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Casting Simulation of Automotive Wheel Rim Using Aluminium Alloy Material

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Abstract

Aluminium wheel rims used in transport vehicles are commonly produced by gravity die casting. In Industries it is been a research issue for improving the quality product and to predict the mechanical characteristics, shrinkages, porosity. It has observed that various type of simulation software has been used in foundry, out of which FEM and VEM based casting simulations are widely used in foundry. To solve the problems in the trial and error method that we followed new simulation software has been introduced. This paper discusses about the casting simulation software ProCast and its utilization on the solidification behavior of material and detection of hot spots in castings of automotive aluminium wheel rim.

Keywords: Aluminium alloy wheel, casting simulation, ProCast software.

1. Introduction

Wheel rims are the most used in general vehicles. These are manufactured by either casting or forging. Forged components were of high cost and low strength mechanical properties compared to the alloy based wheel rims.

Aluminium alloy based wheel rims were later come in to the focus cause of high strength mechanical properties, light in weight and flexible to repair compared to forged rims. ProCAST is a three dimensional solidification and fluid flow package which is developed to perform numerical simulation of molten metal flow and solidification phenomena in various casting processes, primarily die casting (gravity, low pressure and high pressure die casting) and sand casting. It is particularly helpful for foundry applications to visualize and predict the casting results. ProCAST extensively prior to create sand casting and die casting models for the simulation of mold filling and solidification. We prefer to use die casting rather than sand casting for better properties. The cast and mold design of the experiment is transformed into a 3D model and imported into ProCAST to conduct the casting process simulation. In the present work, simulation of mold filling and solidification of alloy steel castings are carried out.

1.1Casting Process Modeling

Generally the simulation software has three main parts shown in Figure1.

- Pre-processing: the program reads the CAD geometry and generates the mesh,
- Main processing: adding of boundary conditions and material data, filling and temperature calculations,
- Post processing: solver, evaluation.

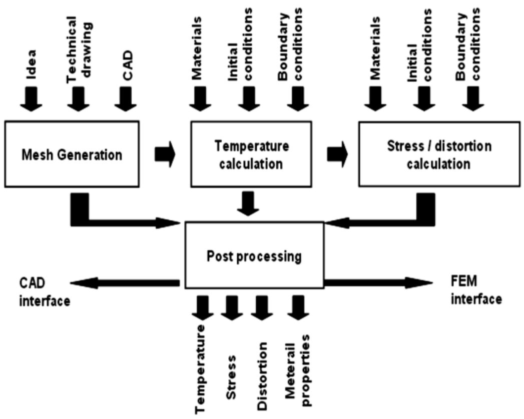

Fig. 1.1 (a) System of simulation

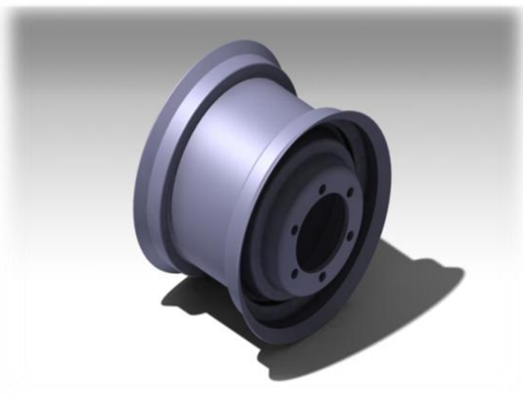

Fig. 1.1(b)3D model of wheel rim

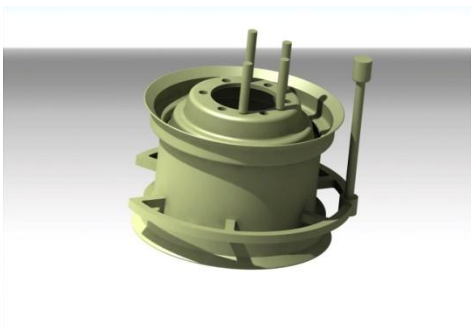

Fig.1.1(c) 3D model of initial gating system

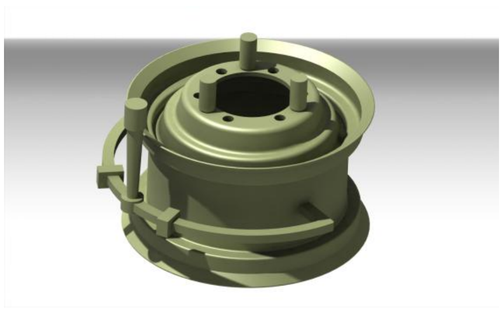

Fig. 1.1(d) 3D model of modified gating system

Fig. 1.1(a) is the tree diagram for system of simulation &Fig. 1.1(b) shows 3D model of wheel rim CAD model and for which simulation tools are utilized to improve the casting process design. Computer simulation based on the design procedures described above have been implemented with one example. Let's consider automotive wheel casting for the present study (Figs. 1.1(c)& 1.1(d) Shows the 3D model of initial & modified gating systems).Used in automobile industry made of Aluminium alloy(Al95.5-Cu4.5). During simulation of the casting process, mold filling and solidification are examined and gravity casting process is optimized.

2. Methodology

The purpose of this paper is to simulate the solidification of aluminium alloy castings, and analyze the results obtained for component after solidification, and to optimize the casting parameters in order to achieve better properties of aluminium castings. The procedures were mainly divided into three stages. They were Simulation Preparation, Computer Aided Simulation on ProCAST, and Analysis. Each stage contained several steps. Researcher followed this operation flow to try and examine different influencing factors, such as molten metal temperature, mold material, inlet velocity, and substrate pre-heating temperature. Fig. 2.1 is the procedure graph showing the entire methodology followed for the present work.

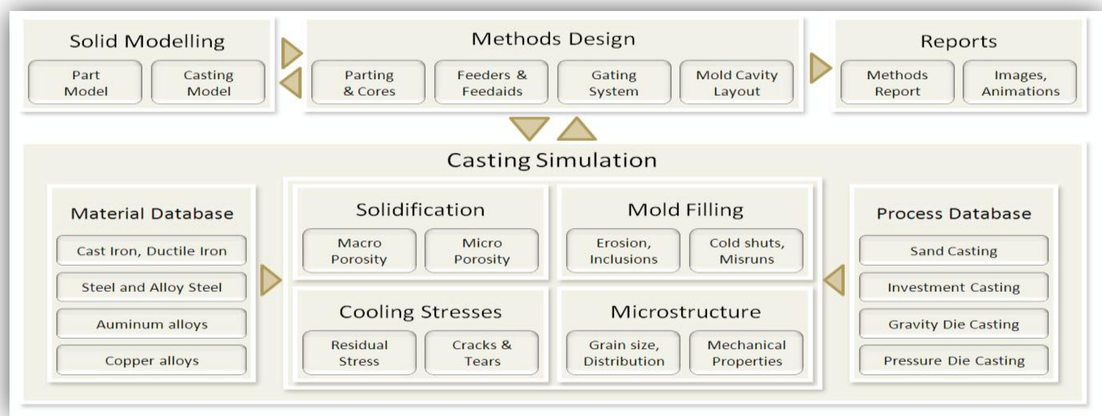

Fig. 2.1: Methodology.

3. Material

Aluminium Alloy (AL95.5-CU4.5) Composition

Aluminium	95.5%
Copper	4.5%

4. Results and Analysis

4.1 Mold Filling

The Mold filling part is carried out by the software based on the given inputs to it in boundary conditions menu. The velocity of the molten metal can be regulated by the user of ProCast as per the material of the component. The Procast simulation solved for mold filling and solidification processes at the same time. The discussion about mold filling is based on ProCAST simulation results. The mold filling processes of the initial and modified gating systems are able to be visualized from Figs. 4(a) & 4(b).

It is found that for every succession of one second fraction of solid and temperatures are changing (encompasses pouring basin, sprue and runner system, gatings, casting and feeder) will be filled up.Figures.4(c)& 4(d). It can be seen that down sprue and feeder were filled up simultaneously since their dimensions and shapes are very similar. Though the down sprue is the entrance of the molten metal, it was not filled up or completely wetted during the mold filling of cavity. Generally, the mold 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 second.

4.2 Solidification & Various Gating Systems

Temperature contour of solidification and solid fractions:

For the cast material (AL95.5 CU4.5) aluminium alloy, solidification will start when the temperature drops below 660°C, and fully completed beneath 250°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 the routes of (C.W Hirt. et al, 2007)

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

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(a)&4(b) Solidification time is proportional to volume to surface area ratio (modulus of casting) [4], therefore the faster solidification rate at the runner tip is expected.

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 Fig. 4(a) Molten metal is poured at a temperature of 680°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 Mold thereby providing no inlet to the mold and leading to a partial filling for the casting.

Moreover with such a gating system high turbulence is seen as in the figures 4(a) & 4(c). 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 is done at 700°C and a defect free casting is obtained during the simulation processes. Accordingly, the 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 680°C with the temperature and solidification behavior of the molten metal as shown in the figures 4(a) & 4(b).Once simulation is complete, a defect free casting is obtained with a yield of 80%. (which is shown in comparison table.2).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.

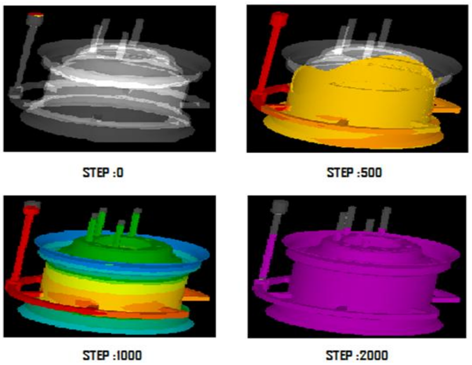

Fig. 4(a): Mold filling and Temperature variations of initial gating system at various stages resp.

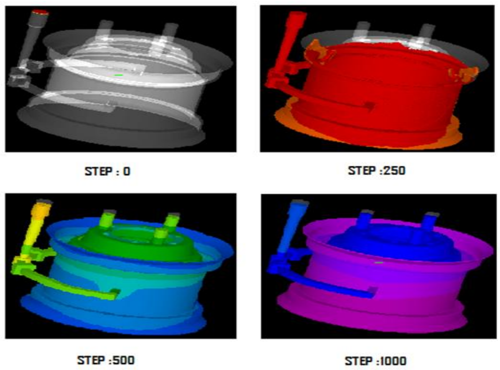

Fig. 4(b): Mold filling and Temperature variations of modified gating system at various stages resp.

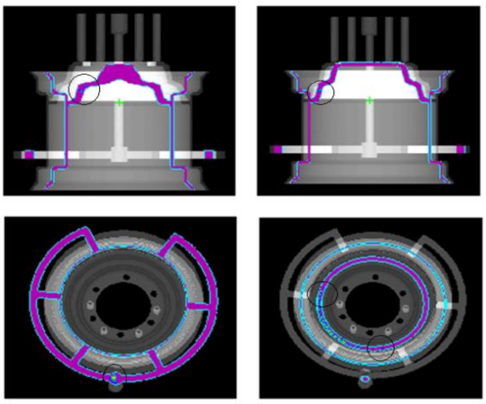

Fig. 4(c): Shrinkage Porosity in initial gating system at various spots

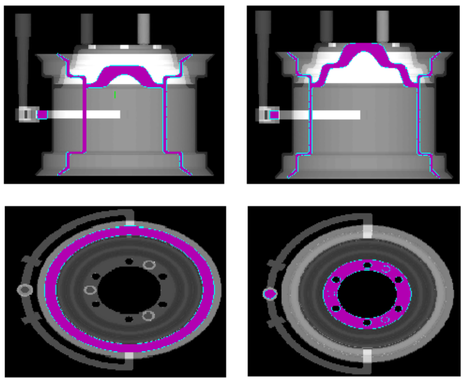

Fig. 4(d): Shrinkage Porosity is eliminated in modified gating. System.

4.3 According to the result analysis obtained from the simulation

Control points temperature time tracking

The Fig. 4(a) &4(b) shows the temperatures changes for the casting points. The fraction of solids and liquid metal in the mushy zone is a function of time and temperature. When the last drop of liquid metal is crystallized into solid, the solidification process is considered. Therefore the ProCAST simulation and experiment obviously differ from each other however, compared with other casting points. In a way the temperature range at the start of mold filling to the end is same in initial gating system. In the modified gating system the temperature variation between nodes at the start seems to be non-uniform but at the end of solidification it is uniform.

5. Conclusions

The main conclusions that can be drawn from this study are:

1. By replacing the trial and error with simulation software which involves a virtual process can be able to utilize our resources efficiently.
2. Simulation tool used has a flexibility of visual and analysis of mold filling and solidification at a time in a high resolution.
3. The simulation tool was used to identify critical locations and filling pattern and solidification related problem areas in the casting.
4. By moving the trial and error process into the virtual world and can determine the cost, time, scrap rate, and the quality of different design and process options.
5. Simulation tool identifies the defects after solidification like shrinkage porosity, distortion, warm holes etc.
6. These defects can be shown in numerical values or in line diagrams at specified nodes.

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