Solidification Simulation of the Casting to predict and eliminate the Shrinkage Defects

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Abstract: *Simulation software is used widely for analysis of casting system to improve the casting design and process. Castings must have maximum casting yield and negligible casting defects to reduce the material wastage as well as to minimize customer rejection. Shrinkage defect is a major casting defect which leads to rejection of part. Optimization of the riser is necessary to reduce the shrinkage defect and also to improve the casting yield. Size, type, and location of riser largely influence the shrinkage defect found in the casting part. Manual design and trial of feeding system require a huge amount of time, labour cost, metal wastage cost, and other resources. In this case, Casting Simulation can be very useful to overcome these difficulties. In this paper, Solidification Simulation is done on casting part to identify the critical zone where shrinkage defect take place. Further modification in riser design is done to eliminate the shrinkage defects from the main casting part.*

Key Words: Casting Simulation Software, Shrinkage Defect, Casting Yield, Solidification Simulation

1. INTRODUCTION

Casting Process is widely used to manufacture the part of complex shape in a very economical way. In the casting process, molten metal poured into a mould cavity and after solidification, it takes the shape of the mould cavity. Further machining is done on the casted part to remove the gating and riser system and to meet the surface finish up to customer requirement. Risers are used in casting to compensate the shrinkage occurs during the solidification process. So, the riser system largely influences the casting defects, casting yield and the cost of the casting of part. Improper design of riser system leads to defects in the main casting and also lower casting yield. So, it is very important to design the riser system with optimum size, shape, and location to reduce the shrinkage defect and to improve the casting yield.

Directional solidification is very necessary to achieve defect-free sound casting. During solidification, solidification starts from the main casting then feeder neck and lastly feeder to achieve directional solidification.

Sometimes, manual design of gating and feeding (riser) system requires more time and shop floor trials, which increase the cost of manufacturing. Casting Simulation Software can reduce the time required for the design of optimum gating and feeding system and eliminate the requirement of shop floor trials. We can get defects free sound casting by using the Casting Simulation Software.

3D CAD model of the part is required for casting simulation software as to main input, followed by design of mould, cores, gating system and risers. Specification of materials and process parameters such as type of mould, pouring temperature, interfacial heat transfer coefficient, mould or room temperature, etc. also required to process the simulation. Outputs from the simulation software are animated visualization of mould filling, casting solidification, the microstructure of casting, etc. which help in better design of gating and riser system [1].

2. METHODOLOGY AND CASTING SIMULATION

Solidification simulation of the casting starts with the 3D modelling of the part. A 3D solid model of the part is generated and saved in an appropriate format compatible with the simulation software. After that model is imported into the simulation software and meshed with a proper mesh size to cover the all minimum wall thickness of the model. In the next step, material and mould properties, and process parameters are applied. After that, simulation is started with the proper runtime parameters. After completion of the simulation, casting is analyzed for shrinkage defects. Modification in the feeding system is done to overcome the shrinkage defects as well as to maintain the optimum casting yield. After modification, simulation of the casting is done again to validate the shrinkage free sound casting.

In this paper, Solidification simulation of Gravity filled sand casting process is done on Tyre mould, a component used to manufacture tyres. This component is made of material **IS 1030 Grade 200-400W**, a commonly used steel alloy in Indian Casting Foundry. Chemical Composition of IS 1030 Grade 200-400W is given in Table 1.

Table-1: IS 1030 Grade 200-400W Composition

Material	Composition %
C	0.25
Mn	1.00
Si	0.60
P	0.035
S	0.035

Ni	0.40
Cr	0.35
Cu	0.40
Mo	0.15
V	0.05
Fe	remaining

3D Model of tyre mould is given in fig 1. Mass of the casting is around 1040kg.

Fig-1: 3D Model of Tyre Mould

Fig-2: Sectional cut of Tyre Mould Model

ProCAST, a finite element method-based casting simulation software, is used for the solidification analysis of casting of a given component. ProCAST software has three main tools for performing the simulation –

VisualMesh – for importing the 3D model of component and to do the meshing.

VisualCast – for applying the material properties and process parameters.

VisualViewer – for viewing and analyzing the result.

Step 1: 3D CAD Modelling and Meshing of Part

Part with the initial design is generated using the Creo Parametric 2.0 modelling software and saved in. prt format. This file is format compatible with the ProCAST software. CAD file imported and its volumetric mesh (3D tetrahedral mesh) generated in VisualMesh (part of ProCAST software) with mesh size 20mm to cover the minimum wall thickness of the part and optimize the time used in simulation as the casting part is of heavy size [figure 3].

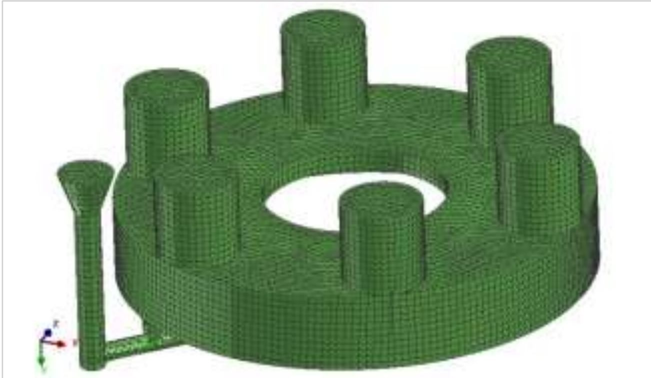

Fig-3: Tetrahedral meshing of 3D model

Step 2: Applying the Properties and Process Parameters

After meshing, the result is saved in .vdb format and reopened in VisualCast to apply the properties and boundary conditions.

Firstly, material properties of IS 1030 Grade 200-400W is calculated using Computherm module. Process parameters such as pouring point of material 1650˚C, room temperature 30˚C and casting process as gravity filled sand casting process is selected for simulation [figure 4].

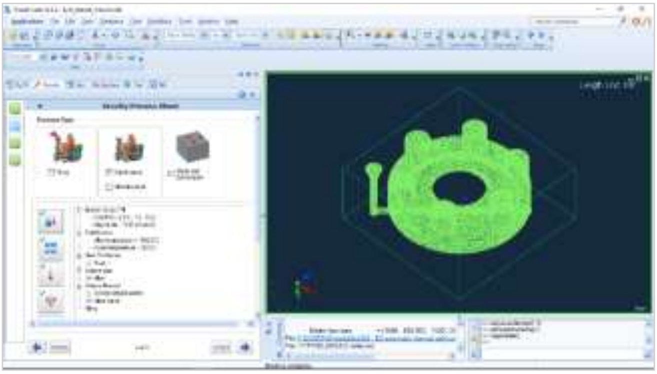

Fig-4: Defining Material Properties and Process Parameters

Step 3: Starting Simulation Process and Analysing Result

After solidification simulation of casting only (without gating and riser system) shows shrinkage defects as given below in fig 5. From this figure, we get an idea about the location of the formation of shrinkage defects in casting.

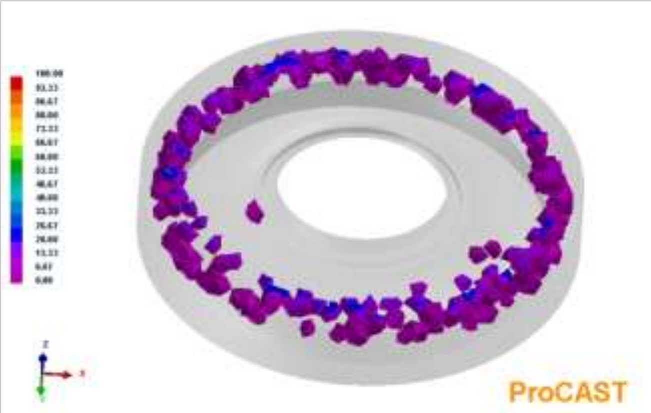

Fig-5: Shrinkage defects in the casting without gating and riser system

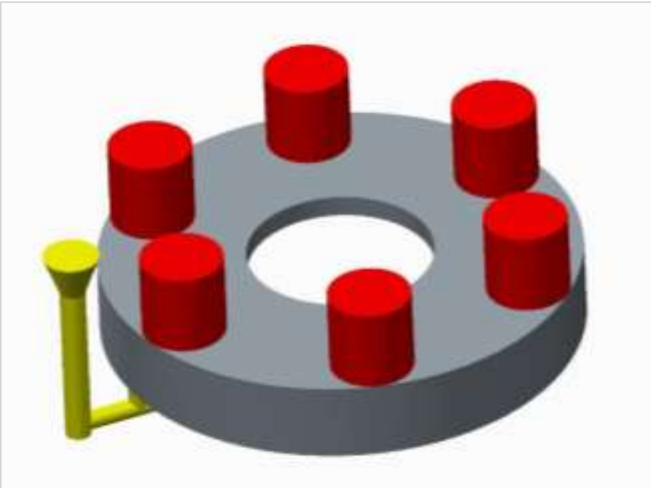

Fig-6: Initial casting design

Initial gating and riser system of casting are given in fig 6. Initially, casting has 6 risers of dimension ø230mm x 230mm. Risers are attached with the boundary of the main casting as shown in the figure. Circular cross-sectional sprue, runner and ingate are used, having diameters as 70mm, 50mm, 50mm respectively.

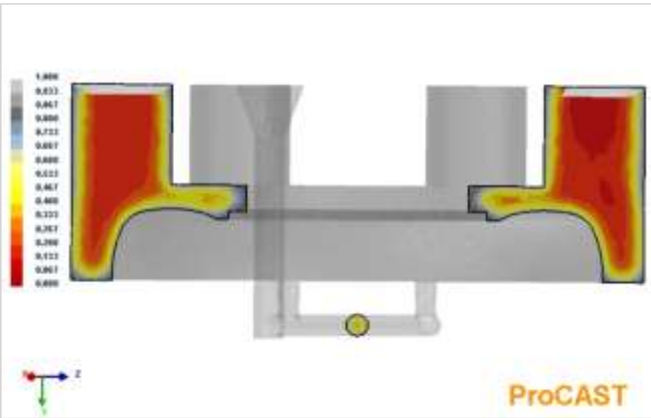

Fig-7: Solidification result of initial casting design

Solidification simulation result of initial casting design is shown in fig 7. XY Section of casting is taken into consideration to see the solidification of casting and compensation of shrinkage cavity by risers. As you can see isolated hotspot found in the main casting which leads to shrinkage defects in the casting. Shrinkage defects found in the initial casting design is shown in fig 8.

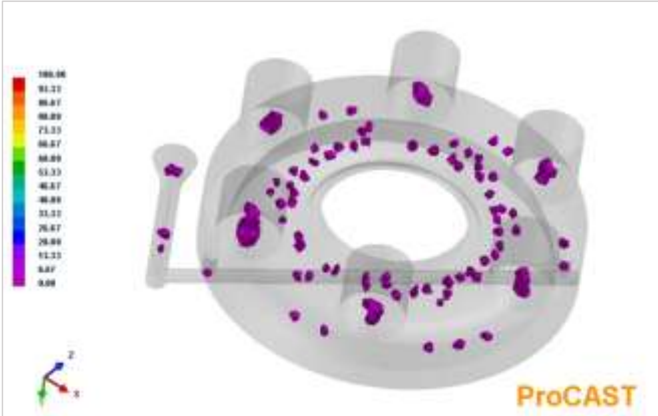

Fig-8: Shrinkage defects in initial casting design

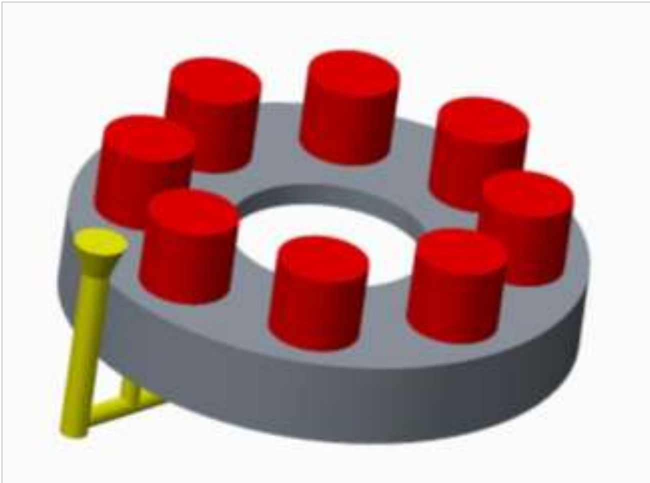

Fig-9: Modified casting design

Now, modification in casting is done according to simulation result from initial casting design. In modified casting 8 risers of dimension ø230mm x 200mm are used at distance from 65mm from the boundary of the main casting as shown in fig 9.

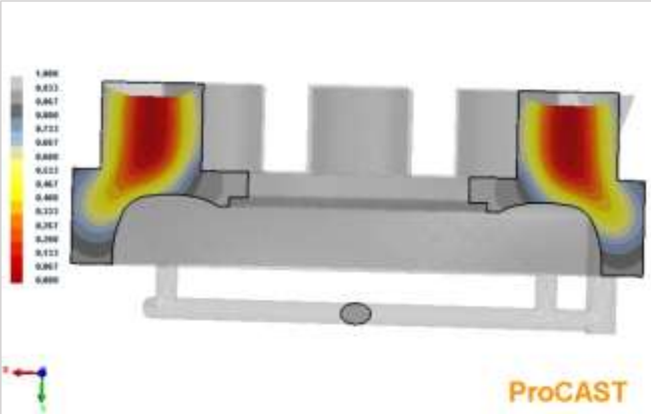

Fig-10: Solidification result of modified casting design

Again, we take the XY section of the solidification simulation result. Now, we can clearly see there is directional solidification achieved [figure 10]. There is no isolated hotspot found in the main casting. Solidification process starts from the main casting and then riser. So, the riser can effectively compensate the shrinkage cavity found in the main casting. As a result, no shrinkage defects found in the main casting as fig 11. Shrinkage defects are found only in the risers and gating system which is a secondary part of the casting.

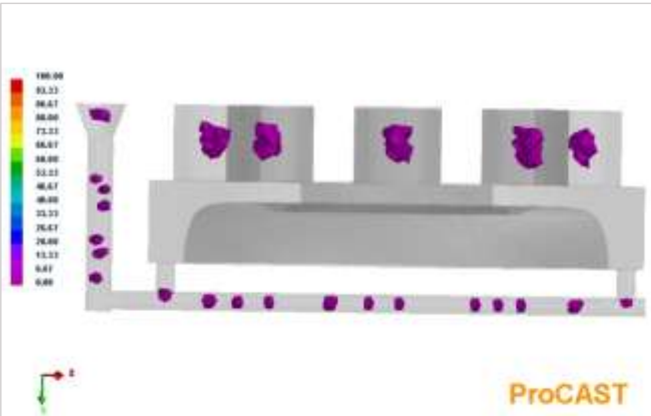

Fig-11: Shrinkage defects in modified casting design

3. CONCLUSION

As we can see from above simulation result, solidification simulation helped us to identify the location of shrinkage defects in the casting and also to redesign the riser system to eliminate the shrinkage defects without any wastage of metal or on-floor trials. Solidification simulation of casting can also be useful for prediction of riser effectiveness in casting. Riser design can be optimized to improve the casting yield as well as to eliminate the shrinkage defects. This leads to low rejection of part and better utilization of resources in the foundry.

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