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Optimisation of Gating and Riser System for Casting of Pump Component using Casting Simulation Technology

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Abstract
Casting components have to be mass produced and so because of huge requirements of customers their needs should be satisfied in short periods of time with the highest quality and less price due to cut throat competition. In this paper computer simulation tools are used to reduce the time required for the development of pump adapter component. Magmasoft Computer Simulation Software is used to visualise a complete solidification process which is not possible during real casting. Defects such as the shrinkage porosity, air entrapments, unfilled moulds etc. can be graphically observed. Initially CAD model of pump adapter has been prepared in Solid Works. The model is exported in Magmasoft in STL format. The model is meshed for Finite Element Analysis. Process parameters such as pouring velocity and pouring time have been applied as simulation inputs. Simulation provides good understanding about temperature distribution, shrinkage porosity and fraction solidification time. The simulation results are used to optimise the gating system to improve *Directional Solidification* and reduce *Shrinkage Porosity*.

1. INTRODUCTION

Casting simulation essentially replaces or minimises shop-floor trials to achieve the desired internal quality at the highest possible yield. A number of casting simulation programs are available today, such as CastCAE, MAGMA, Novacast, ProCAST, and SolidCAST. Most of them use Finite Element Method to discretise the domain and solve the heat transfer and/or fluid flow equations. The main inputs include the geometry of the mould cavity (including the part cavity, feeders, and gating channels), thermo-physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mould material, as a function of temperature), boundary conditions (such as the metal-mould heat transfer coefficient, for normal mould as well as feed-aids including chills, insulation and exothermic materials), and process parameters (such as pouring rate, time and temperature). The filling sequence of the mould can be visualised easily and helps to find defects like sand erosion, cold shuts, etc. The results of solidification simulation include colour-coded freezing contours at different instants of time starting from beginning to end of solidification. This provides a much better insight into the phenomenon compared to shop-floor trials (real moulds being opaque). [1]

For wider application of casting simulation in foundry as well as OEM firms, the programs should require little domain knowledge, and must be fast, reliable, easy-to use, and economical. For example, the location and size of the feeders is an important input for solidification simulation. This decision requires considerable methoding experience from the user. Further, the engineer has to create or modify the solid model of the feeder, attach it to the casting model using a CAD program, and import it into the casting simulation program for each iteration. These tasks require computer skills. The accuracy of results (such as solidification time and location of shrinkage defects) is influenced by metallurgical models and availability of temperature dependent material property database. The simulation of intricate castings may involve more time and cost than shop-floor trials, and any error in program inputs implies further delay and expenses.[1]

The design of the gates should result in filling of all sections at approximately the same time. Uniform filling ensures less variation in mechanical properties developed during solidification. This is influenced by flow parameters like pressure, velocity, discharge and geometric parameters in gating systems. The gatings are designed using the empirical formulas derived using experimental observations. These results are limited to small number of geometries; therefore the gating designs need to be validated using computer simulations for a particular casting.

Volume reduction occurs during the cooling of the liquid metal after pouring. These contractions will create internal unsoundness (i.e.,porosity) unless a riser, or liquid metal reservoir, provides liquid feed metal until the end of the solidification process. The riser also serves as a heat reservoir, creating a temperature gradient that induces directional solidification. Without directional solidification, liquid metal in the casting may be cut off from the riser, resulting in the development of internal porosity. To be effective, a riser should continue to feed liquid metal to the casting until the casting has completely solidified. Thus, the riser must have a longer solidification time than the casting.

Fig. 1 shows the procedure to use solid modelling and casting simulation technology for casting production

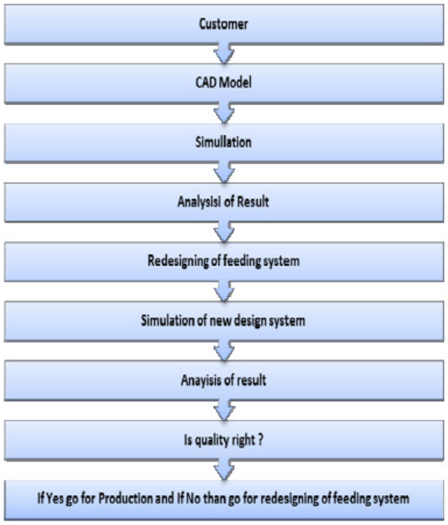

Fig. 1. Framework for casting simulation[2]

2. PROBLEM FORMULATION

2.1 Product Detail

The details of the product (Fig. 2) are as follows:

- Product Name: Pump Adaptor
- Material: FG200
- Type of Casting: Green Sand Casting

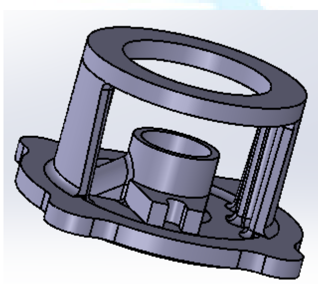

Fig. 2. Pump Adaptor

3. PROCEDURE FOR ANALYSIS

The procedure to conduct FEA analysis for casting of the product is as follows:

a) 3D Modelling: Create a 3D model of the casting including the gating and riser components of the mould in Solid-Works (Fig. 3).

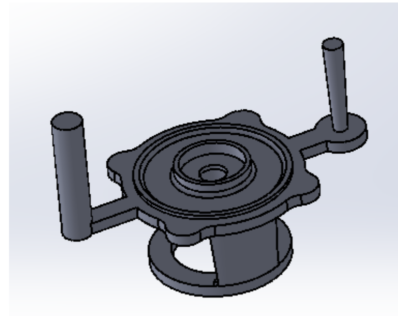

Fig. 3. 3D Model of the casting with gating and riser.

b) Importing in Magmasoft: Convert the Solid-Works model into STL format and import it into Magmasoft Pre-Processor (Fig. 4).

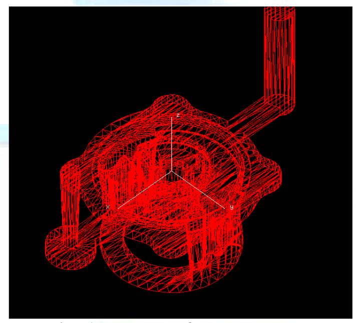

Fig. 4. Magmasoft Pre-Processor

c) Meshing: Mesh the component using the inbuilt meshing tool. The mesh element size takes was 5mm (Fig.5).

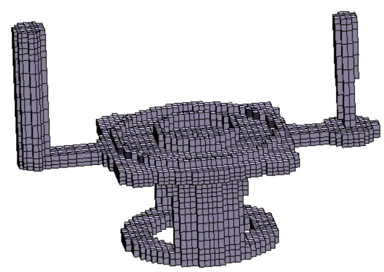

Fig. 5. Meshed Model

d) Boundary Conditions: Boundary conditions are applied as follows:

- Metal Pouring temperature=1300°C[6]
- Metal Pouring Velocity=2.5m/s
- Thermal Conductivity of Mould Sand[6]= 0.703 W/mK

e) Solving the FEA model

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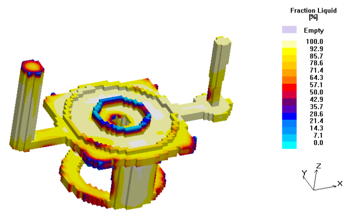
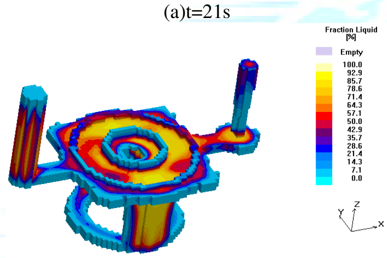
4. RESULT ANALYSIS

Initially simulation was conducted on the model with the gating design as shown in Fig. 3. The results of the filling simulation show that the filling sequence is non-uniform. The sections of the mould are not filling approximately at the same time. This results in variation of solidification time of the metal in different sections of the mould.


(a)t=21s


(b)t=66s

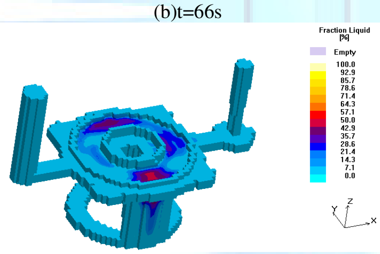

(c)t=166s

Fig. 6. Fraction of liquid metal percentage during solidification

Fig. 6 shows the percentage of liquid metal yet to be solidified in three time steps. At 166s (Fig. 6(c)) the metal is still in the liquid form in some portions. The liquid metal in the riser cools down faster than the liquid in the rest of the mould. This is not a sound solidification state, and can result into defects like shrinkage porosity, hot tear etc. This is due to non-uniform filling of the mould with molten liquid. The riser design was defective as it should act as supply of liquid metal and should be the last portion of the mould to cool down. [5]

Results of the first simulation led to the re-design of the gating system and the riser. An additional runner was introduced and the position of the ingrates was changed (Fig. 7). So the bottom portion of the mould to fill in first and uniform filling of all sections of the mould was achieved.

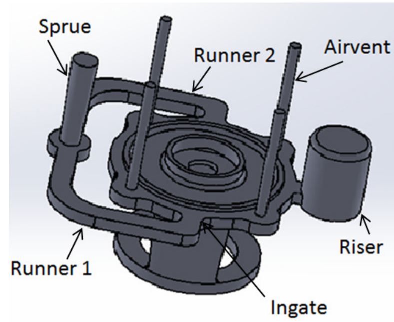
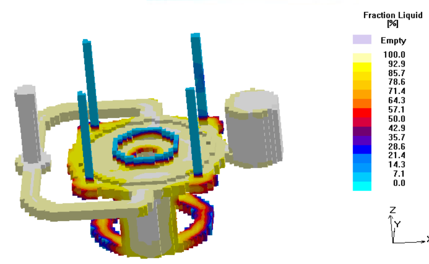


Fig. 7. Model of redesigned gating system and riser.

The simulation results of the redesigned gating system (Fig. 8) shows that the metal in the mould cools gradually from the bottom to the top portion of the mould. The riser cools down after rest of the metal in the mould solidifies and continues to feed liquid metal to the casting until the casting is completely solidified. This establishes that the redesigned gating system and riser led to directional solidification of the metal in the mould.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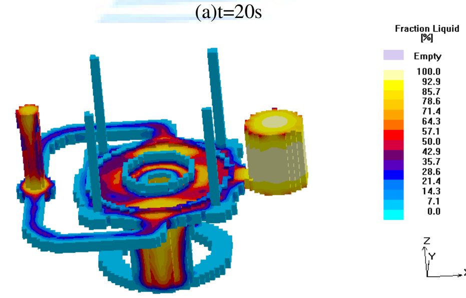
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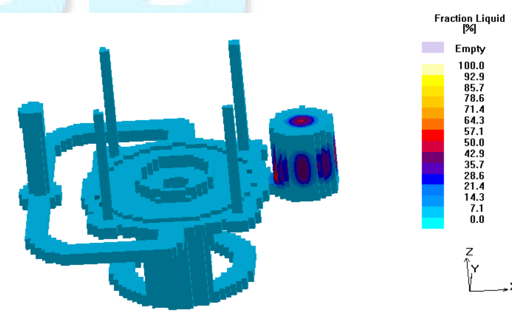
(c)t=166s

Fig. 8. Fraction of liquid metal percentage during solidification for redesigned gating and riser

5. CONCLUSION

The application of computer solid modelling, and casting simulation technologies in foundries can able to minimize the bottlenecks and no value added time in casting development, as it reduces the number of trial casting required on the shop floor. The application of casting simulation software based on finite element method shows that filling of mould and solidification of molten metal in the mould. The simulation results help to validate the gating and riser design to achieve best quality casting. It has also proven to be very useful for verifying the manufacturability of a casting and improving it by minor modifications to part geometry, before freezing the design in early stages of product lifecycle.

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