkhede B.E [9], suggested that the significant improvement in the quality of casting obtained by optimization of location and design of gating and feeder system through simulation technology and minimized shrinkage porosity and cracks in casting. The effect of gating system design on mold filling for light metal casting and experimental studied Masoumi et al. [10], results shown that the geometry and size of the gate and the ratio of the gating system has a great influence on the pattern of mold filling and suggested that the application of CAD method, and casting simulation technique in foundries can minimize the bottlenecks and non-value added time in casting improvement.

II. METHODOLOGY

Figure 1 shows the drawing of a typical wear plate and Table 1 shows its specification. The wear plate casting model were generated in Pro-E modeling software and with essential elements of the gating system like in gate, runner, sprue and risering system were generated in Auto-CAST X1 simulation software. The gating system was implemented to optimize the gating system for wear plate of sand casting. The methodology adopted for gating and risering system are as fallows.

Parameters	Values
Part Name	Wear Plate
Material	Ductile Iron
Grade	SG 69-45-12
Length of plate	342
Height	596
Thickness	38
Weight	49.50 Kg

Table 1: Specification Of Pump Casting

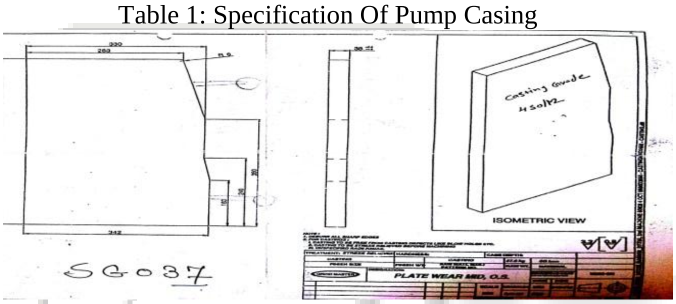

Fig. 1: Typical Wear Plate

A. Designing the gating System:

Conventional gating system for Spheriodal Iron (SGi) casting, a mold cavity must be filled with the clean molten metal in a controlled manner for the casting to be free of discontinuities, solid inclusions, voids, gas porosity, blow holes etc. the main objective of designing of gating system is to lead clean molten metal poured from ladel to the casting, ensuring smooth, uniform and complete filling. Theoretical concepts and casting rules are some of the design consideration taken into account to calculate gating system needed to ensure shrinkage free casting. Gating system design considered is shown in table II.

Parameters	Type/Dimensions/value
Gating system	Parting line
Gate Type	Edge
Runner Type	Rectangular
Sprue type	Cylindrical
Gating ratio	1:2:1.5
Runner area	8.01 cm^2
Ingate area	6.08 cm^2
Sprue area	792.75 mm^2
Gating yield	94.68%
Pouring time	18 sec
Mold cavity height	38

Table 2: Parameters And Dimesions Of Gating System

B. Design of Riser System:

Riser is designed to compensate the solidification shrinkages of a casting and make it free of shrinkage porosity. The pressure control Risering system design sequence involved firstly determining casting significant modulus (MS), then corresponding modulus of riser neck (MN) and modulus of riser (MR). Riser neck dimensions are measured at the bottom of the radius between riser and casting. Additional notching of the contact was introduced with notch depth not more than fifth contact thickness.

Parameters	Formula	Values
Volume of casting	-	6906420 mm^3
Surface area of the casting section	-	456872 mm^2
Modulus of the casting section (Ms)	Volume/ surface Area	15.1 mm
Modulus of the riser (MR)	1.2x MN	100 mm
Diameter of the riser	6x Modulus of riser diameter	45 mm
Height	-	125 mm
Numbers of riser	Based on number of major region of shrinkages porosities	2

Table 3: Modulus Parameters For The Riser

C. Feedaid:

Feedaids include chills, insulation and exothermic materials, which are used when progressive directional solidification cannot be achieved by riser alone. Chills increase the local rate of heat transfer and reducing the local solidification time. They are made of copper, iron/steel or graphite. They may be rectangular blocks or cylinders. Table IV shown that dimension and parameter of chill.

Parameters	Values
Type	External
Material	Iron
Weight	587.2 g
Density	8940 kg/m3
Area	32.37 cm^2
Thickness	20 mm

Table 4: Parameter And Dimensions

D. Simulation process:

Auto-CAST is casting simulation software developed by IIT Bombay. This was used to simulate fluid flow and solidification process for gating design, riser design. Casting simulation and result analysis was done to predict the molten metal solidification behavior inside the mould. The casting component of 3D model was made in Pro-E cad modeling software in STL file format and imported into Auto-CAST software and meshing of the model was done in the preprocessor 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 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, liquids and solidus temperatures of SG Iron and other input parameters of fluid flow and solidification conditions, like pouring time, pouring type, direction of gravity etc. were assigned. Table V, VI and VII show the input material properties, Mold Specification, fluid flow & solidification parameters. After the assignment of material properties and simulation conditions, predication 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.

Parameter	Values
Pig Iron	100 Kg
CRCA Bundle	400 Kg
Carbon	19.7%
Silicon	9.7%
Inoculant	0.8% (150 gm/ laddle)

Table 5: Input Material Properties And Liquids Condition

Parameter	Type of Mold	Condition
Material	Green sand	SG 450/12
Parting orientation	Horizontal	Horizontal
Density	1.5 gm/cm^3	6.9 gm/cm^3
Intial temperature	20^0c	1480^0c
Liquidus Temperature	-	1200^0c
Solidus Temperature	-	1100^0c

Table 6: Mold Specification And Condition

Parameter	Input Condition
Molten Metal Temp.	1530^0c
Pouring Temp.	1380^0c
Velocity of fluid flow	22.6 cm/s
Filling Time	16 sec
Filling Rate	5.48 Kg/s
Output files	– Air entrapment – Gas porosities – Shrinkage porosity – Solidification Pattern
Risier Type	Open

Table 7: Input Fluid Flow and Solidification Parameter

III. RESULTS AND DISCUSSION

A. *Air Entrapment:*

Figure 2 shows that the molten metal at the botton portion and air sweeping (Blue color) from the top portion of casting surface of mold cavity. From the simulation result it is clear that as the mould is filled with molten metal, air escape through the top of the mold surface. The ingates and runner bar placed accordingly due to which even flow of melt makes the air gently to rise above, as the metal starts filling from the bottom to top of the mold cavity.

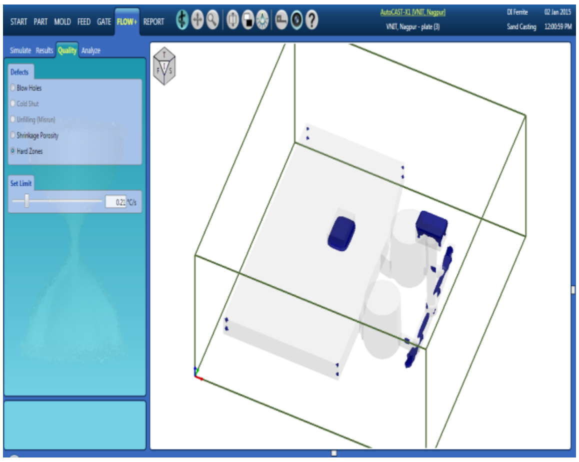

Fig. 2: Air Esaping From Mold Cavity

B. *Solidification and temperature Distribution:*

The actual solidification of metal begins at liquids temperature of 1380^0c (Reddish Yellow color). The solidification of metal ends at solidus temperature 1140^0c (yellow color)

Figure 3(a) shows the temperature distribution of the molten metal. The metal is in complete contact with the mould surface (no air gap is formed). Temperature distribution is also uniform because of ingates and runner are symmetrically placed. Figure 3(b) shows that there is no hot spot present on the surface of matel part all the hot spots goes to the riser (yellowish color).

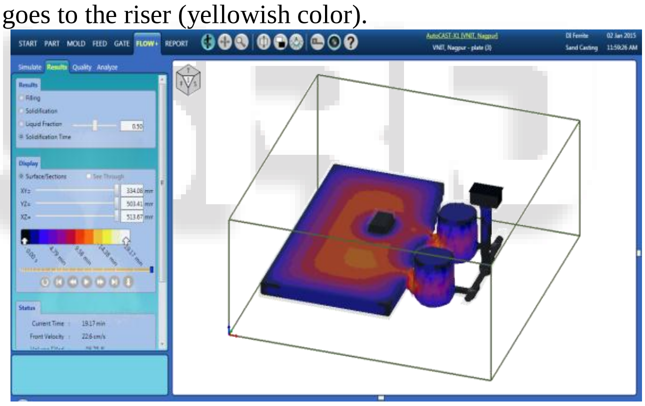

Fig. 3(A): Solidification Analysis

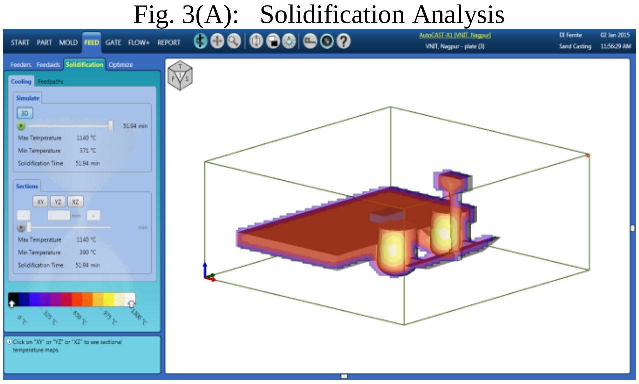

Fig. 3(B): Hot Spot In The Casting

C. *Shrinkage porosity:*

Figure 4 shows shrinkages porosity in the casting components for the first iteration of gating system. It has been observed that the shrinkage porosity at three different location observed. After changing the dimensions of feeder and ingates found no such type of shrinkages porosities observed which is shown is figure 4(b).

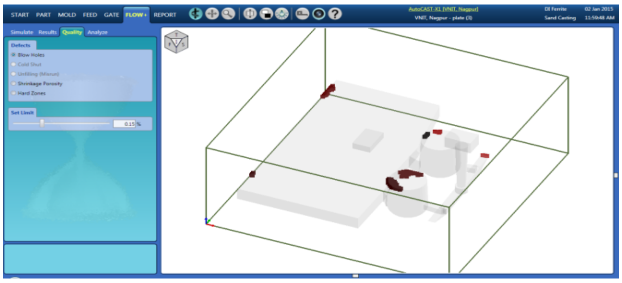

Fig. 4(A): Shrinkage Porosity In Casting

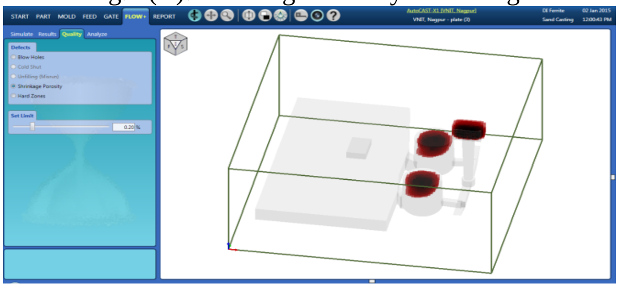

Fig. 4(B): Shrinkage Porosity Escape From The Casting

D. Solidification Analysis:

Figure 5 (a) shows that solidification behavior of molten metal in the mold cavity. In that placed seven thermocouple at different location or places and check on where the solidification takes more time to solidify the molten metal. After it is observed that more time consume at the center and very less time consume at the end of the part for solidification and which is shown in figure 5 (b).

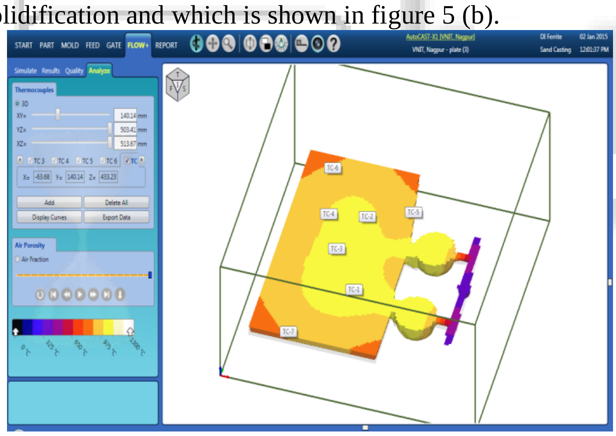

Fig. 5(A): Temperature At Various Locations

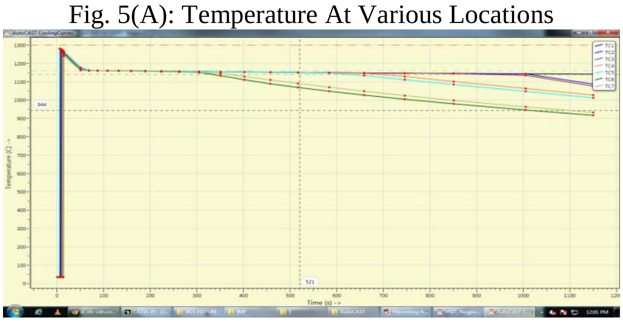

Fig. 5(B): Temperature Vs Time Curve

IV. EXPERIMENTAL RESULTS

Figure 6 (a) shows that finished part of wear plate after removal from sand mould. There are no blow holes and shrinkage porosity observed on the surface of the casting and improved surface texture. Similarly figure 6 (b) shows that finished surface of casted part after machining 15mm from top of the part and found no gas porosities and blow holes, shrinkages found in the part.

V. CONCLUSIONS

In this present work a 3D component model was developed using Auto-CASt X1 simulation software to evaluate possible casting defects under suggested gating system design for sand casting of wear plate. In that horizontal type of gating system adopted and examined result through numerical simulation and an optimized design was chosen through this process.

- By adopting the parting line and horizontal gating system, the fluid flow was smooth and uniform throughout the casting. no turbulence was occurred at the ingates and therefore gases not entrapped in the casting. air was expelled without any entrapment inside the mold cavity.
- Simulation showed that metal was able to fill the mould within the desired time and therefore the fluid heat distribution was good and no cold shut was observed.
- By using spherical bottom feeder with exact location and dimension no shrinkage porosity, blow holes, gas porosity found. The symmetric locations of ingates and feeder helped to drive solidification.
- The first iteration resulted the shrinkage porosity found on three different location and after that it was reduced by 70% and gas porosity reduced by 85% which by industry standard is acceptable and also observed that time required for solidification of molten metal after pouring of metal resulted in solidification or cooling curve graph

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