Design and Analysis of Gating and Risering System for Casting of Ball Valves

P. G. Panchal, S. J. Joshi and N. D. Ghetiya

Abstract—Casting is suitable economical manufacturing process for various components. It may experience different defects such as crack, porosity, hot tear etc. because of poor design of gating and risering system. The objective of the project is to optimize gating and risering systems of ball valve component based on CAD and simulation technology with the goal of improving casting quality and increasing casting yield.

In the work presented, CAD model of ball valve has been developed and simulation has been carried out using ProCAST. ProCAST results are compared with the experimental results for validation. Risering and gating parameters are modified to get better yield. It is observed that with new gating and risering system casting yield is improved by 8\% and porosity is decreased by 1\%.

Index Terms—Casting Defects, Casting simulation, Casting yield, Gating system design.

I. INTRODUCTION

CASTING is one of the economical manufacturing processes used in foundries. There are two important stages in casting, first is filling process and second is solidification process. In filling process gating system is designed to guide liquid metal filling. Riser system is used to compensate shrinkage caused by casting solidification. Systemic Casting process design is important for production quality and yield. Poor design results in many different defects such as porosity, incomplete filling, crack and hot tear.

Hence how to improve the casting quality and reduce defects becomes important. Casting quality is mainly dependent on the systematic gating and risering design, which is mainly relied on workers experience. Computer assisted casting solidification process helps the foundry industries to optimize the design parameters, better understand the mould filling and temperature history of the solidifying castings hence to identify the defects with the aid of obtained time-temperature contours.

Pro-CAST is a three dimensional solidification package developed to perform numerical simulation of molten metal flow and solidification phenomena in various casting processes. It is very helpful for foundry applications to visualize and predict the casting results so as to provide guidelines for improving product also mold design to get the desired casting qualities. Conventional sand casting is not a precision process and requires machining and surface finishing process after casting. However, advanced high technology sand casting process enables this method to produce higher precision cast products with better surface finishing that reduces the cost of machining and surface finishing processes. This will enhance the capability of sand casting to produce almost exact shape products and improve its qualities.

A. Modelling Process

Generally the simulation software has three main parts: 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: presentation, evaluation.

Casting simulation package requires three dimensional CAD model for the simulation purpose. CAD model should be designed with gating and risering system. Computer simulation based on the design procedures described above have been implemented with one case study. Consider main body of ball valve for the present study, creo 1.0 is used to develop the 3D CAD model of the part. 3D Model of ball valve with gating and risering system is shown in figure 1 and mold of ball valve is shown in figure 2.

II. METHODOLOGY

The purpose of this paper is to simulate the mechanism of the solidification of sand castings for the ball valve, and
analyze the results and to optimize the gating and risering parameters in order to achieve better properties of sand castings. The procedures were mainly divided into three stages shown in Figure 3.

A. Pro-CAST Working Flow

Pro-CAST is a modular system and allows the coupling of various modules. Based on Finite Element technology, Pro-CAST provides a complete solution covering a wide range of simulation. The purpose of this stage is to generate a finite element model, to setup the calculation, to run the analysis and, to interpret the results. The primary working flow of Pro-CAST was divided into three main parts, to begin with: Pre-Processing; in addition: Solving to run the analysis; and finally was the step Data Output to interpret the results and each step includes several sub-steps. The principal process of Pro-CAST is indicated in Figure 3.

### III. CASE STUDY

A case study is conducted to verify the use of Pro-CAST in an industry casting environment. The selected case study is a main body of ball valve made from low carbon steel by Vulcan Iron Industries, Duheshwar, Ahmedabad. The tests is conducted in this case study by Pro-CAST to find defects in the casting at different locations and compare them with the real casting design and to find possible outcomes and modifications attempted to improve the existing casting design. The modification of existing riser and gating design are changed to improve the existing casting design, riser, and gating systems with improved yield. Composition of casting material is C-0.168%, Si-0.252%, Mn-0.761%, P-0.0162%, S-0.0139%, Cr-0.234%, Mo-0.0208%, Ni-0.106%, Cu-0.0587%, V-0.0056%, W-0.050, Nb-0.0021, Al-0.0500, Co-0.0039, Se-0.0020, Ca-0.00051, Pb-0.0010, Sn-0.0077, Sb-0.0010, As-0.0116, Ta-0.0070, Ti-0.0014, B-0.00090, Fe-98.2, Zr-0.0010, Bi-0.0010, Ce-0.0021, Zn-0.0038, La-0.00030, Te-0.0045.

### IV. RESULT AND ANALYSIS:

3D models of the casting has prepared with different gating and risering system by using creo software. The different parameters used in casing simulation processes have given in Table 1 and the size of gating and risering parameters of original and modified models are shown in Table 2. Due to the design of taper sprue and unpressurized gating system, the molten metal enters the mould through gate and rises almost uniformly in the cavity of the mould until it has completely filled up. This is a good filling because it ensures no sand erosion in the mould and solidification of liquid metal immediately starts in the mould cavity. By changing the dimension of the riser, the total mould filling time is not much affected.

#### Option 1(Original)

The input parameters for casting simulation in all cases are same as given in the Table 1 and the size of gating and risering system has given in Table 2. In model 1, the size of riser is 152.5*89mm. Here Figure 5 to Figure 7 shows the simulated results obtained by using FEM based casting simulation of
model 1, the simulated results indicated that the shrinkage defect and shrinkage porosity remains in the casting. It also shows step by step variation of temperature distribution and Fraction of solids. The original casting is shown in Figure 4 with gating and risering system design.

**Temperature Distribution**

The phase changes from liquid state to solid states gradually with the decrease of temperature, in which a lot of physical and surrounding parameters play an important role for the casting quality. Temperature distribution of ball valve body with respect to time is shown in Fig.5. The temperature distribution at time step 0 shows that whole shell is at same temperature i.e. pouring temperature. Temperature distributions a different time steps are shown in various color. From graphical result, change in phase from liquid to solid can easily find out.

**Fraction solid**

Fraction solidification situation are shown in fig.6. Initially whole model is filled with liquid and as the time passes liquid metal is converting into solid as latent heat is released. At time step 0, fraction solid is zero and as time step passes latent heat is removing from metal and phase change occurs. At time step 350 the model is completely solid. Step-300 heat is removing from last of flange area so defects is occurs in this portion. Fig.6 is indicates that outer surface of component is solidified quickly and riser will solidify last.

**Shrinkage Porosity**

The shrinkage cavity and slack can be predicted with the computer simulations of the filling and solidification processes. Shrinkage porosity of the riser but it is acceptable at this position. As metal solidify it is going to change phase from liquid to solid and going to shrink so the compensating liquid metal available from riser due to this reason riser must solidify last. Shrinkage factor for every metal are different it depends on its chemical composition and cooling process. 1.95% defects shown in Fig.7

Above Contour Plots shows that at some of the location of casting, temperature gradient becomes too high and this is the potential cause of porosity and shrinkage therefore at that location, we have to change geometry of casting if application does not allow to change geometry of casting then we have to use either chiller or change the casting process. Riser design can change to achieve better casting yield compare to existing design.

**Option 2(Modified)**
The input parameters for casting simulation are given in the Table 1 and the size of gating and risering system has given in the Table 2. In model 2, the size of riser height is changed to 178 mm and riser diameter is changed to 127 mm. Here
2 side risers are removed. Total number of risers becomes 6. Modified casting shown in Fig.8. The Fig.9 to Fig.11 shows the simulated results obtained by using FEM based casting simulation of model 2. In Fig.9 temperature distribution at step 0, 270.490,600 are shown. Step-270 indicates uneven solidification. At time step 0, fraction solid is zero and as time step passes latent heat is removing form metal and phase change occurs. After step 220 the model is completely solid as shown in Fig.10. As shown in Fig.10, step-220 indicates high temperature is generating in flange area so shrinkage porosity will occur in these flanges. 1.05 % defects indicate in fig.4.11. As shown in figure metal will change phase from liquid to solid and it will shrink and compensating liquid metal available from riser. This model gives least porosity and it is acceptable.

A. Comparison of Results

Solidification plots shows that at some of the location of casting, temperature gradient becomes too high. This is the potential cause of porosity and shrinkage at that location. As a remedial step change in geometry of casting design can achieve better casting yield compare to present design. Original model is compared with modified models. Table 3 shown the comparison of the both models. The table reveals that shrinkage defects are reduced in modified model. The gating system design has been changed to increase the casting yield without creating any turbulence during mould filling. There is increase in casting yield by 8%.

V. Conclusions

The developments in the production of castings, computer simulation can be a useful tool for rapid process development.

<table>
<thead>
<tr>
<th>No.of Risers</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riser size (mm)</td>
<td>152.5*89</td>
<td>178*127</td>
</tr>
<tr>
<td>Runner size (mm)</td>
<td>50*50</td>
<td>50*50</td>
</tr>
<tr>
<td>Ingate size (mm)</td>
<td>40*40</td>
<td>60*60</td>
</tr>
<tr>
<td>Sprue size (mm)</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Porosity %</td>
<td>1.95</td>
<td>1.05</td>
</tr>
<tr>
<td>Yield %</td>
<td>58</td>
<td>66.1</td>
</tr>
</tbody>
</table>

TABLE III: Comparison of Results
Application of casting simulation software in foundries can be able to optimize the size and the position of the risers to avoid shrinkage defect in the casting.

New design has the following improvements:

- The casting simulation software results are matching experimental results.
- Modified design reduces shrinkages porosity defect.
- The casting yield is increased by 8%.
- The modified casting is clearly a better proposition since it increases productivity while at same time decreasing production costs.

REFERENCES


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