Optimization of sealing casting by identifying solidification defect and improvement of strength by casting simulation

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Abstract - *The casting industry employs a variety of ways to address casting fault issues. A large number of casting rejections results in a waste of both money and effort. Single flaws in casting might have a single or several causes, thus it's critical to figure out what's causing the problem. This industry's productivity has risen to an all-time high. Modern technology has reduced resource use while simultaneously reducing faults. Adopting a more controlled approach to describing, recognizing, and regulating the underlying cause of an issue will be advantageous. The primary goal of this research is to identify solidification defect and minimize it by optimizing new design with help of casting simulation software. This research will aid in improving strength of material and hence quality.*

Key Words: **Sand casting, Solidification defect, ProCAST, L-type Sealing casting, shrinkage porosity, Misrun**

1. INTRODUCTION

Casting is one of the main economical production processes used in industry and is a complex process that involves important metallurgical and mechanical aspects. The rate of solidification largely determines the microstructure, which in turn determines mechanical properties such as strength, hardness, machinability, etc. The location, size, and shape of risers in a casting depend on the shape, mold design, and heat of the casting, properties of the metal and other factors, process parameters. Improperly designed riser and gate systems will always result in defective molds with shrinkage cavities or poor experimental results, which are always better for mold design and development and to achieve optimal process parameters.

However, this can be expensive, time consuming, and in some cases impossible. Therefore, the casting simulation process is a convenient way to properly design a riser system and analyze the effect of various parameters. The number of foundry simulation programs in India is also increasing day by day, as it essentially replaces or minimizes shop floor testing to achieve the desired internal quality in the maximum possible time. It can greatly reduce iterations on the shop floor and is mainly used for proof-of-concept. Simulation programs generally increase the confidence of foundries when creating more complex castings (complex, large) with higher margins. It also provides a scientific and documented basis for quality assurance and certification.

1.1 Related Work

Ravi (2008) have studied at the benefits of casting simulation, bottlenecks and best practices for overcoming bottlenecks without burial testing, they provide quality assurance and significantly minimize lead times to cast the first good sample.

Naveen (2014) has discussed the steps which is included in simulation the possible source of error and care to be has to be taken during the time of casting simulation process. According to him the designer should have confidence in casting simulation tool which are going to be used. The confidence level will come only by experience and usage of the tool to mimic effect of various process parameters.

Prabhakara et al. (2006) have studied on the solidification mold filling simulation of green sand casting, ductile iron casting sand, and using casting simulation software such as PRO CAST, it was concluded that defects such as shrinkage, porosity, etc. could be eliminated. It can also improve yield of the casting, optimize the gating system design & mold filling.

Karl B. Rundman explained metal casting procedure, sand casting procedure and other casting procedure. He discusses the defects in casting. He also studies the solidification phenomena in casting procedure.

C. W. Ammen [1979] He discussed the different elements required in sand castings. He also discussed the defects in sand casting.

1.2 Problem Definition:

In order to remain competitive in today's market, a modern foundry has to take full advantage of the benefits offered by casting simulation. These allow the foundry man to analyses problems in detail, faster, and at an early stage in the design cycle, thus enabling decisions to be made towards improving design and quality. Therefore, the costs and the risk associated with the trial and error procedure of experimental castings are minimized. In the present dissertation we use the casting simulation software to identify the solidifying defects present in the sealing casting and an attempt was made to optimize the sealing casting.

1.3 Objectives

The main objective of present investigation is optimization of sealing casting by casting simulation process.

1. To study the casting procedure, application, problems and defects in sealing casting.

2. To do solidification Analysis of the existing sealing casting.

3. To give solution for the defects like shrinkage, Misrun and improve strength of sealing casting by using casting simulation process.

4. To carry out the results of analysis.

2. Methodology

In this chapter, the approach employed in the present work is briefly discussed. In this research, a sealing casting model constructed of grey cast iron is examined. For sand casting, different circumstances are simulated numerically using the commercial software pro-CAST. Various solidification performance metrics, including temperature, hotspot, total shrinkage porosity, voids contour, and solidification contour, etc. The existing technology utilized for simulation of solidification is investigated as the foundation of this work. At the conclusion of the chapter, the findings obtained using the existing gating system for the moulds are discussed.

Typically, simulation software consists of three primary components: (1) Pre-processing (the programme reads the CAD geometry and generates the mesh), (2) Main processing (addition of boundary conditions and material data, filling, and temperature calculations), and (3) Post processing (presentation and evaluation). Based on Finite Element technology, ProCAST offers a comprehensive simulation solution for a wide variety of applications. proCAST's objective is to construct a finite element model, configure the calculation, execute the analysis, and evaluate the findings. The following actions (procedures) were carried out in ProCAST's simulation of the seal casting process.

- Computer-aided design (3D) of a seal casting featuring a gating system utilizing the ANSYS Design Modeler programme.
- Save the CAD file in IGES format and import it into the proCAST software using the geometry transformation tool.
- Mesh the mould and cast using a 2D and 3D surface mesh and volume mesh.
- Input data including volume manager, interface HTC manager, process condition manager, and simulation parameters, and initiate simulation by selecting ProCAST with a solver count of four.

Analyze the results with the view cast, such as temperature, solidification time, and fraction of solid and total shrinkage porosity. The steps related to simulation are shown in Figure 1.

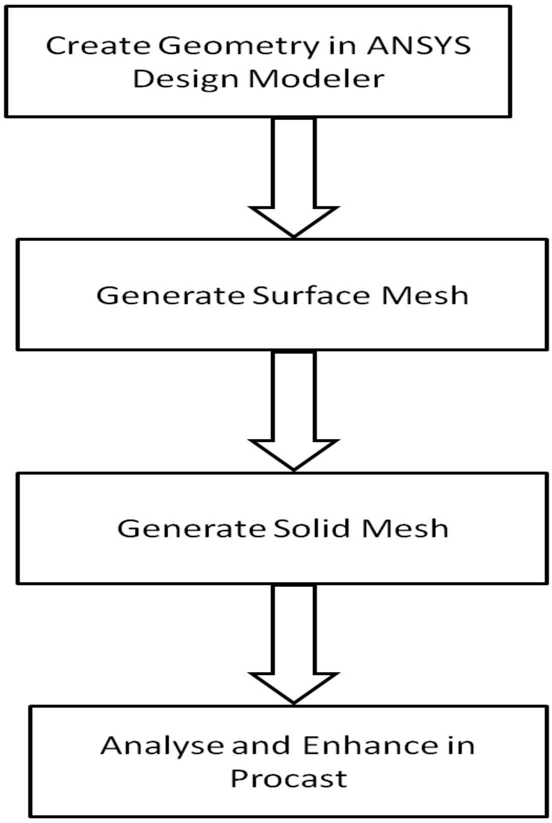


Fig -1: Steps Involved In Numerical Simulation of Solidification Process

2.1 Pre-processing (the programme reads the CAD geometry and generates the mesh)

Figure 2 shows the isometric wireframe view of the casting mold used for the study. The dimensions of the same are given as below,

Length = 300 mm, Width = 300 mm, Height = 120 mm.

The model is drawn and developed in the Ansys Design Modelers software. The developed model is then imported for the meshing purpose. The meshing of the model is carried out in two steps, first the surface meshing is carried out followed by the volume meshing of the model. Both the surface meshing and volume meshing of the model are shown in Figure 3 and Figure 4 respectively.

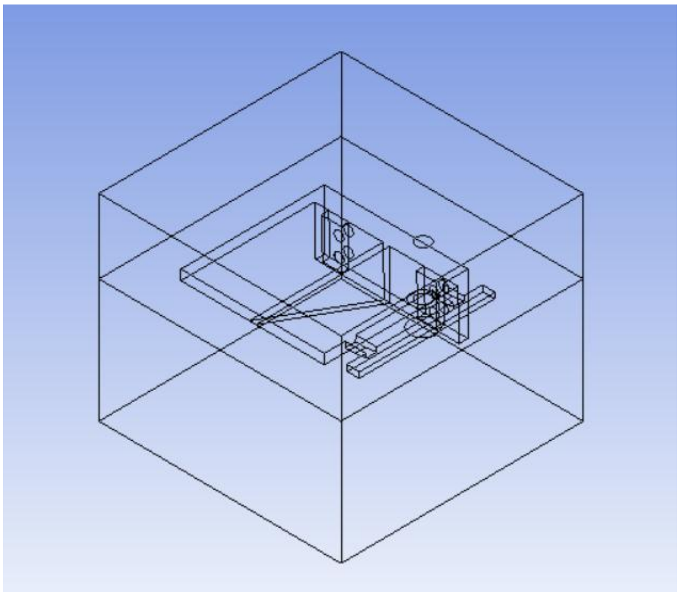


Fig -2: Isometric Wire Frame Model of the Casting Mold Used For the Study

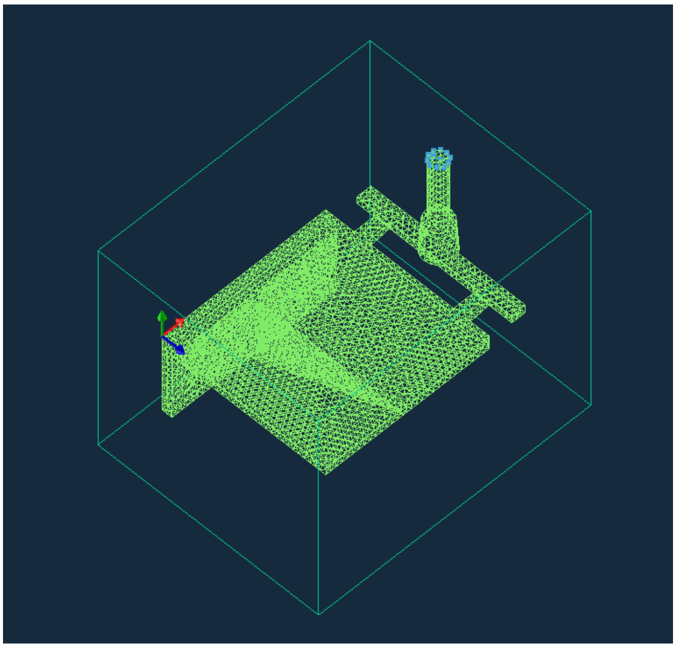


Fig -3: Surface Meshing Of the Model

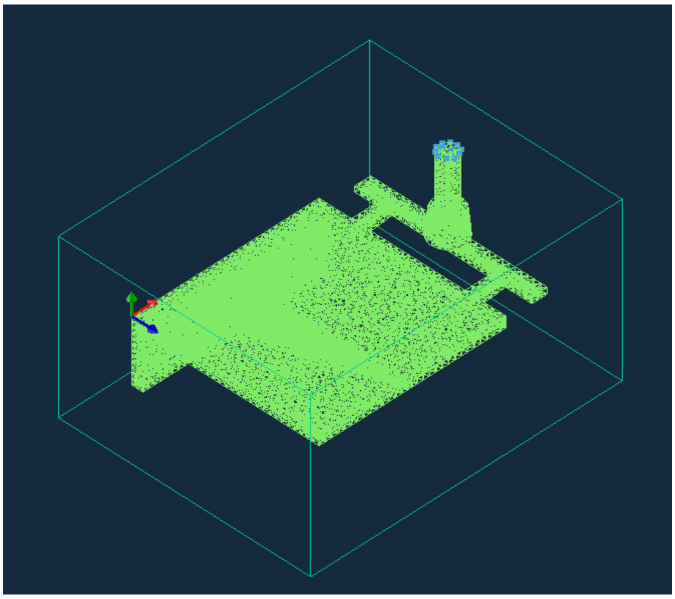
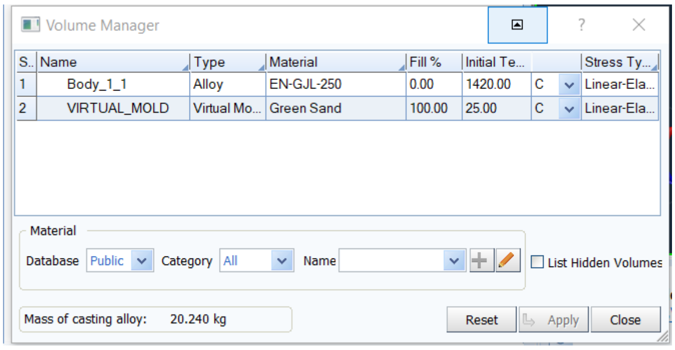


Fig -4: Volume Meshing Of the Model

2.2 Main processing (addition of boundary conditions and material data, filling, and temperature calculations)

After meshing the main processing stage comes in picture. In main processing material assignment, boundary condition and heat transfer conditions from body to mold should be given. Material assignment is done in volume manager as shown in figure 5.


Volume Manager

S..	Name	Type	Material	Fill %	Initial Te...		Stress Ty...
1	Body_1_1	Alloy	EN-GJL-250	0.00	1420.00	C	Linear-Ela...
2	VIRTUAL_MOLD	Virtual Mo...	Green Sand	100.00	25.00	C	Linear-Ela...

Material
Database Public Category All Name
List Hidden Volumes
Mass of casting alloy: 20.240 kg
Reset Apply Close

Fig -5: Volume Manager

Boundary conditions are given in process condition manager as shown in figure 6, in which we generated inlet boundary condition as BC_inlet_2. In BC_inlet_2 we added mass flow rate and pouring temperature and also velocity component. Heat transfer condition from body to mold is given in interface HTC manager as shown in figure 7.

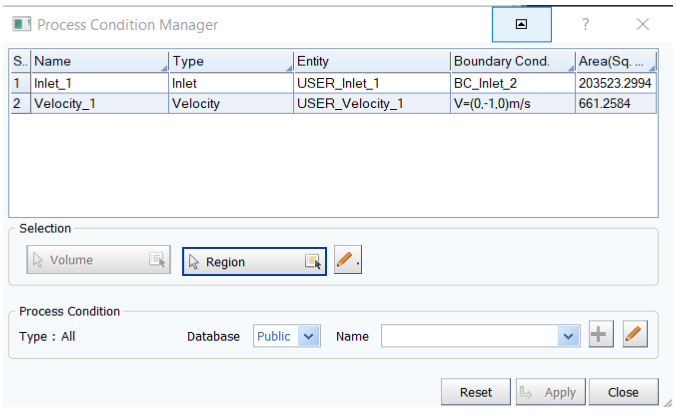


Fig -6: Process Condition Manager

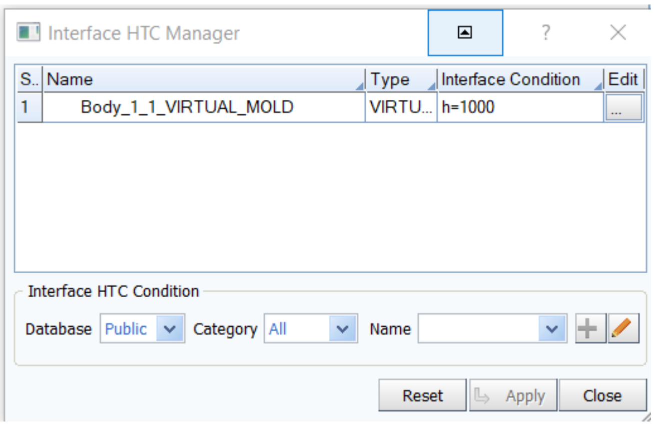


Fig -7: Interface HTC Manager

2.3 Post processing (presentation and evaluation).

Post processing is the last and important step in the simulation process. In post processing we got various contours, graphs charts, etc. our focus in this research is mainly on the shrinkage porosity, hotspot and misrun sensitivity. Figure 8 shows total shrinkage porosity of the existing model which is about 6.67% at different locations.

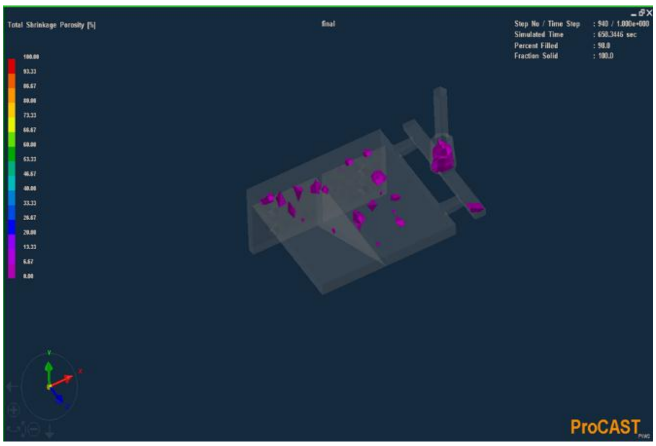


Fig -8: Total Shrinkage Porosity of Existing Model

Figure 9 shows the contour of hotspot on the existing model, from the figure we may say that existing model has several hotspots on its top surface. Misrun sensitivity of existing model is shown in figure 10, from the figure we may conclude that existing model has high risk misrun sensitivity.

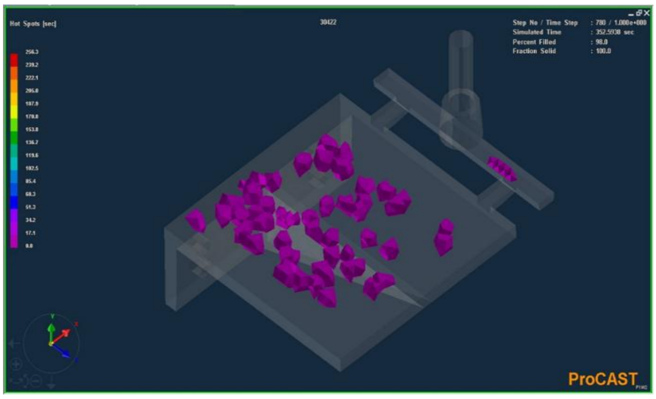


Fig -9: Hotspot on Existing Model

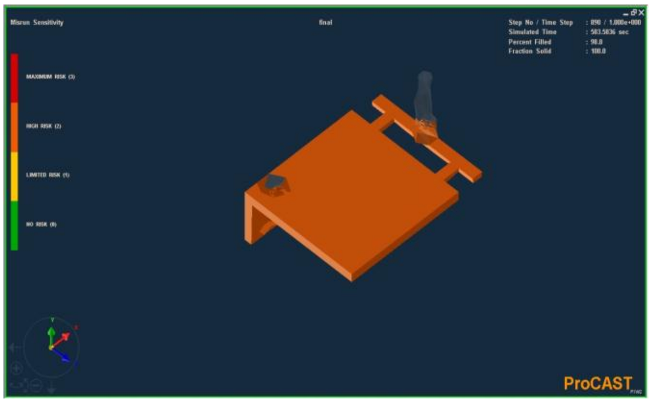


Fig -10: Misrun Sensitivity of Existing Model

3. Modified Design of L type sealing Casting

In the previous chapter the existing model of L type sealing casting is simulated in ProCAST software. The existing model has several casting defects which needed to be rectified. In present chapter, a modified design is developed based on the several design calculation and the same is simulated in the ProCAST software under variable conditions. At the end of this chapter the results obtained from the numerical simulation of the modified L type sealing casting are discussed.

3.1 Pouring time

Pouring time,

$$t = k[1.41 + \frac{T}{14.59}]\sqrt{w}$$

For less than 40 Kg

Where,

$$k = \frac{fluidity\ of\ iron\ in\ inches}{40}$$

T = Average section thickness in mm

W = Mass of casting

So,

$$t = 0.8\,[1.41 + \frac{18}{14.59}]\sqrt{20}$$

$$t = 9.46\ sec$$

3.2 Choke area

Choke area:

$$A = \frac{w}{dtC\,\sqrt{2gH}}$$

Where,

W= casting mass in kg

d=mass density of molten metal

t=pouring time

C=efficiency factor

g=acceleration due to gravity mm/s^2

H=effective metal head in mm

So,

$$A = \frac{20}{6756 \times 10^{-9} \times 9.46 \times 0.9 \times \sqrt{2 \times 9810} \times 152.4}$$

$$A = 201\ mm^2$$

3.3 Gating Ratio and Sprue well

Gating ratio = 1:2:1 (sprue: runner: gate)

Choke area A = 201 mm^2

Runner area from gating ratio (1:2):

$$x = \frac{201 \times 2}{1}$$

$$x = 402\ mm^2$$

Ingate area from gating ratio (1:1) = 201 mm^2

Sprue well area:

$$Sprue\ well\ area = 5 \times Choke\ Area$$

$$Sprue\ well\ area = 5 \times 201$$

$$Sprue\ well\ area = 1005\ mm^2$$

$$Sprue\ well\ diameter = 36\ mm$$

$$Sprue\ well\ height = 2.5 \times width\ of\ the\ runner$$

$$Sprue\ well\ height = 2.5 \times 25$$

$$Sprue\ well\ height = 62\ mm$$

3.4 Riser

$$Volume\ of\ casting = 2.6569 \times 106$$

$$Surface\ area\ of\ casting = 2.9908 \times 105$$

$$Volume\ of\ riser = \frac{\pi}{4} D^3$$

$$Surface\ area\ of\ the\ riser = \pi D^2 + \frac{\pi}{4} D^2 = 125 D^3$$

$$Freezing\ ratio = x = \frac{\frac{surface\ area\ of\ the\ casting}{volume\ of\ the\ casting}}{\frac{surface\ area\ of\ the\ riser}{volume\ of\ the\ riser}} = 0.22488D$$

$$Y = \frac{Volume\ of\ the\ riser}{Volume\ of\ casting} = 0.0000933988 D^3$$

[Note: Constant Canies equation for Grey Cast Iron a = 0.3, b = 0.03, c = 1.00]

Substituting above values in to Canies equation for grey cast iron

$$X = \frac{a}{Y - b} + C$$

$$0.22488D = \frac{0.33}{0.0000933988 D^3} + 1$$

$$D^4 + 44.468 D^3 = 15613.216$$

By trial and error method,

$$D = 6.73 \approx 7\ cm$$

Height of the riser = diameter of the riser = 7cm.

3.5 Pre-processing (the programme reads the CAD geometry and generates the mesh)

Figure 11 shows the isometric wireframe view of the modified casting mold used. The dimensions of the same are given as below,

Length = 300 mm, Width = 300 mm, Height = 120 mm.

The model is drawn and developed in the Ansys Design Modelers software. The modified model is then imported for the meshing purpose. The meshing of the model is carried out in two steps, first the surface meshing is carried out followed by the volume meshing of the model. Both the surface meshing and volume meshing of the model are shown in Figure 12 and Figure 13 respectively.

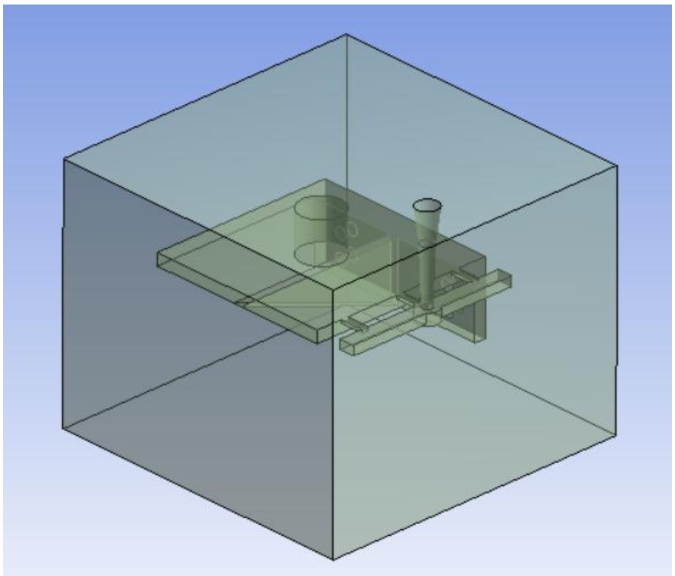


Fig -11: Isometric Wire Frame Modified Model of the Casting Mold

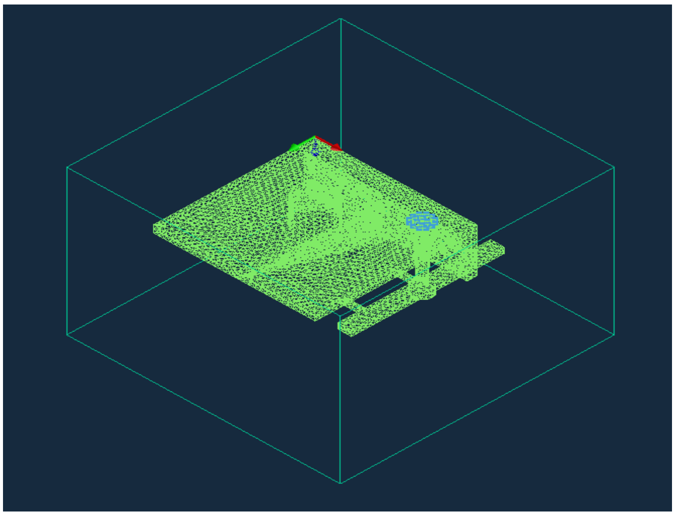


Fig -12: Surface Meshing Of the Modified Model

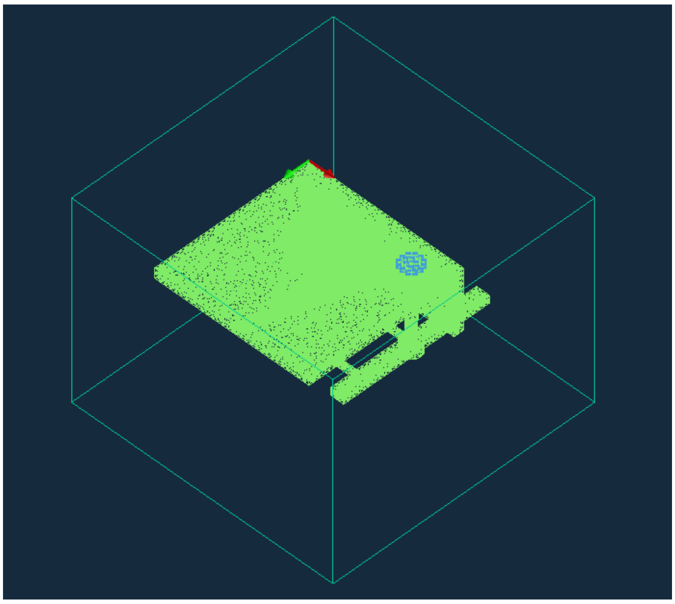


Fig -13: Volume Meshing Of the Modified Model

3.6 Main processing (addition of boundary conditions and material data, filling, and temperature calculations)

After meshing the main processing stage comes in picture. In main processing material assignment, boundary condition and heat transfer conditions from body to mold were given as per the existing model shown on figure 5, 6 and 7.

3.7 Post processing (presentation and evaluation).

At post processing we got the contours of total shrinkage porosity, hotspot and misrun sensitivity. In figure 14 we can clearly see that total shrinkage porosity reduced and present at only few points.

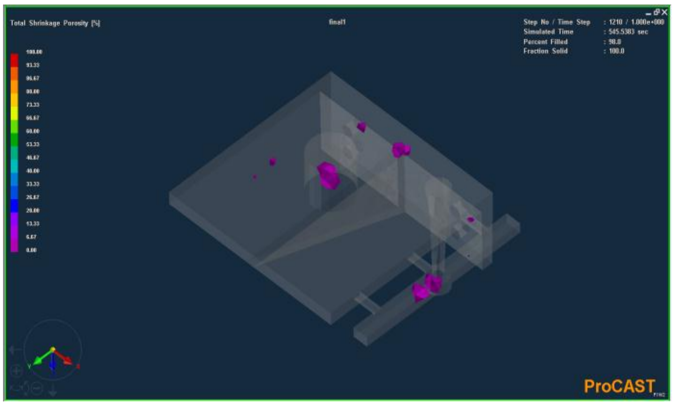


Fig -14: Total Shrinkage Porosity of Modified Model

Figure 15 shows the contour of hotspot on the modified model, from the figure we may say that modified model has fewer hotspots on its top surface. Misrun sensitivity of modified model is shown in figure 16, from the figure we may conclude that modified model no risk misrun sensitivity.

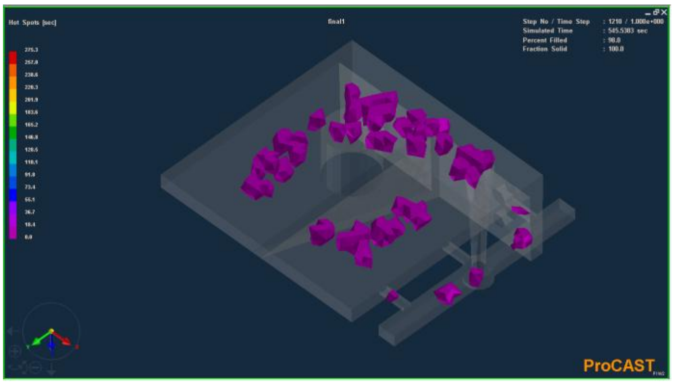


Fig -15: Hotspot on Existing Model

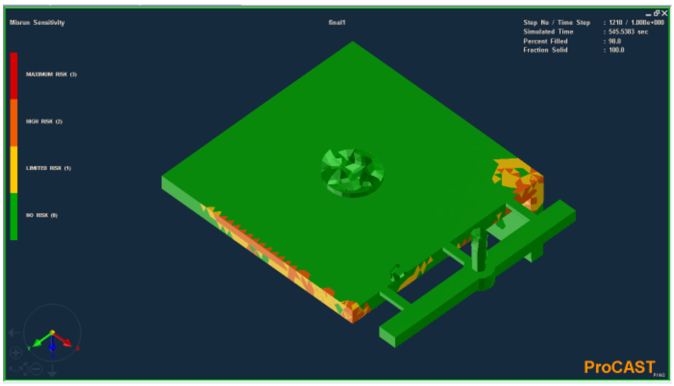


Fig -16: Misrun Sensitivity of Existing Model

4. CONCLUSIONS

In this research, it is proposed to examine a sealing casting model produced from grey cast iron. For sand casting, different circumstances are simulated numerically using the commercial software pro-CAST. Various solidification performance metrics, including temperature, hotspot, total shrinkage porosity, and solidification contour, etc.

1. Casting simulation technology has sufficiently matured and has become an essential tool for casting defect troubleshooting and method optimization. It enables quality assurance and high yield without shop-floor trials, and considerably reduces the lead-time for the first good sample cast.

2. By moving the trial and error process into the virtual world and determine the cost of different design and process options. By minimizing real world trial and error (and surprises) making castings right the first time.

3. From above thesis work, we found that when riser is introduced the shrinkage porosity decreased. Also by modifying geometry as per the sizes of the gating system defects like hotspot, misrun and shrinkage porosity decreased. After all it reduces the casting rejection rate.

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