"Shrinkage Porosity & Temperature Distribution analysis of air cooled Cylinder liner block of Grey cast iron – ASTM class 35"

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ABSTRACT

The major requirement of any foundry is to provide high quality casting products. Since the quality is depended on thermal stress and solidification of the casting, a thermal analysis is a key area to work on. Heat transfer coefficient is the vital element of any thermal analysis. Mould and the Casting interface is the most critical area that gets affected during the solidification. Heat transfer ratio at the inter face will give an explanation about temperature distribution and thermal stress analysis. Pro-Cast helps to understand heat flow of the casting. The moment when the molten metal solidifies is the most important instant and at that time thermal analysis is required to forecast the outcome of the casting solidification and to understand its behaviour..

Keywords: *Casting, Temperature Distribution and Thermal Analysis, FEA, Pro-Cast.*

1. Introduction:

Casting is one of the oldest manufacturing processes that produce variety of domestic and industrial products. From melting the metal/alloy to machining of the final goods have many stages which affect the final output in a different manner. The most important instant is when the object solidifies and goes through various transient temperature flow variations that produce stress levels in different areas causing problems and defects. [2]

Su Ling-Lu aims on the wet type cylinder liner produced by horizontal centrifugal casting and defects like macro segregation and shrinkage holes. After simulation and optimization of the solidification of the WTCL model using casting software, temperature field can be found. Author investigates starting time for water cooling, variation in mold wall thickness, thermal insulation criteria and coating thickness, through which coating thickness is the most influential parameter on the defect area. After study, the optimum method was proposed [3]

Srinivasulu Reddy has used Pro-Cast software saying that Pro-Cast is a 3D analysis software and carries out solidification and temperature analysis.He has worked in the object called casting wheel Rim [4]

P. Prabhakar Rao has worked on a crushing component and load bearing structure which requires good mechanical properties and zero porosity. The combination of CAD technologies and process simulation tools helps in achieving this in a given limited time span. This study helps in reducing scrap rates due to unpredictable defects [5]

There is a lot of work already been done in the thermal analysis in the zone of casting. In this study a review of such work has been prepared and steps to solve thermal analysis using ANSYS are discussed

Thermal analysis software helps the tedious process of finding and understanding the heat flow of the casting during the solidification procedure. To analyze the process various programming tools like Pro-cast, Opt-cast ANSYS etc are available to give out the results of thermal analysis. [1]

Here in this study we are concentrating on the Cylinder liner block of 85.5 mm used in Volkswegan Betel Car engine.

In the Rajkot based Company Esteem Auto Pvt. Ltd. this liner block is manufactured and the manufacturing is done by sand casting which has a porosity defect.
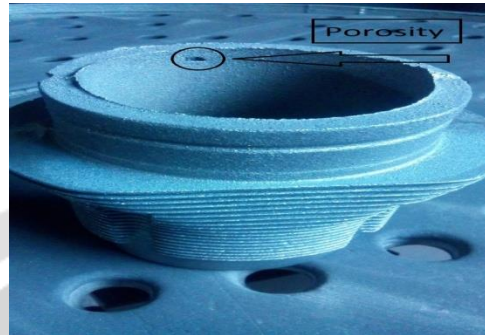
Figure : 1 (Defected Cylinder)

Few input parameters of the simulation are discussed here. Material properties of Grey Cast Iron ASTM class 35 is shown below.

Material Properties	Values
Compressive (Crushing) Strength	860 MPa (130 x 10^3 psi
Density	**7.2 g/cm³(450 lb/ft³)**
Elastic (Young's, Tensile) Modulus	100 to 119 G Pa (15 to 17 x 10^6 psi)
Elongation at Break	1 %
Fatigue Strength (Endurance Limit)	110 MPa (16 x 10^3 psi)
Melting Onset (Solidus)	1090 °C (1990 °F)
Shear Strength	334 MPa (48 x 10^3 psi)

Table 1 : Material Properties of Cast Iron

Material Properties	Values
Specific Heat Capacity	450 J/kg-K
Strength to Weight Ratio	33 to 38 KN-m/kg
Tensile Strength: Ultimate (UTS)	240 to 270 MPa (35 to 39 x 10^3 psi)
Tensile Strength: Yield (Proof)	165 MPa (24 x 10^3 psi)
Thermal Conductivity	46 W/m-K
Thermal Diffusivity	14
Thermal Expansion	10.5 µm/m-K

Table 1 : Material Properties of Cast Iron

Sand Properties of Silica sand is shown below in the table.

Property of Silica Sand	Value
Conductivity	0.4 to 0.8 W/m K
Specific heat	1172.304J/Kg K
Density	1520 Kg/m^3

Table 2 : Silica Sand Properties

2. Methodology

Modelling of a casting Process [1]

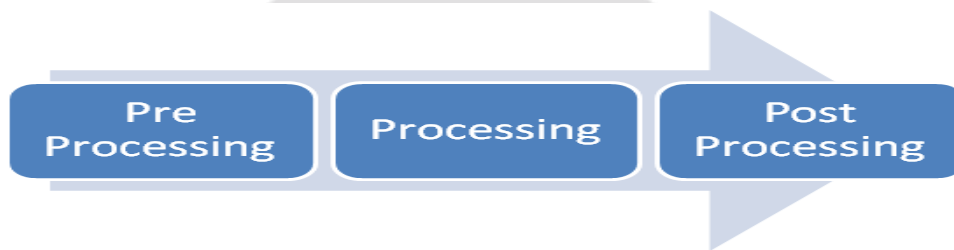In a regular casting simulation software the simulation takes following three steps:

Figure 2: (steps of analysis)
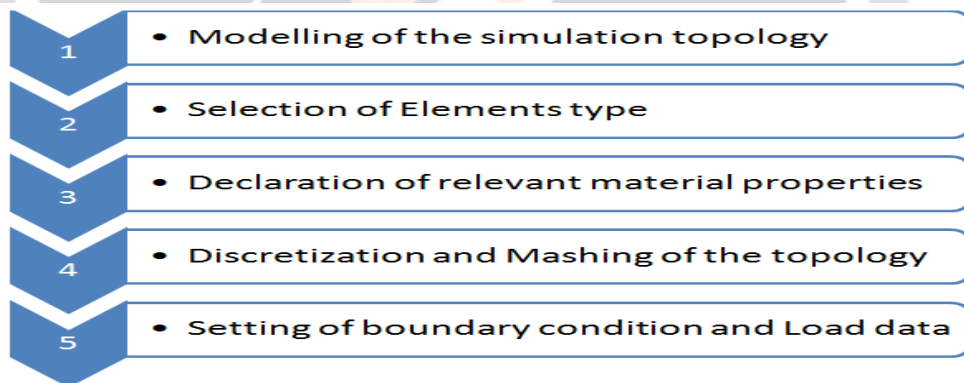
1) In Pre-Processor stage following jobs are done:

Figure 3:(Steps of pre-processing)

2) In the Main processing stage following jobs are done
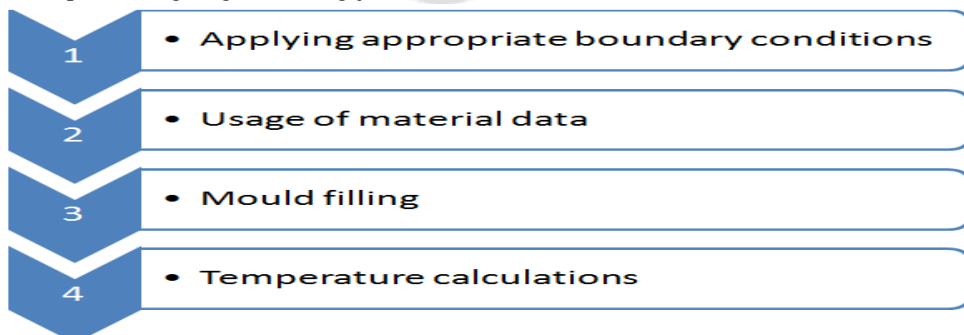
Figure 4: (Steps of Main processing)

3)   In the Post processing stage following jobs are done
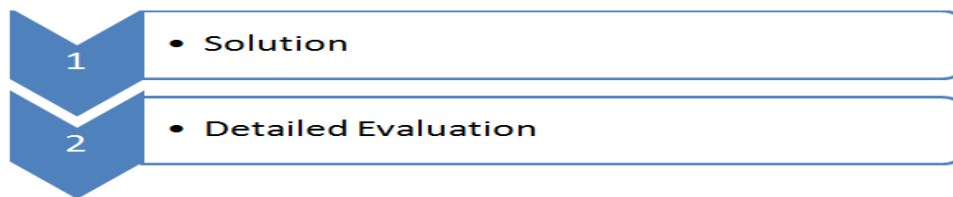
Figure 5: (Steps of Post processing)
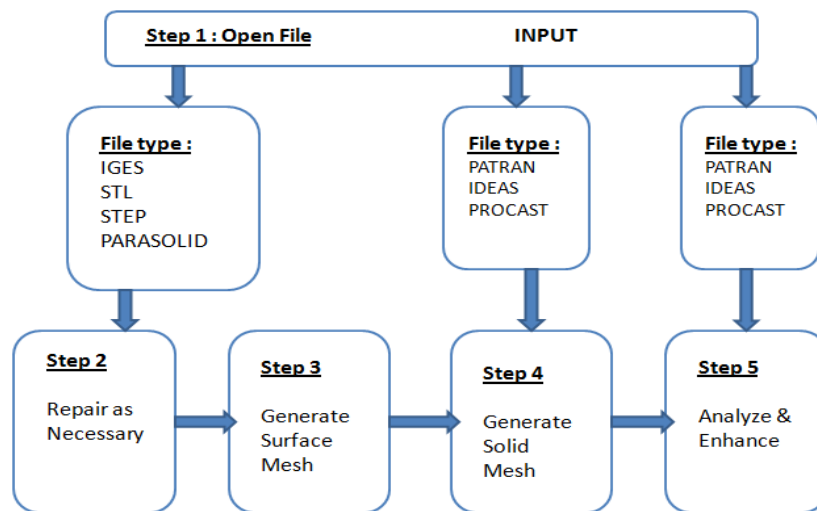
Generalized idea of Procast simulation is given below.

Figure 6 : Pro-Cast Stages

1)   After The 3D models of entire gating system and mold has been created the file type is chosen to open it in the Pro-Cast environment for the further simulation. The file type may be STL,STEP, Parasolid etc.
2)   After opening the relative file for the simulation one has to coincide the Casting 3D model with the 3D Model of the Mold, which is known as Boolean operation of Cast & Mold.
3)   Meshing is Generated of the Half symmetry assembly of the Cast & Mold. Basic Mesh in Pro-Cast is done by the following manner
      a.   Surface Mesh : Meshing of the peripheral surface is done
      b.   Check Mesh : Meshing Quality in the mesh environment is checked weather it is up to the mark or not.Is there any unmeshed surface left or not?
      c.   Correct Mesh : It corrects and solves the meshing irregularities and unmeshed surface.
      d.   After the surface mesh is completed the entire body is meshed inan environment called Solid mesh or Volume Mesh.
4)   The next environment is Cast. It has a provision of declaring the Material Specification in our case is Thermal Properties of the Cast Iron Class 35. Also some of the basic parameters are discussed below.
5)   Material neeeds to be given their solidus and Liquidus temperature that has been specified in the table. Also Body 1 & 2 that are Casting & Mold reapectively needs their initial temperature for the further analysis as boundary Condition. It gives out the weight of the object on the base of the size of the mold and density as 4.756 Kg which is close to actual weight
6)   When one co incide Cast & Mold one get some interface between their respective boundary that undergoes thermal distribution as well. Heat transfer Co-efficient at the cast mold interface is given to the system which is taken as 500 W/m^2 K.

Here some of the input and output parameters of the research has been shown in the following diagram
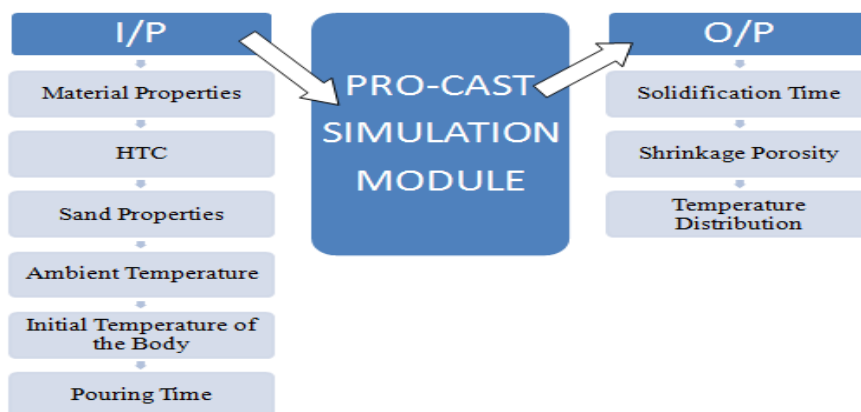

Figure 7 : Input – Output Parameters

Here is the 3D model of the gating system created in CREO APDL workbench.

Figure 8 : 3D model of Gating System

Following are the surface and solid mesh geometry of the object created in Procast software.
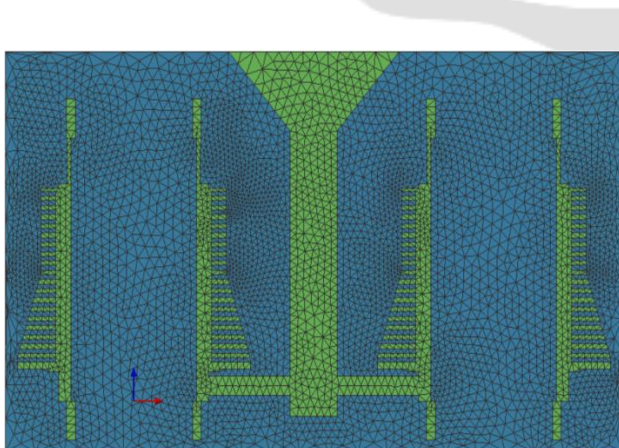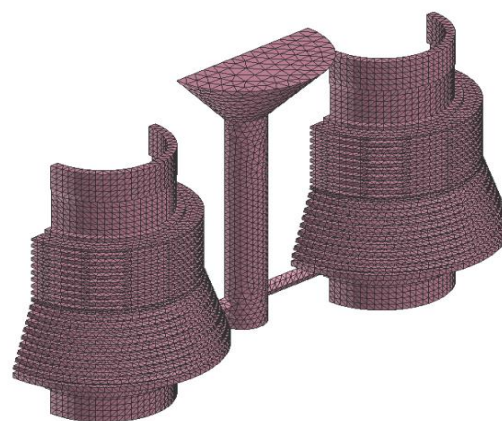

Figure 9 : Surface Meshing   Figure 10 : Volume Meshing

Boundary Condition is applied now and Half symmetry Constraint is also selected because it takes lees time for simulation for half of the object then the full it self

Air cooling is applied around the surface of the mold as shown.

Velosity required to fill in the cast in a minute is applied on the half circle Temperature range of 1350 °C and Pressure of 1 bar is applied.
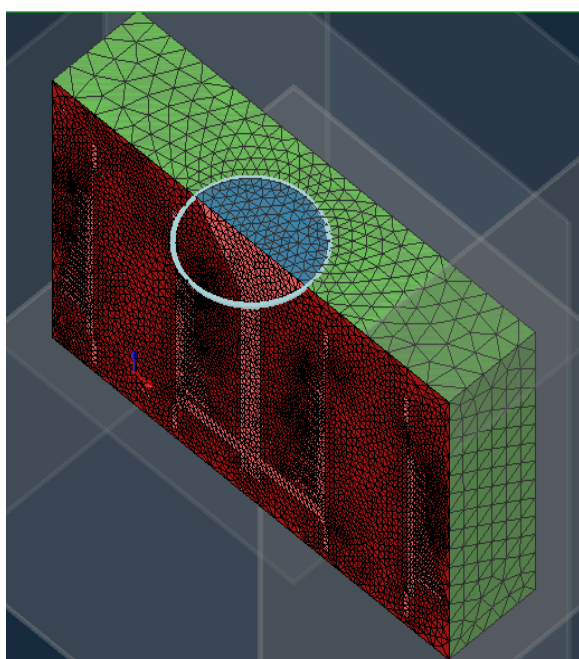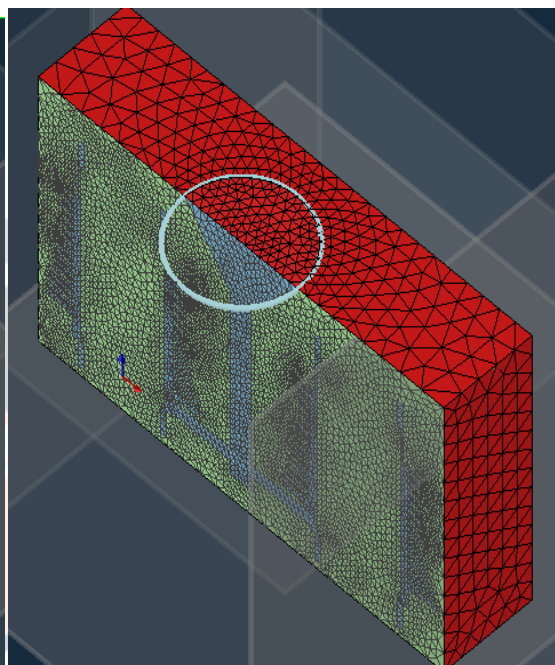

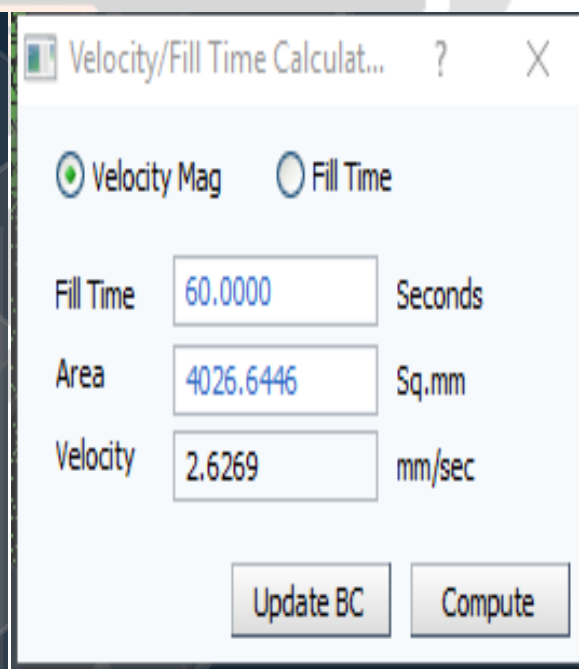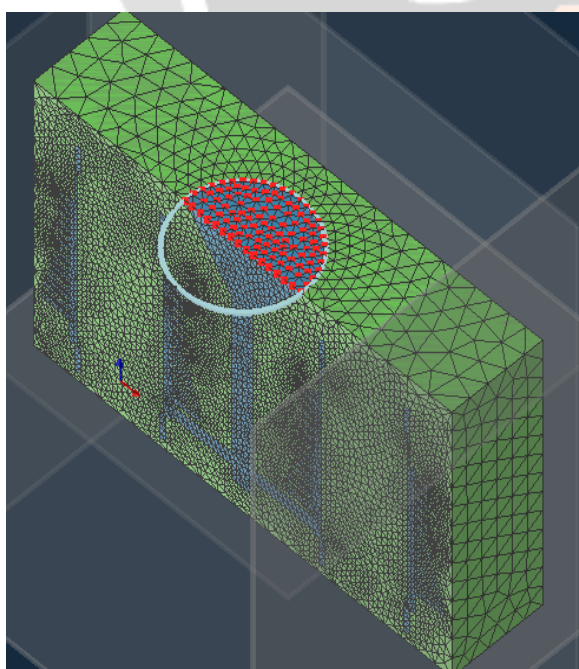Figure 13 : Half Cymmetry Constraint   Figure 14 : Air cooling Constraint

Figure16 : Velocity Constraint

3. Temperature Distribution

Here after all the boundary Condition applied to the file, Temperature distribution is carried out

Following are the four iterations shown when the mould is filled 5%, 20%, 40%, and 90%. It shows the thermal behaviour of the casting object.
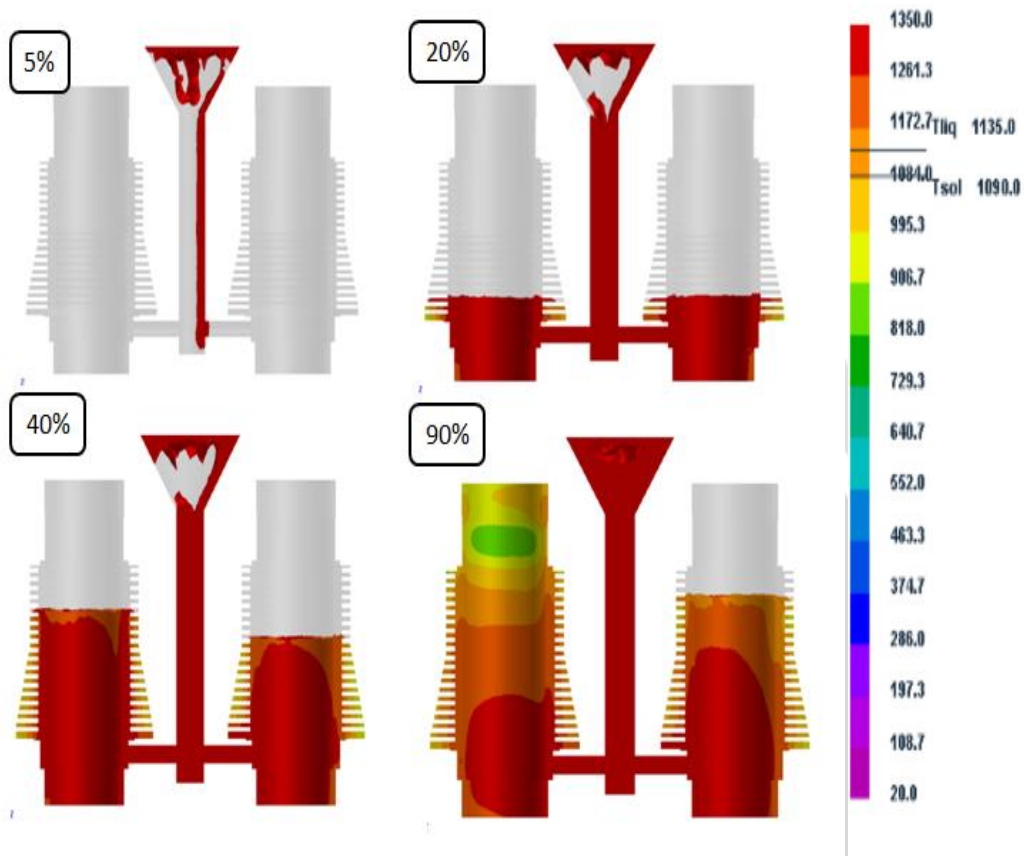

Figure 18: Filling Iterations

Following is the final temperature distribution and thermal behaviour of the object when the mould os filled maximum
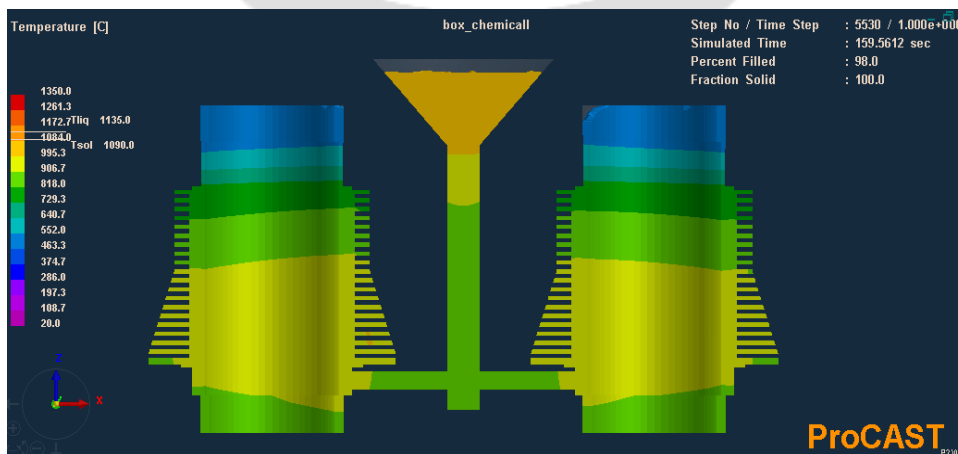

Figure 19: Temperature Distribution Analysis

Following is the solidification simulation showing the start instanteneous time that has been observed **159.56 seconds**
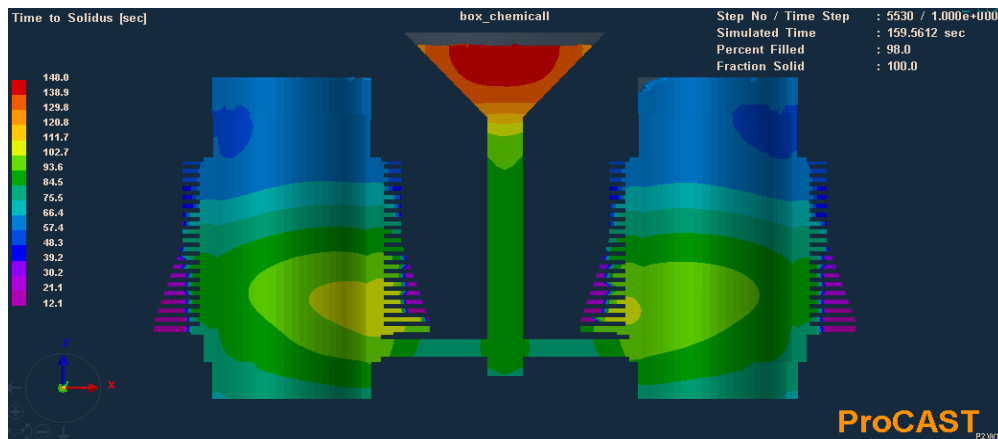

Figure 20: Solidification Simulation

4. Porosity Analysis

Following is the final porosity analysis report that shows that the porosity around the bore is measured. Also tiny micro porosity measured in the fins

The amount of porosity measured is measured by the software is **2.69 %** to be exact.

In shop floor trials in the Esteeme Auto Pvt.Ltd is also shows the porosity in side the bore which is not negligeble.
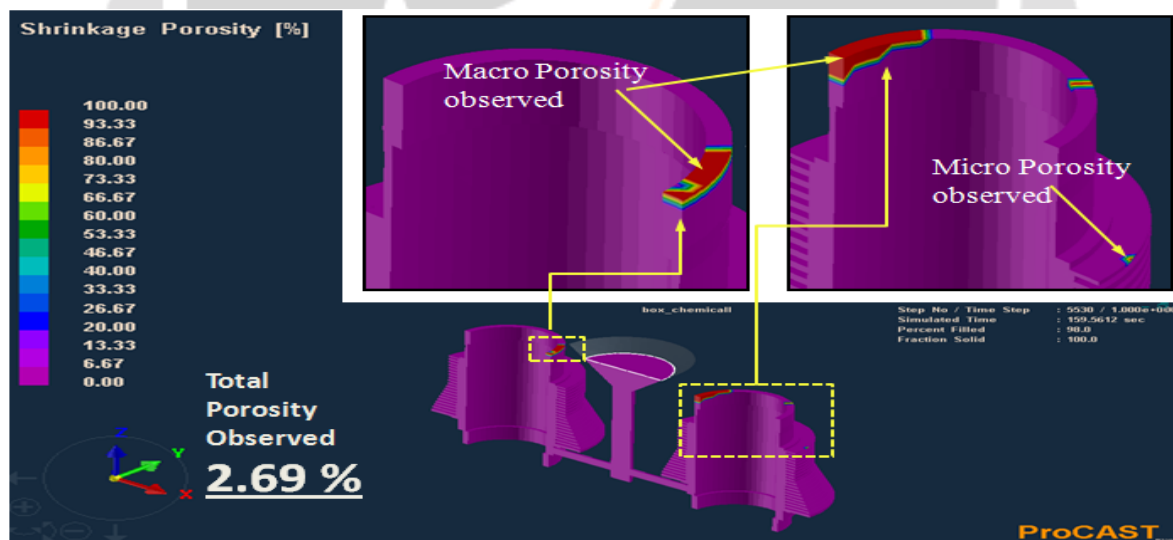

Figure 21: Porosity Analysis and location Detection

5. Conclusion

Pro cast is one of the finest casting simulation software and simulation cuts down the shop floor trial that helps predicting the amount and location of the porosity.

After performing simulation in pro cast, porosity amount has been found to be 2.69 % and It has been found around the inner bore area which matches industrial output as well. Solidification simulation shows solidus time has been observed as 159.56 seconds.

Also the detailed temperature distribution of the object has been carried out.

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