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Improvements in Productivity and Quality for Ductile Iron Flange Castings Using Simulation Technique

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Abstract: An important element of the automobile manufacturing process involves the utilization of foundries. Today's foundries' quality and output are low because of variations in the casting process's many variables. The solidification procedure following pouring is crucial to the final quality of the casting. In order to plan the casting process for making castings before castings are produced or before new or better equipment is built, foundries are increasingly turning to computerized casting modelling and solidification simulation. With the use of computerized casting modelling and solidification simulation, manufacturers may improve the quality of their castings at a lower cost, without sacrificing quantity. As a result of casting solidification simulation, the number of trials performed on the shop floor may be cut significantly, and defect-free castings can be guaranteed. Finite element method (FEM), finite difference method (FDM), and finite volume method (FVM) are the theoretical basis of the casting simulation methods (FVM). In this study, we explore the application of the finite difference method (FDM) and the finite volume method (FVM) to simulate the solidification of a casting and to optimise the casting gating system for maximum yield. This research looks at how modelling and simulation can help improve our understanding of Flange. Flanges are made of ductile iron using a shell moulding method. Mechanically, ductile iron may be used to make a variety of vehicle components.

Keywords: Ductile iron, Casting modeling, Simulation, Optimization of gating system, Yield optimization.

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1. Introduction

High-quality castings can't be made without careful consideration given to the design of the casting process. Some imperfections will always be present in castings. A common defect in ductile iron castings is shrinkage. The gating method is utilized to make up for the casting's shrinkage after solidification. In order to maximise casting yield, the casting simulation tool is used to fine-tune the design of the casting process. Casting process simulation has been effective in predicting potential issues before a casting is poured. Nowadays foundries utilize casting simulation to lessen flaws. But only a minority of foundries have fully exploited casting solidification simulation's potential. It was found that computer modelling and solidification simulation of the casting were helpful in cutting down on casting time and raising quality. Successfully competing on a global scale requires lowering costs while simultaneously increasing output and reducing waste. The pattern is drawn in exquisite detail by the computer model. The number of prototypes needed to achieve a flaw-free casting is cut down using the simulation method. The gating system for every casting is traditionally designed by foundrymen based on their knowledge or a set of established norms [1]. Gating design formulas are used by certain engineers for this function. The final step is pouring molten metal into a mould made from the previously produced design. When a problem occurs with this system, the gating is adjusted to account for its location and severity. This process of trial and error will continue until the flaw in the casting has been eliminated [2]. This time-consuming and labor-intensive approach of trial and error threatens to damage the relationship between the foundry and the consumer.

2. Methodology and Part Design Improvement

It is possible for castings to have shrinkage porosity and cold shut as a result of a thick junction and a long thin section. In order to avoid such circumstances from occurring, a component designer should communicate with the foundry engineer to ensure that the part is castable using casting simulation software as soon as possible after encountering them. In addition, the early detection of castability may force the part designer to make modest changes to the component without impacting the part's functioning.

Inputs

Maximum commercially available casting simulation software are Finite Element Method based. So, this discussion is applicable for FEM based simulation software.

- 3D CAD model is the main input for any casting simulation software. The CAD model can be created using a solid modeling program. Model of the part can be obtained from OEM customer.
- Various allowances like draft, machining, shrinkage, distortion etc. are to be provided on the CAD model if not given earlier.
- Now, the model has to mesh. Meshing means that the model is to be split into several simple elements. A tinier mesh size returns more delayed but more stable outcomes. Adaptive meshing (finer in decisive domains and coarse elsewhere) provides quicker outcomes without compromising on the precision.
- Following meshing, material characteristics like density, thermal conductivity, specific heat, latent heat etc. are to be provided as input to the software.
- Next, the boundary conditions have to be defined.
- Simulation software furnishes reliable and precise outcomes if the CAD model, FEM mesh, material characteristics and boundary conditions are exact.

Outputs

- The principal outputs of simulation applications incorporate animated visualization of mould filling, casting solidification, and further cooling to room temperature.
- Mould filling simulation assists in forecasting the total filling time as well as help in predicting following casting defects like mould erosion (heading to sand inclusions), incomplete filling (cold shuts and misruns), and air entrapment. Blowholes, produced by entrapment of gases, are yet difficult to predict.
- The outcomes of solidification simulation incorporate colour-coded freezing profiles with respect to time. These temperatures profiles help in predicting the position of shrinkage porosity based on Niyama criteria.
- The casting simulation software can also predict the microstructure, mechanical properties, residual stresses etc.

3. Results and Discussions

The design of the casting process is critical in the production of high-quality castings. In the casting process, several flaws are inevitable. The most common flaw in ductile iron castings is shrinkage. Casting solidification shrinkage is compensated for by the use of a Gating system [4-6]. It is possible to increase the overall casting yield and efficiency by using a casting simulation tool. Casting process simulation has solved the challenge of predicting casting issues before a true casting is poured. Increasingly, foundries are employing casting simulation in an effort to minimise the number of defects. However, only a small percentage of foundries have fully embraced casting solidification modelling technology. The majority of foundries have not yet benefited from this technique's capabilities [7]. The computerized modelling and solidification simulation of the casting helped to reduce the time and increase the casting quality. The ability to compete successfully in the global market requires defect-free products, cheaper price, and increased efficiency. The pattern can be seen in great detail thanks to the computer model. The number of attempts necessary to produce a defect-free casting is reduced thanks to the simulation approach. The gating system for every casting is designed by the foundrymen using their experience or certain established norms [8]. For this, some engineers turn to gate design equations. Mold and pattern are then prepared for metal pouring into. If a problem emerges, the gating system is adjusted to accommodate the defect's location and severity. As long as the casting defect is decreased, this trial-and-error technique will continue [9].

In order to get started with the casting simulation, the first thing that needs to be done is collect the data and the sketch of the desired component. Tabulated information on the flange may be found in Table 1. Ductile iron, which has a tensile strength of 500 N/mm2 and an elongation of 7%, was used in the casting of the flange. After that, a CAD model of the casting is constructed with the assistance of the CATIA V5R19 software.

Table 1. Ductile Iron Physical and Mechanical Properties

Property	**Values**
Material	Ductile Iron
Tensile Strength (N/mm^2)	500
Elongation (%)	7
Density (kg/m^3)	7150
Melting Point (°C)	1150

3.1 Numerical Simulation of the Flange

3.1.1 Pre-processing

Importing a CAD model into the simulation environment and setting boundary conditions are both required steps in the pre-processing phase of simulation software. The flange was constructed using CI GI 4.0 material, and the mesh size that was chosen was 1 millimeter. The pouring time is listed as seven seconds.

3.1.2 Processing

The processing begins with the creation of a meshing model of the casting bunch using the finite difference approach, and then continues with the simulation of the meshed model.
The difficulty of calculating heat transport is directly proportional to the size of the mesh. The heat transmission calculations get more difficult as the mesh size gets smaller. The amount of time required for processing is determined by the dimensions of the casting and mould, the mesh size that is applied, as well as the computer setup and processing speed.

3.1.3 Casting Simulation

The casting process is modelled with the casting simulation Programme AutoCAST to forecast the defect before the metal is poured in order to assure that the casting will be free of flaws. The AutoCAST Programme utilizes the Vector Element Method as its basis (VEM). Imported into the simulation environment is a 3D model of the casting, complete with a gating system for both the original layout and the new layout. The Programme that does numerical simulation has had all of the design parameters accurately specified. The simulation of the solidification process is then carried out. AutoCAST offers the most extensive functionality available, spanning from the design of parts and techniques through sophisticated simulation, defect analysis, and quality assurance. This capability is applicable to ferrous and non-ferrous metals, as well as various processes. The simulation is carried out using a fine mesh, and the pouring time is set to seven seconds.

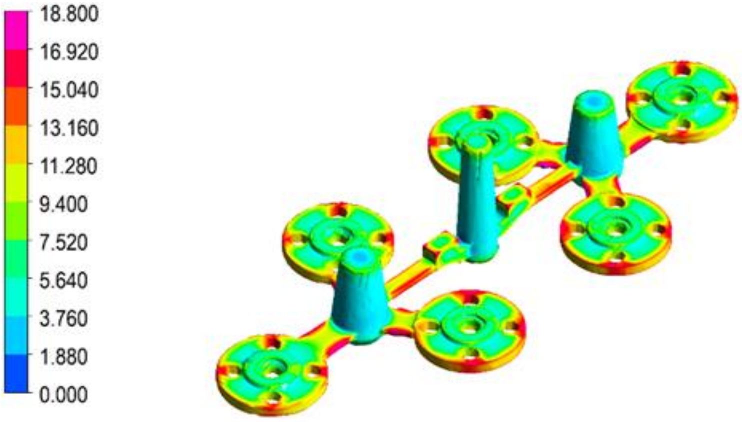

Figure 1. Solidified casting view with runner thickness 10 mm.

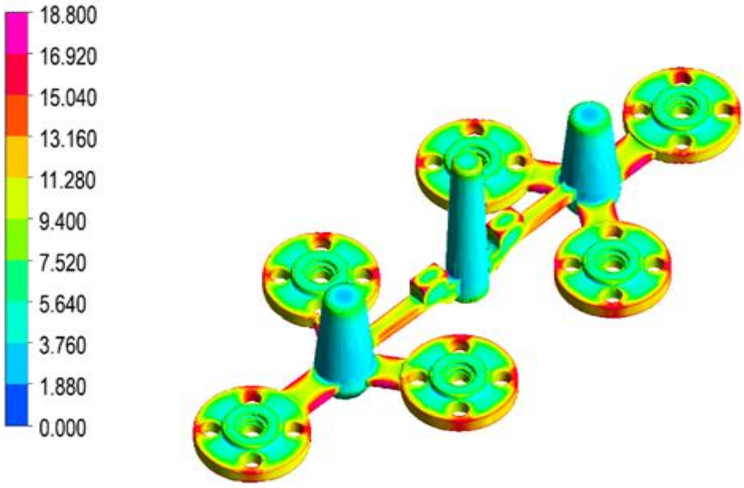

Figure 2. Solidified casting view with runner thickness 20 mm.

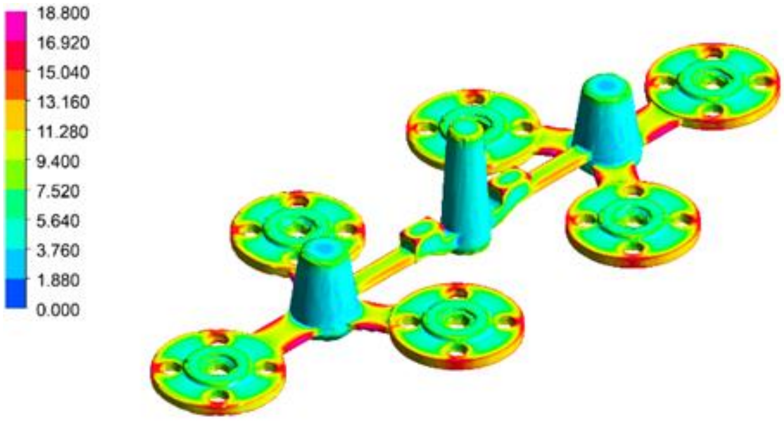

Figure 3. Solidified casting view with runner thickness 30 mm.

The solidified casting view is depicted in Fig. 1, 2, and 3 for various gating system thicknesses, while the average pouring temperature was kept at 1240 degrees Celsius throughout the process the details of the castings are tabulated in Table 2. The casting process is simulated while using the current gating system, and the findings from the solidification simulation are compared to the actual casting shrinkage. The simulation attempts to estimate the shrinkage that will occur in the casting by altering the thickness of the gating system, which ranges from 10 to 30 millimeters. in addition to this, the volume of the entire casting is taken into account when determining the yield of the casting. According to the findings, the optimal gating thickness for optimum yield is 20 millimeters, with the least amount of shrinkage.

Table 2. Details of castings

Thickness of gating (mm)	Total Volume of the castings (mm^3)	Poring Temperature (°C)
10	1190	1232
20	1320	1264
30	1440	1305

4. Conclusions

In accordance with the drawing, the three-dimensional modelling of the flange casting has been completed. The component drawing is imported into SolidCAST and AutoCAST, where the software is then used to build and simulate the gating and feeding system. In addition to this, the optimization of the gating system is performed utilizing the simulated results obtained by the Programme. On the basis of the investigations mentioned above, the following conclusions may be made:

1. Using casting simulation software like SolidCAST and AutoCAST, it is possible to precisely forecast the amount of shrinkage that will occur during casting.
2. Additional casting simulation will be employed in order to optimise gating dimensions while simultaneously keeping casting quality stable.
3. Casting solidification simulation may be utilized to great advantage in order to cut down on the number of faults in the casting.

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