STM JOURNALS

Journal of Production Research & Management
ISSN: 2249-4766(online), ISSN: 2347-9930(print)
Volume 6, Issue 1
www.stmjournals.com

Casting Simulation using ProCast–A Review

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Abstract

Productivity improvement is the need of current market and manufacturing sector globally. In India the manufacturing sector is concentrated towards the casting process and majority of the products are manufactured by casting process. Various factors and parameters affect the quality and productivity of the casting process. Due to variation in these parameters various types of defects and shortcomings come to the scene during the casting process. In this review paper author aims to study the casting process and the shrinkage porosity occurring during the process. The defect has been eliminated using the simulation process and the various parameters are analyzed. Optimum parameters are found and validated using the mathematical model. The simulation has been done using Pro-cast software and the optimum results are obtained. The results obtained indicate that the computer simulation results are quite accurate and reliable.

Keywords: *Casting, shrinkage porosity, simulation, Pro-cast*

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INTRODUCTION

The demand of the global market is high quality products with lower costs which can be achieved through appropriate controlling of the production process. In India casting process is considered as a very vital process used for producing a variety of products.

Casting is considered a very ancient technique in which the molten metal is poured in the mould and allowed to cool and hence the desired shape can be obtained. So it is very important to control various parameters of the process to achieve quality products. Casting process involves number of process parameters so it is difficult to produce defect free casting even in a controlled process, defects in casting are observed which challenge explanation about the cause of casting defects [1].

Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameters in casting process. Even in a completely controlled process, defects in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects [1].

To find and eliminate defects and problems in the casting process is a very tedious task. To assist in this problem, the recent technological advancements suggest the use of computers and other simulation techniques to eliminate the various defects surfacing during the casting process. Many computer aided tools and software are being used such as Pro-cast, Soft-cast, Auto-cast, Magma soft and various optimizing tools such as FMEA, ANOVA technique, FEM, VEM, Pareto analysis are being frequently used to assist in defect elimination.

Following are the various methods for elimination of casting defects as explained by various authors:

- Lu aims on the wet type cylinder liner produced by horizontal centrifugal casting and defects like macro segregation and shrinkage holes. After simulation and optimization of the solidification of the WTCL model using casting software, temperature field can be found. Author investigates starting time for water cooling, variation in mold wall thickness, thermal insulation criteria and coating thickness, through which coating thickness is the most influential parameter on the defect area. After study, the optimum method was proposed [2].

- Casting expert Ravi explains that engineers use simulation software for assuming quality and yield optimization without trial and error on shop floor. Here simulation program should be fast, reliable, user friendly, and cost efficient which is possible by automation of feeder location calculation of minimum size, solid model creation and solidification simulation. Here algorithms including geometric reasoning, automatic solid modeling, and vector element method reduce simulation iteration time and verify manufacturing of casting [3].
- Ravi and Srinivasan have reviewed few geometry-driven analyses for casting driven solidification. The new method is based on the direction of largest thermal gradient of any instant. Influence of cores, gating, pouring can be accounted through this method. Also, effects of feeding aids, chills, insulations and exothermic materials can be estimated through this. They concluded that geometric method is a vital substitution for numerical simulation in defect prediction areas in casting. This application is versatile, accurate and user friendly. Industry and laboratory validated the system. It is first applied for 2D cross section and then for 3D object [4].
- Behera observed that around 90% of all the casting defects are because of improper design of gating, feeding, and rise ring system and rest is due to production faults and human errors. For simulating such defects FEM and VEM based methods are widely used. Here author has worked on casting product of aluminum alloy LM6 and simulation results have been experimentally proven. It shows that optimum value of riser neck drastically reduces the shrinkage porosity defect and also minimizes the iteration time for method modification and finalizing safe design [5].
- Rao has worked on a crushing component and load bearing structure which requires good mechanical properties and zero porosity. The combination of CAD technologies and process simulation tools helps in achieving this in a given limited time span. This study helps in reducing scrap rates due to unpredictable defects [6].
- Suleiman focuses on validation and validity of MAGMA soft for casting simulation. Previous research work data has been used to validate. Control point temperature details in the casting job are used for qualitative comparison between computation and experimental studies in spite of hot spot found in middle, the directional solidification in the runner if found. Here validation is successful. MAGMA soft helps in designing sprue, mold feeder runner and gating system due to high fidelity of the software. This much validation also opens the door for using it for gravity die-casting and low-high pressure die-casting [7].
- Umezurike did an analysis of grey cast iron casting object, core prepared with phenolic urethane no-bake binders. Paper shows pouring temperature above 1482^{o}C Poor binder dispersion and binder ratio favoring higher level of poly isocyanate component of the binder increases porosity, while an addition of 0.5% zirconium, 0.025% of titanium, 0.25% of ferrous oxide reduces porosity [8].
- Kinagi has combined design of experiment (DOE) and FMEA for analysis purpose. FMEA and Pereto analysis has been used for defect analysis. The sand casting parameters have been optimized using DOE. Pareto analysis has showed defect and their causes, FMEA showed potential failure mode [9].
- Dabade examined for optimization of process parameter, DOE and computer aided simulation are used combined. For experimental purpose Taguchi L18 Array and ANOVA-Minitab for analysis were used. Then the developed solid model of the new gating system was analyzed. With developed design and parameters 15% of reduction in porosity was noticed [10].

Hence, it can be stated from the above study that out of all the casting defects, shrinkage porosity is the main cause which affects the quality of the products. This defect can be eliminated by selecting proper process parameters. The different process parameters can be optimized by using various optimizing techniques such as ANOVA, Pareto analysis, and FMEA. Also various simulation software such as Pro-cast, Magma soft, Soft-cast can also be very much helpful in eliminating the defects.

METHODOLOGY

Modelling of a Casting Process

In a regular casting simulation software the simulation takes following three steps:

1) Pre-processing: Mesh is generated by reading the 3D model of the casting object,
2) Main processing: Applying appropriate boundary conditions, given material data, mould filling and temperature calculations,
3) Post processing: solution and detailed evaluation.

The tree diagram is shown for system of simulation and to improve the casting process design. This type of design procedure has already been implemented in various casting object defect analyses.

Fig. 1: *Casting Process.*

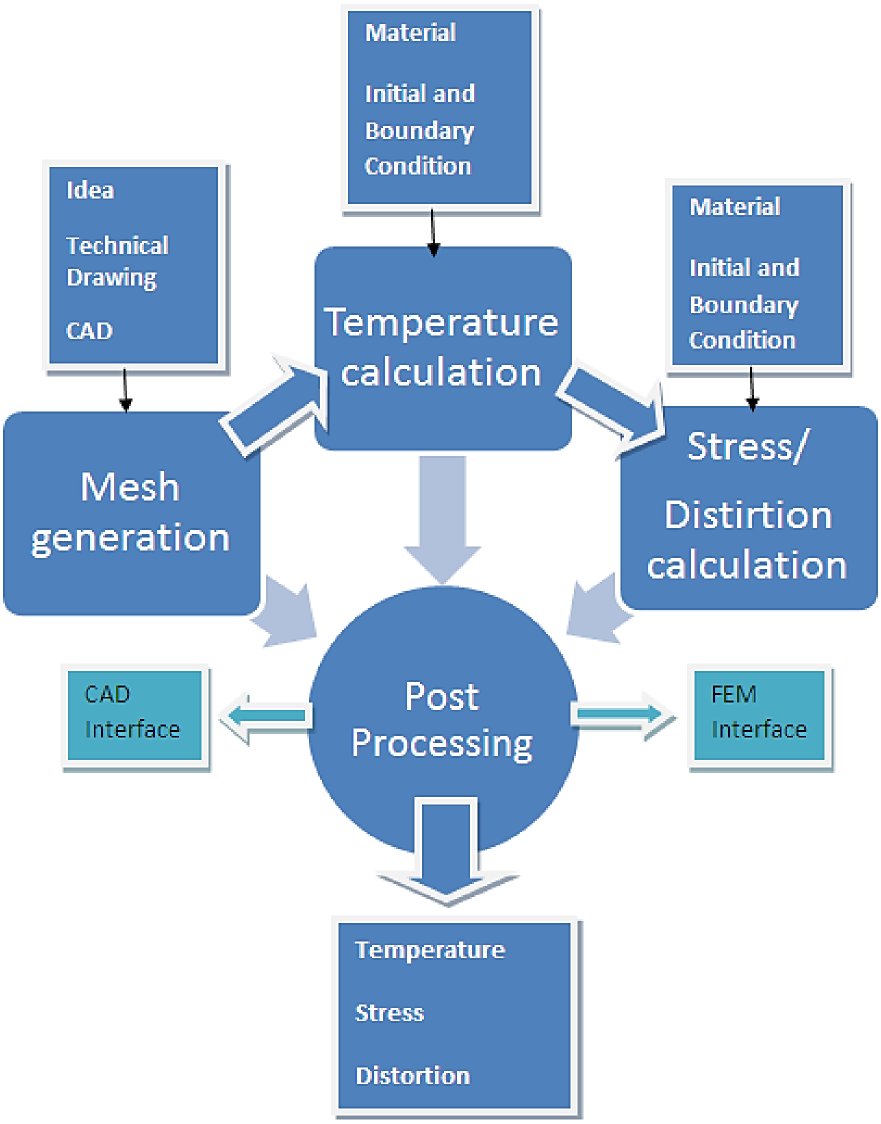

Fig. 2: *System of Simulation.*

Methodology utilized here is casting simulation and analysis of the solidification results. In order to achieve better properties, optimization of casting parameters is done. The procedures consist of three stages. They are:

1 Simulation preparation,

1. Computer aided simulation on Pro-cast,
2. Analysis.

Each stage contained several steps. This has helped to examine different influencing factors, such as mould material, inlet velocity, molten metal temperature, and substrate pre-heating temperature.

Mould Filling

In the present case we compare the solidification simulation results of the automotive wheel rim castings at different time intervals and different gating systems as shown in the Figures 4–6.

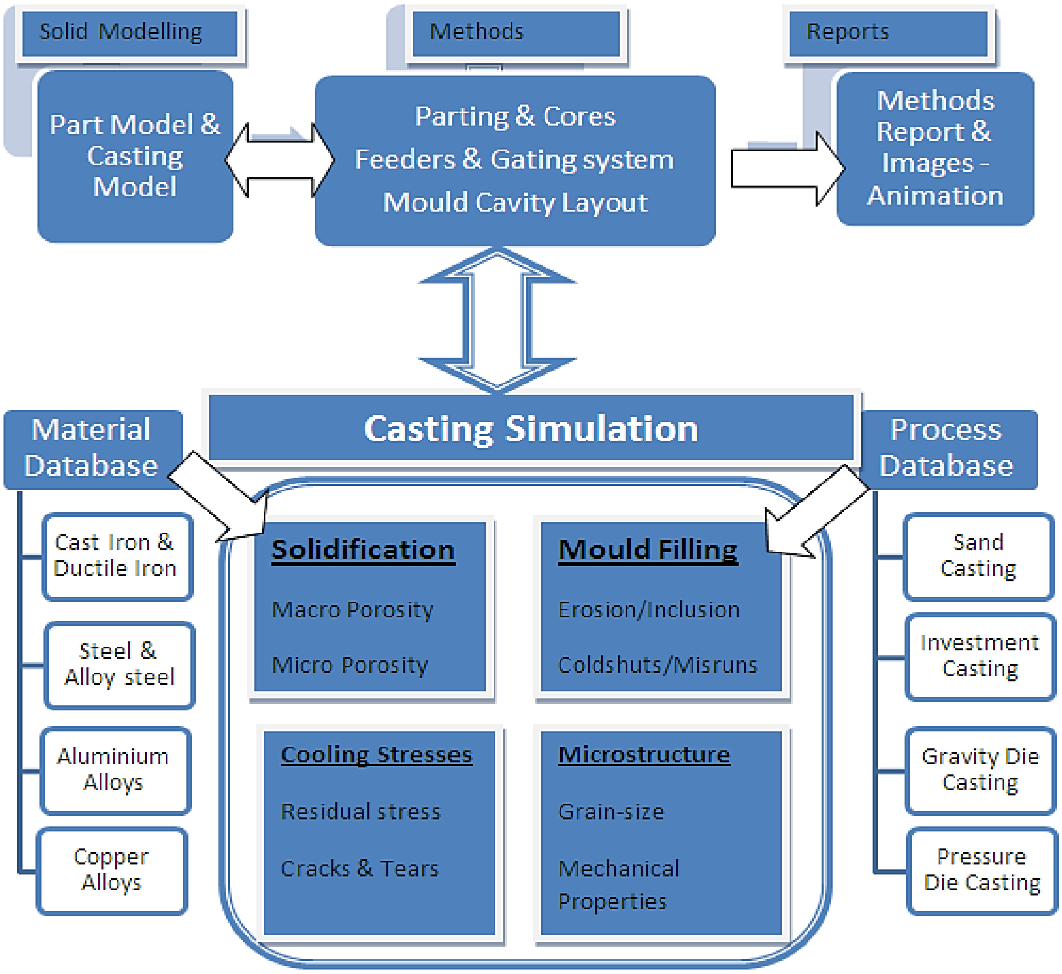

Fig. 3: *Methodology.*

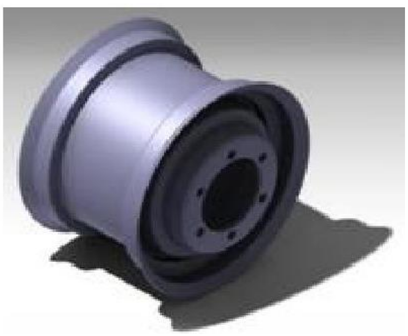

Fig. 4: *3D Model of Wheel Rim.*

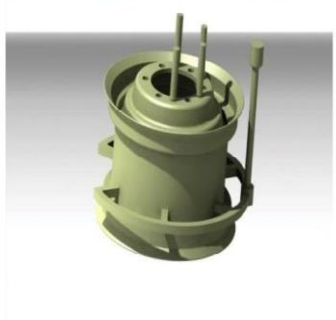

Fig. 5: *3D Model of Initial Gating System.*

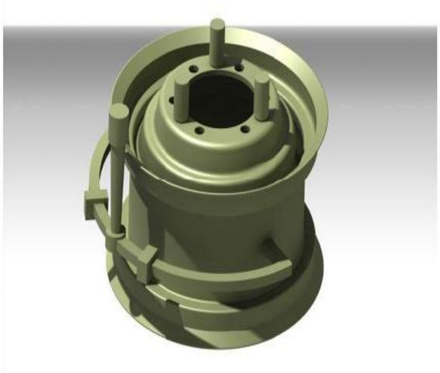

Fig. 6: *3D Model of Modified Gating System.*

Using the given inputs mould filling will be carried out in the boundary condition manu bar. The flow rate and velocity of the liquid metal van be carried out and controlled by the user himself as per the requirements of the component material characteristics. Major thing in Pro-cast simulation solver is that mould filling and simulation of the solidification can be carried out at the same time. The mould filling processes of the initial and modified gating systems are shown in Figures 7–8.

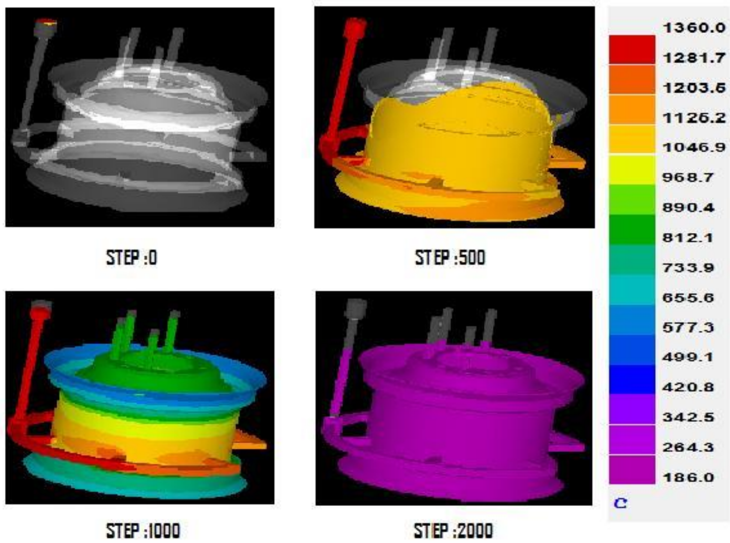

Fig. 7: *Mould Filling and Temperature Variations of Initial Gating System at Various Stages Respectively.*

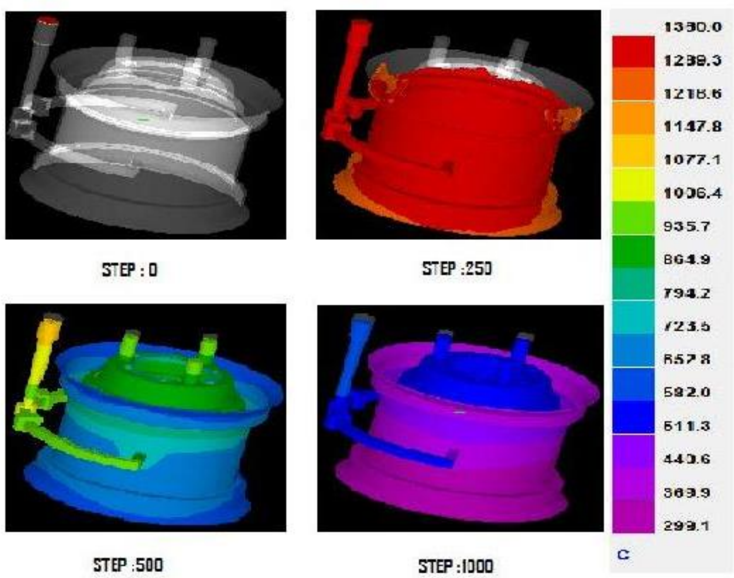

Fig. 8: *Mould Filling and Temperature Variations of Modified Gating System at Various Stages Respectively.*

Fraction of solid and its temperatures are changing which encompass pouring basin, sprue, runner system, gatings, casting and feeder for every iteration of every second. Here down sprue and feeder have similar shapes; which results that both of them are filled simultaneously. We can see that though despite of being the entrance for the molten metal the down sprue does not seem to be completely wet. Straight runner and optimum design makes the mould filling successful. In a first few seconds straight runners and feeders are filled easily and quickly.

Solidification and Gating System

Around the span of 1360 and 700°C entire solidification process is done. Heat transfer from internal casting to external environment helps the solidification procedure. This heat transfer during the solidification goes from various phases mentioned below:

1) Internal liquid convection above liquidizing temperature during mould filling.
2) The solidified metal conduction after complete solidification achieved throughout the bulk of casting.
3) The heat conduction at the metal mould interface.
4) Heat conduction within the mould.
5) Convection and radiation from mould surface to the surrounding.

Volume to the surface area ratio influences largely the solidification time. They are directly proportional to each other, which is the reason of faster solidification rate at the runner tip. Longest solidification time is consumed by the mould cavity at the centre. For a given casting element more than one possibility are there; and tried and tested in the Pro-cast software. Pouring temperature is around 1200°C. The free end distortion defect commonly seen in plate casting can be reduced by choosing proper gating system design. Major defect with this gating system is that the ingate solidifies earlier the liquid metal reaches the mould which causes major partial filling in the core area.

In addition to that, increasing the molten metal temperature reduces the high turbulence and molten metal at higher temperature reaches easily to every cavity and solidifies gradually. At 700°C another simulation is carried out and defect free casting is achieved. The initial gating system caused high turbulence and high amount of stress in casting.

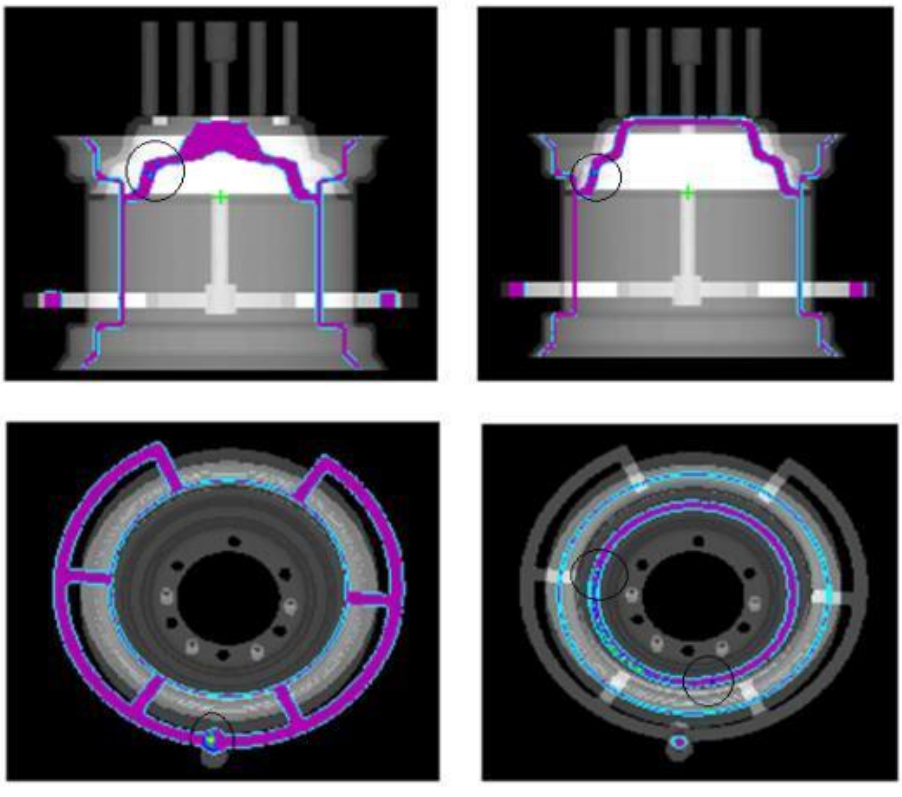

Fig. 9: *Shrinkage Porosity in Initial Gating System at Various Spots.*

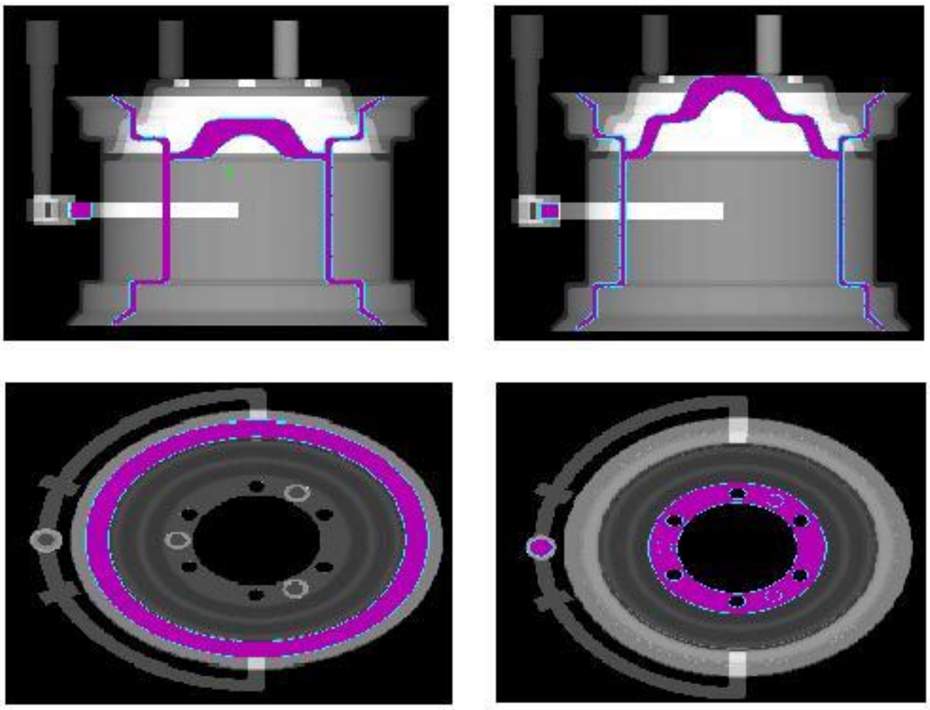

Fig. 10: *Shrinkage Porosity is Eliminated in Modified Gating System.*

With around 80% of yield, a new and modified gating system is created and gating calculations are done and defect free casting is obtained. The fraction of solid and liquid metal in the mushy zone is a function of time and temperature. The solidification process is considered to be completed when the last drop of liquid metal crystallized. In initial gating system temperature range is same at start and at the end. The temperature variations between nodal points at start appear to be non-uniform unlike at the end it seems to be uniform in the revised gating system.

Shrinkage porosity in initial gating system and modified gating system are shown in Figures 9–10. It can be seen that shrinkage porosities are eliminated in the modified gating system.

CONCLUSION

After studying the above stated methods in sand casting, we can conclude that the simulation tools can act as a helping hand in elimination of casting defects such as shrinkage porosity, distortion etc. Simulation tools can also be used to identify and optimize critical factors affecting the casting defects. Hence we can say that simulation tools can provide accurate and efficient results.

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Cite this Article

Parth Lakum, Chauhan HN. Casting Simulation using ProCast-A Review. *Journal of Production Research and Management*. 2016; 6(1):