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Research Article

Casting Simulation of Cast Iron Rotor Disc using ProCAST

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Abstract

Many researchers reported that about 90% of the defects in castings are due to wrong design of gating & risering system and remaining 10% are issues related to actual manufacturing processes. By replacing the existing trial and error casting method with casting simulation in foundry, can reduce the rejection rate (defects) of the products from 8.5 to 3.5%. This paper discusses the study of solidification behaviour of Cast Iron rotor disc and detection of hot spots in castings with the help of casting simulation software ProCast.

Keywords*: rotor disc, casting simulation, riser, casting defects, ProCast.*

1. Introduction

A disc rotor is the rotating part of a disc brake assembly normally located on the front axle. It consists of a rubbing surface, a top-hat and a neck section. Cast iron is commonly used to develop components of varying complexity in foundries. This is because of two reasons, relatively inexpensive and easily formed into complex shapes. ProCAST is widely used for simulation and analysis of various casting processes. It allows the modeling of Thermal heat transfer (Heat flow), including radiation with view factors, Fluid flow including mold filling, Stresses fully coupled with the thermal solution (Thermo mechanics). Besides that, it also includes microstructure modeling and porosity modeling.The processes carried out in procast are discussed below precisely.

1.1 Casting Process Modeling

Generally the simulation software has three main parts.

Mesh cast: the program reads the CAD geometry and generates the mesh,

Pre cast: adding of boundary conditions and material data, filling and temperature calculations, Datacast & Procast: solver, evaluation.

Mesh generation →Material assigning→Boundary conditioning →Datacast→ProCast

Cast Iron rotor disc is used in brakes of an automobile. During its casting simulation process, mould filling and solidification are examined and gravity die casting process are optimized. Fig 1 & 2 represents the 3D model of rotor disc and rotor disc with gating system respectively.

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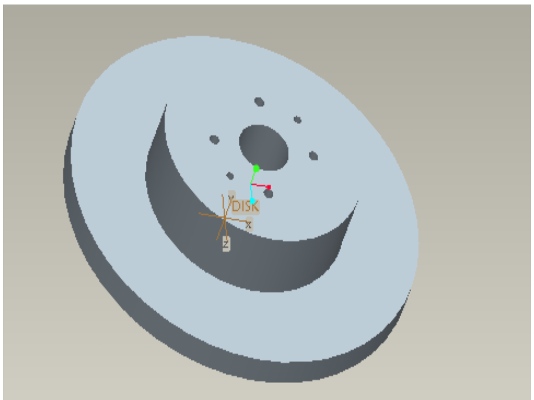


Fig.1 model of rotor Disc

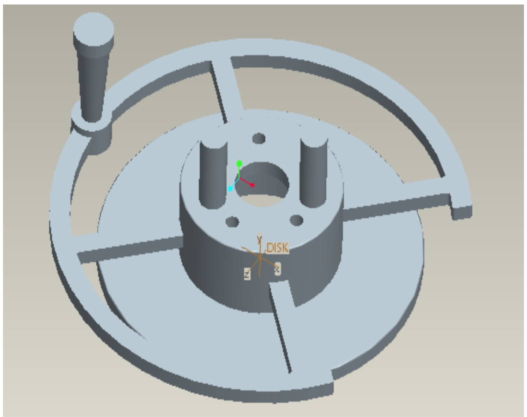


Fig.2 3D model of gating system

2. Methodology

To simulate the mechanism of solidification of Cast Iron castings, analyze the results and to optimize the casting parameters in order to achieve better properties, entire

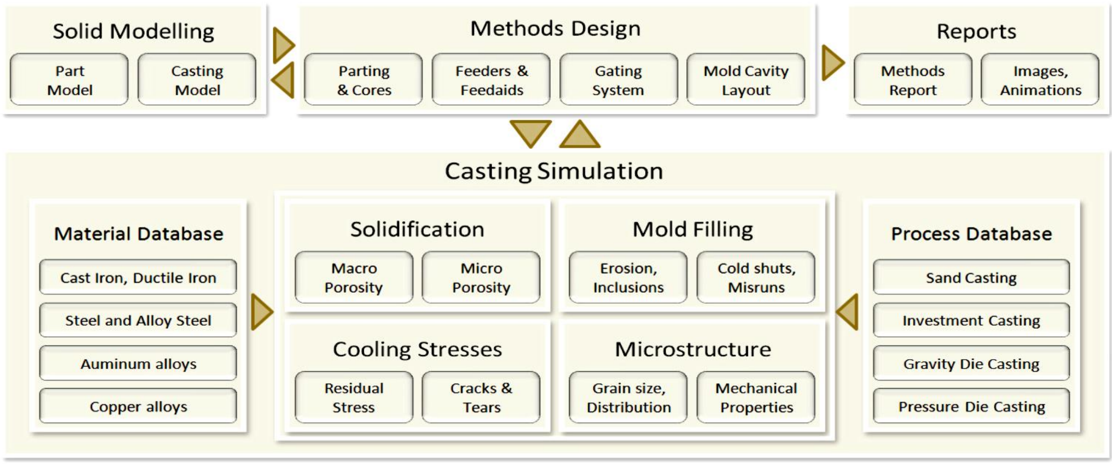


Fig.3 Methodology

procedure is broadly divided into three stages. They are Simulation Preparation, Computer Aided Simulation on ProCAST, and Analysis. Each stage contains several steps. Figure 3 gives the procedure showing the entire methodology followed for the present work and succeeding this section, the substantial software (P.Prabhakara Rao *et al*, 2011). By following the operation flow, the effect of different influencing factors such as molten metal temperature, mould material, inlet velocity, and substrate pre-heating temperature are studied. Composition of Cast Iron is given in table 1.

Table 1 Cast Iron Composition

Material	Composition %
Fe	93
C	3.3
Si	2.16
Mn	0.67
Cr	0.13
Mo	0.29
Ni	0.1
P	0.02
Ti	0.02
Cu	0.31

3. Results and Analysis

3.1 Mould Filling

The mould filling is to be directed by the user by selecting the surface of the pouring basin above the sprue. The fluid flow speed in the casting by default it will take some value or can also be specified by the user. ProCast simulation can solve mould filling and solidification processes at the same time(B. Hu-Hong jun *et al*, 2006) The mould filling processes of the initial and modified gating systems are shown in Figures 4 & 5. It can be seen that down sprue and feeder are filled up simultaneously since their dimensions and shapes are very similar. Though down sprue is the entrance of the molten metal it was not filled up or completely wetted during the mould filling of cavity. Generally, the mould filling is successful as a result of proper design of straight runner system. It can be seen that the straight runner and gatings were filled up with in the first few seconds.

3.2 Solidification

For the cast material, solidification will start when the temperature drops below 1380°C, and fully completed beneath 1200°C. Solidification is a result of heat transfer from internal casting to external environment. The heat transfer from the interior of the casting has to go through different routes. Internal liquid convection above liquidous temperature during mould filling, the solidified metal conduction after complete solidification achieved throughout the bulk of casting, heat conduction at the metal –mould interface, heat conduction within the cast iron mould and convection and radiation from mould surface to the surrounding (C.W Hirt *et al*, 2005).

In the present case, we compare the solidification simulation results of the rotor disc castings at different time intervals and different gating systems as shown in the Figures 4 & 5. Solidification time is proportional to volume to surface area ratio (modulus of casting), therefore the faster solidification rate at the runner tip is expected. The mould cavity which is in the center has the longest solidification time (B.Ravi, 2005)

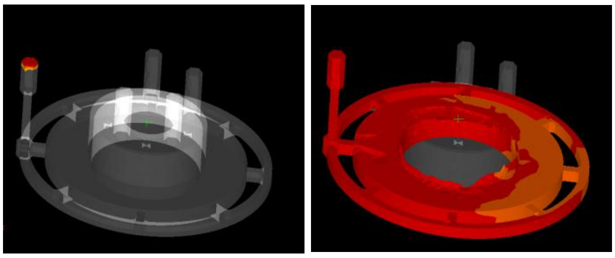
3.3 Various Gating systems

Since there are long list of possibilities for a gating system of a particular casting, various gating systems were tried and tested in the ProCAST software. One of those gating system with ingates settling all around the casting can be seen in the figure 4. Molten metal is poured at a temperature of 1200°C with a yield of 60%. A defect usually seen in plate castings is the free end distortion which is avoided through an improvised gating system. The main defect with this gating system is that the ingates solidify before the molten metal reaches the mould thereby providing no inlet to the mould and leading to a partial filling for the casting.

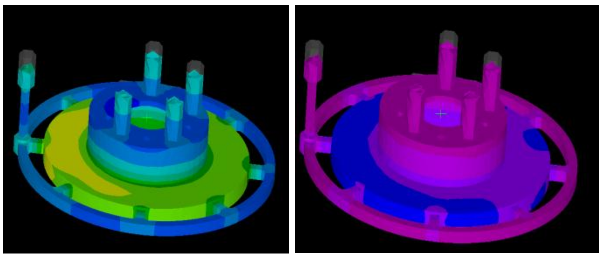
Moreover with such a gating system high turbulence is seen as in the figures 4 & 6. Hence, a remedy for such defect would have been to increase the temperature of the pouring molten metal so that the molten metal reaches the cavity and then solidifies. A Simulation at 1200°C is done again and a defect free casting is obtained during the simulation processes. Accordingly, turbulence levels are quite high in the initial gating system and the stresses in the casting are quite high after the solidification. A modified gating system is prepared and gating calculations performed with a yield of 80%. The molten metal is poured at 1200°C with the temperature and solidification behavior of the molten metal as shown in the figures 4 & 5. Once simulation is complete, a defect free casting is obtained with a yield of 80%. On comparison of the entire defect free castings yield, turbulence, flow, etc are to be taken into consideration such that a sound casting could be provided to the user. A defect free gating system with perfectly sound casting was the one with the modified gating system. This Gating system has higher yield, lesser turbulence of flow during mould filling and hence it has been chosen as the optimum gating system.

3.4 Result analysis of ProCAST simulation

Figure 4 & 5 shows the temperatures changes at the different casting steps. The fraction of solid and liquid metal in the mushy zone is a function of time and temperature.

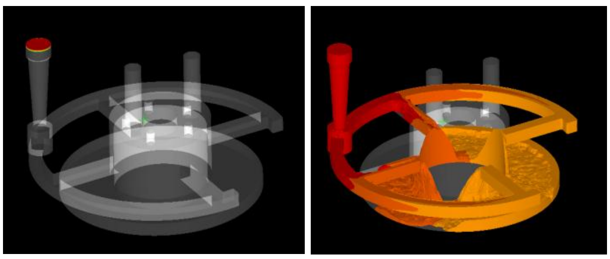


At step 0 At 250th step

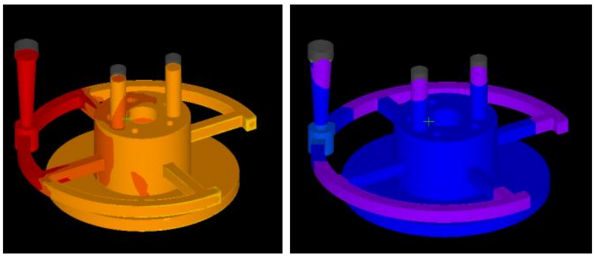


At 500th step At 1000th step

Fig. 4 Mould filling and temperature variations of initial gating system at various stages



At step 0 At 250th step



At 500th step At 1000th step

Fig. 5 Mould filling and temperature variations of modified gating system at various stages

The solidification process is considered when the last drop of liquid metal is dissolved into solid, in a way the temperature range at the start of mould filling to the end is same in initial gating system. In the modified gating system the temperature variation between nodes at the start is not in a uniform way but at the end of solidification it attains uniformity throughout the mould.

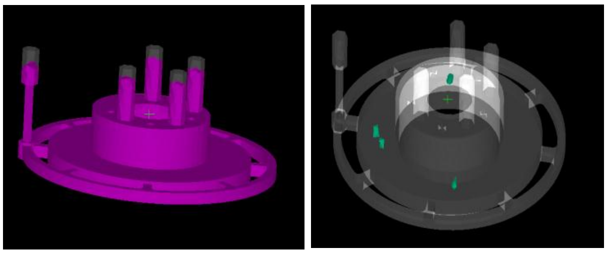


Fig.6 Initial gating system & porosity

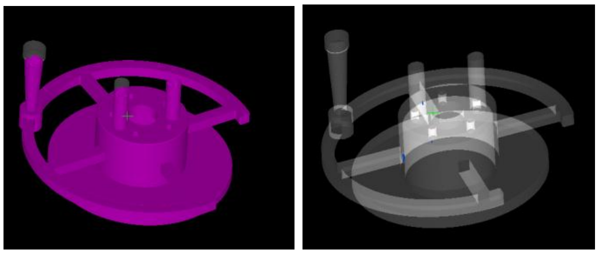


Fig.7 Modified gating system & porosity

Conclusions

1. The Simulation software used is helpful to foundries to abort the time associated for trial and error and to reduce the cost, scrap rate, defective components and to produce a sound casting.
2. The simulation tool utilized has a provision of visual and analysis of mould filling and solidification at a time on a high integrity part.
3. The identification of defects can be carried out after the solidification like shrinkage porosity, distortion, cracks, warm holes etc.
4. The defects found out can be shown in variant graphs at specified nodes by line graphs in software, or by numerical values manually.
5. By replacing the trial & error tedious casting procedures with virtual world simulation using tools like ProCAST, one can able to determine the amount of material to be used, time required and can determine the cost of different

manufacturing products. This brings integration in casting process between the foundry engineers and design engineers.

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