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"Design and Analysis of fluid flow in AISI 1008 Steel reduction gear box and fluidity index"

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Abstract:- *In present situation we are founding problems in industries that are in casting. Now a day's industries are saving money and time to manufacturing products because there is much of competition in world industries. Coming to research the main aim of the project is redesigned the product in FEM analysis using commercial software and increase the product life. Many of the researchers considered that90% of the defects shows in the casting that is solidification time and shrinkage and hotspots, due to the mis-run and improper filling and gating and risering these are the problems and only 10% is manufacturing problems in industries. To minimize defects in casting systems based on the CAD simulation and analysis in simulation technology with the goal to improve the casting quality. Therefore in this dissertation optimize the results in present based on the CTIA and simulation technology. Design a model in CATIA to pat design and convert in casting model. After analysis simulation results shrinkage and solidification and hotspots system is used to improve the casting quality. In these reduction gear box is used to verify effectiveness to optimize the method. Comparison with previous model simulation process is used to solve the problems and the simulated results are compared with experimental work*

Key words: *casting design, shrinkage porosity, hotspots, and solidification time.*

I - INTRODUCTION

Casting is one of the oldest and cheapest methods of producing parts of desired shape. It is defined as the shaping of a material in liquid state. In casting the liquid metal is poured in mould cavity, usually made of sand, and allowed to solidify. After complete solidification the part is removed from mould either by breaking or separating the two parts of a mould. The part obtained by casting is called casting. The process takes advantages of molten metal to conform the form of the mould into which it is poured and it is possible to produce the castings ranging in size from few grams to more than hundred tons. Casting in various forms represents one of the most important metals shaping process used in engineering manufacturing

The main inputs for the casting simulation process are:

- 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 (i.e. the metal mould heat transfer coefficient, for normal mould as well as feed aids including chills, insulation and exothermic materials).
- Process parameters (such as pouring rate, time and temperature).

2-Review

Sabau *et al.* (2002) considered porosity is usually to be either "hydrogen porosity" or "shrinkage porosity". Hydrogen porosity is the term given to porosity that is generally rounded, isolated, and well distributed. Porosity that is interconnected or clustered and an irregular shape corresponding to the shape of the interdendritic region are usually termed shrinkage. In general, the occurrence of micro porosity in alloys is due to the combined effects of solidification shrinkage and gas precipitation.

A. Reis *et al.* (2008) classified important defects that arise from shrinkage solidification are
- External defects: pipe shrinkage and caved surfaces;
- Internal defects: macro porosity and micro porosity.

Generally short freezing alloys are more prone to internal defects, whereas long freezing alloys are more prone to surface depressions.

B. Formation of shrinkage porosity

From a scientific point of view, the problem of porosity formation is complex and most interesting. The thermal properties of the alloy being cast (latent heat of fusion and thermal conductivity), the composition of the alloy (freezing range and dissolved gas content), the mould properties, and the geometry of the casting are all important to the properties of the final cast product. However, the relative effect of these variables is very complicated. The problem has been studied in detail for nearly 20 years, but there appears to be no clear agreement as to which mechanisms control the formation of porosity. In the absence of a clear scientific understanding, foundry men used empirical rules to design their mould.

Despite of all these things, effort has been made to provide information regarding the shrinkage porosity formation in this section because the objective of this project is limited to predict shrinkage porosity for different metals. Starting with the definition of the first cause, shrinkage is the term for obstruction of fluid flow coupled with a difference in the specific volumes of liquid and solid metal. As the casting solidifies, metal that is still fluid will try to flow to compensate for the liquid/solid volume change; however, the flow may be hindered by the solid which has already formed. If a poorly fed region is large and completely cut off from a source of liquid metal, then a large void (generally greater than 5 mm in maximum length) is formed. The resulting void is termed `macro porosity'. (Note that gas solubility differences may contribute to macro pore formation as well). The area in which macro pores form solidifies after the surrounding region, termed as a `hot spot' with reference to the islands of hot metal completely surrounded by colder material.

Pellini's (1953) observations are of some importance to the theoretical thermal analysis. The feeding length of a riser is best considered by examination of Figure 2.1. The data presented are for a steel bar cast in green sand. The distance from the riser to the end of the casting is sufficiently long that there is a central section which is "semi-infinite." In this region, the solidification proceeds as if the bar had no ends and was infinitely long. In other words, the temperature in this region is uniform along its length, so the entire section freezes at the same time. Consider the experimental freezing velocity curve at the lower right-hand section of the figure. Five minutes after pouring, a shell 1.5 inches (~40-mm) thick from the end has formed at the centreline of the bar. At 10 minutes, there is a region 3 inches (~80-mm) thick which is completely solid.

Solidification proceeds, the volume diminishes and surrounding liquid flows in to compensate. Depending on the amount and distribution of solid, the fluid flow may be impeded or even completely blocked. When sufficient liquid is not present to flow in cavity, voids (pores) form. This *shrinkage porosity* can either be many small distributed pores or one large void.

D.R. Gunasegarama *et al.* (2009)

Believed that shrinkage porosity defects occurring in castings are strongly influenced by the time-varying temperature profiles inside the solidifying casting. This is because the temperature gradients within the part would determine if a region that is just solidifying has access to sufficient amounts of feed metal at a higher temperature. Shrinkage pores will emerge in regions experiencing volume reduction due to phase change with no access to feed metal.

After pouring molten metal in a mold the casting solidification with liberation of heat of fusion. At the temperature decreases the volume shrinkage of casting occurs in 3 stages.

- **Liquid contract ion (1.6% per 100c):** From pouring temperature to solidification temperature.
- **Solidification contraction (3.0%):** It occurs by changing liquid state to solid state
- **Solid contraction (7.2%):** As the casting cools from solidification temperature to room temperature.

FE Analysis using commercial software:

Which 3D model and simulation tools utilized to improve the design of the castings. Castings geometrics represented the meshing and volume mesh to get the new nodes and generate the tetra elements before surface mesh. Pro-cast is the modular system to analysis the various models. It is based don numerical simulation technology, it provides a complete solution of the casting a wide range of simulation. For these purpose of the stages it will generate finite element model to setup calculations and results by analysis it will get the results. Primary working flow of the pro-cast is dividing in to three main parts as shown below the flow chart

STEP 1. 3D CAD Modeling:

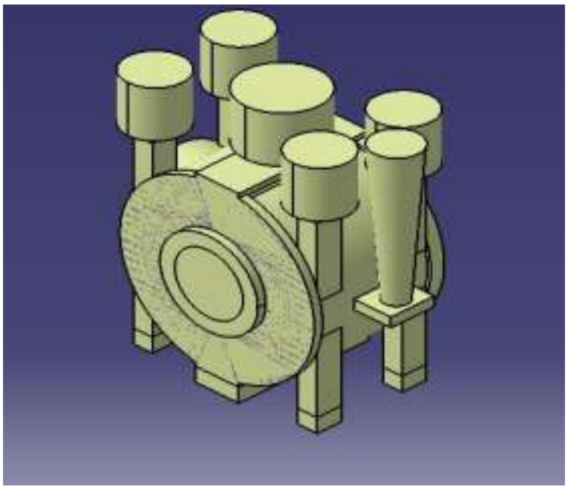


Fig: 3D CAD model Reduction gear box after inserting chills

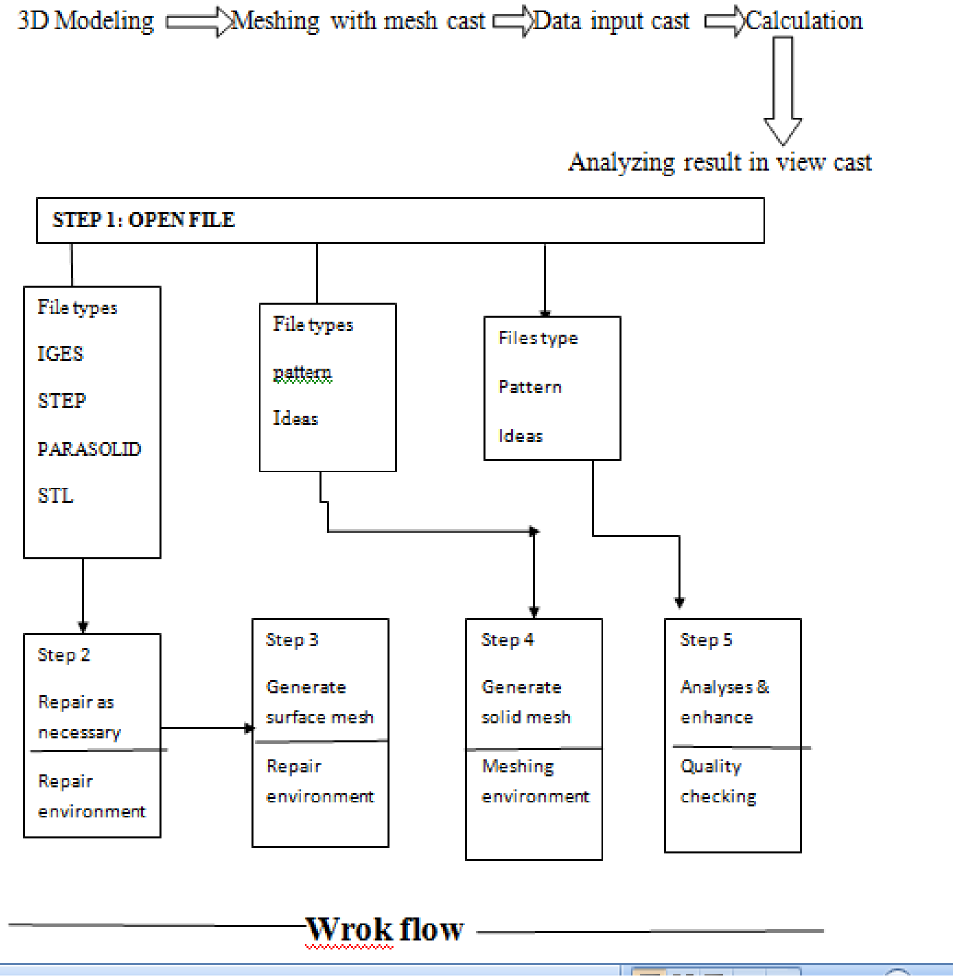


Fig. 2 Steps needed to make a simulation

Meshing with Mesh Cast:

The works steps which you follow when using mesh cast depend upon the following the nature of your project intended use of the meshes generated by Mesh Cast and the type and quality of model you use as initial input. While doing meshing we have got 172 surfaces are succefully meshed and 61302 Elements are generated. The main aim of meshing analysis is to get temperature distribution with respect time. It is chosen in FEM which is capability of heat transfer to analysis the element has new nodes with single degree of freedom, temperature, at each node. These node quadrilateral elements with linear shape function

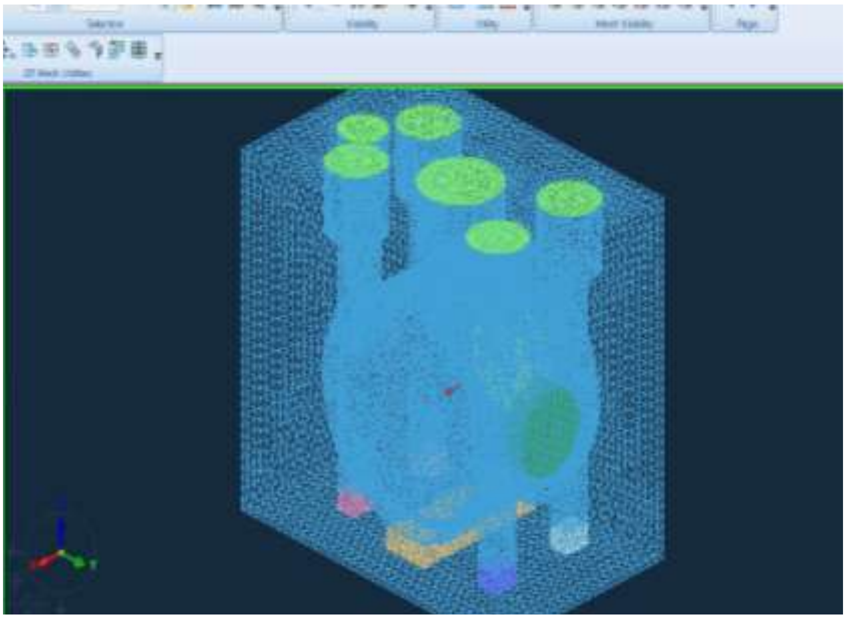


Fig: Mesh Cast

- Import meshing file

MODEL STATISTICS

No. of Nodes	= 162024
No. of Solids (TETRA/HEXA/WEDGE)	= 791743
No. of Enclosure Elements	= 0
No. of Materials	= 9

Please update your graphic card to benefit from our optimized rendering
File I:/reduction gear box/MB_W/MB_Wg.unf loaded

Result info written to file I:/reduction gear box/MB_W/MB_W_summary.txt

Fig:Import meshing

Apply Mould material as Silica Sand:

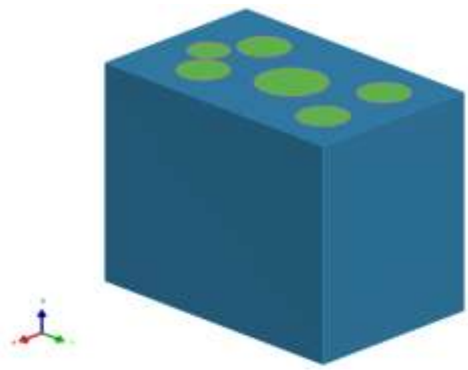


Fig. 6 Mould material as Silica Sand

Element Size in casting

NAME	Element	MAX ELEMENT	Transition factor	Shape factor	Surface 2D EMIS (solid EMIS)
casting	8	10	1	2	133/0(0)
Mould	16	10	1	2	157/0(0)
Chill	8	10	1	2	60/0(0)
Chill	8	10	1	2	60/0(0)
Chill	8	10	1	2	60/0(0)
Chill	8	10	1	2	60/0(0)
Chill	8	10	1	2	60/0(0)
Chill	8	10	1	2	60/0(0)
Chill	8	10	1	2	60/0(0)

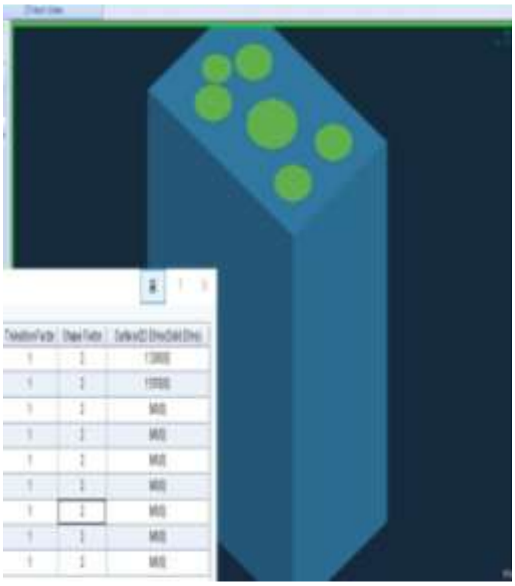


Fig: Element Size in casting

Input Parameters:
In these works, analysis is carried out for the time from pouring temperature to solidification. Input parameters required for model.

- **Initial boundary conditions**: For sand mold casting and temperature air
- **Thermal boundary conditions:** Convective heat transfer coefficient
- **Material specifications**: thermal conductivity and density specific heat is required for atmospheric air and sand cast.

Casting Material	**Low carbon (steel AISI 1008)**
Molding Material	**Silica sand**
Pouring Temperature	**1550°C**
Mold Temperature	**30°C**
Chill	**Copper**

Volume Mesh:
In these FEM based while doing volume mesh we got 770029 Tetra elements generated.104595 new nodes created finally the volume mesh is applied. In this volume manager, we have added the copper chills to decrease the shrinkage porosity.

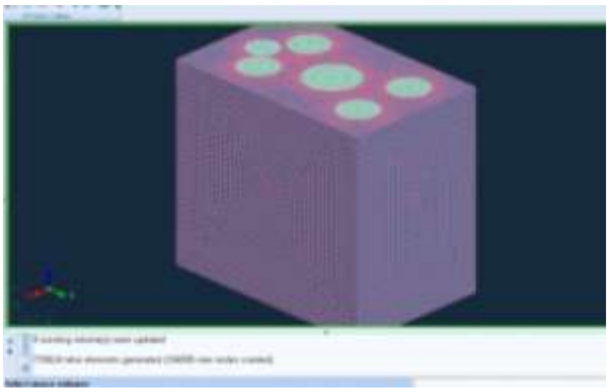


Fig: volume mesh

Element Quality:

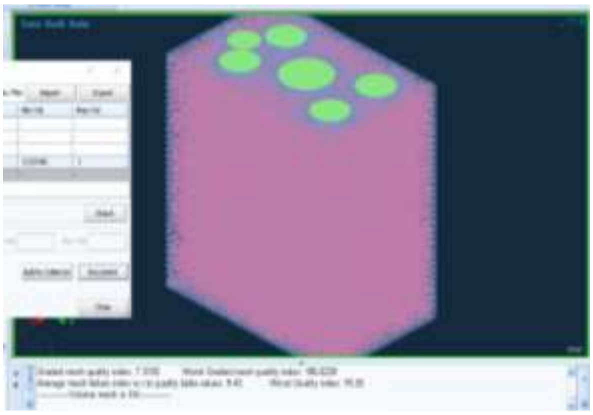


Fig:Element quality checking

Step 4 – Define job:

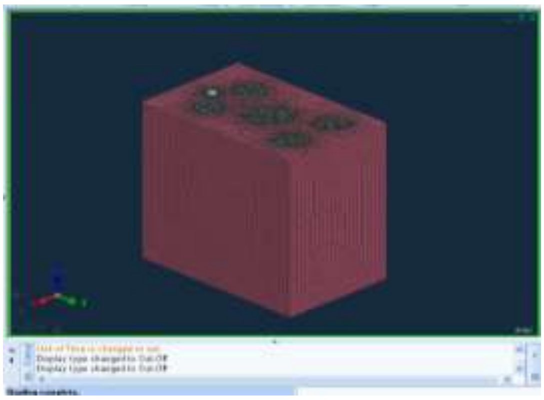
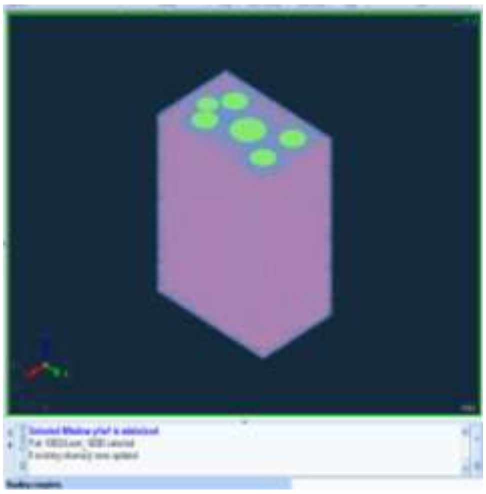


Fig4.7.3 (e):Define job

Step 5 –Volume Manager:



SL	Name	Typ	Material	Fill%	Initial temp	Stress types	
1	CASTING	ALLOY	LOW-CARON	0	1550.0	Linear elament	
2	MOLD	Mould	Silica sand	100	30.0	Rigid	
3	CHIL1	Insulation	Copper chill	100	30.0	Rigid	
4	CHILL2	Insulation	Copper chill	100	30.0	Rigid	
5	CHILL3	Insulation	Copper chill	100	30.0	Rigid	
6	CHIL4	Insulation	Copper chil	100	30.0	Rigid	
7	CHILL5	Insulation	Copper chill	100	30.0	Rigid	
8	CHILL6	Insulation	Copper chill	100	30.0	Rigid	
9	CHILL7	Insulatin	Copper chill	100	30.0	Rigid	

Fig4.7.3 (f):Volume manager

Apply interface HTC manager between mould and Casting:

In interface menu showin fig, create the interface betweent the different Maeteral domains and give the desired interface heat transfer coefficients.the type of interface should be specified.the desired interface heat transfer coefficient should be selected in the database and assigned to the corresponding interface

Name	Type	Interface condition
Casting mould	Conic	h=100
Chill 1_Mould	Conic	h=500
Chill 2_Mould	Conic	h=500
Chill 3_Mould	Conic	h=500
Chill 4_Mould	Conic	h=500
Chill 5_Mould	Conic	h=500
Chill 6_Mould	Conic	h=500
Chill 7_Mould	Conic	h=500
Casting_Chill5	Conic	h=500
Casting_Chill6	Conic	h=500
Casting_Chill7	Conic	H=500
Casting_Chill1	Conic	H=500
Casting_Chill2	Conic	H=500
Casting_Chill3	Conic	H=500
Casting_Chill4	Conic	H=500

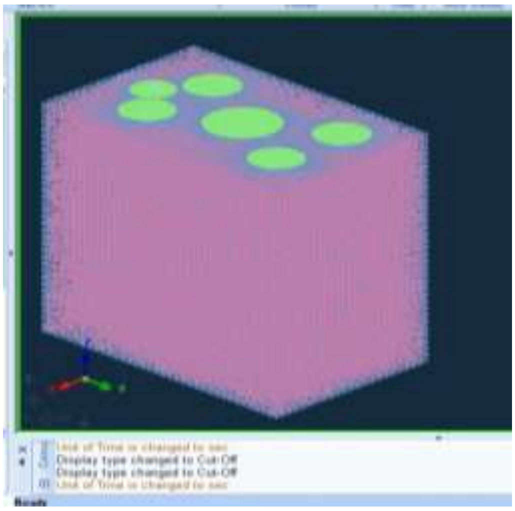


Fig: Interfaces HTC manager between Mould and Casting

Process condition:

Name	Type	Entity	Boundary conditions	Area (Sq.mm)
Heat_1	**Heat**	**Exit-Mould**	**Air cooling**	**1313495.0**
Inlet_1	**Inlet**	**USER_Inlet_1**	**BC_Inlet_5**	**229.0562**

Table: Boundary conditions

The cooling of the outside of the mould with the air, as well as the top surface of the casting should be defined in the "Boundary Conditions" list of options. The type of boundary condition should be selected. The "Heat and Inlet" type should be selected in the list which is appearing as shown in Fig. Then, this “Heat” boundary condition appears in the data base and selects the point of the Sprue.

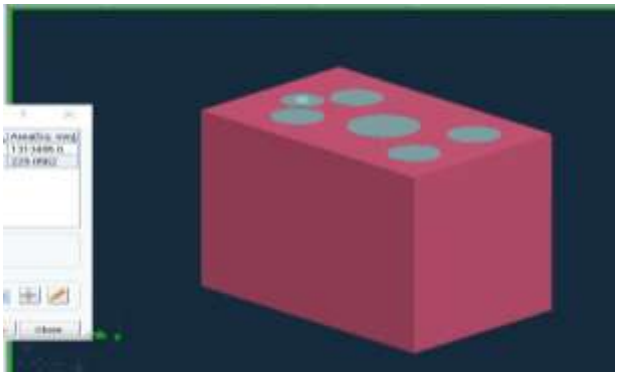


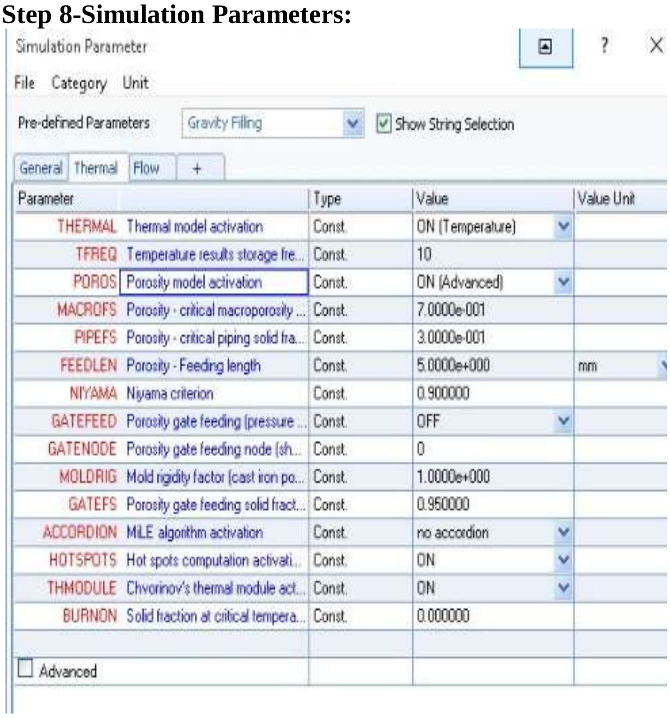
Fig: process boundary conditions

Flow Rate Calculation

Fill time	7 Sec
Temperature	1550ºC
Flow Rate	11.8981 kg/sec
Weight	1 kgs

Table 4.7.3(e): flow rate calculation

Step 8-Simulation Parameters:



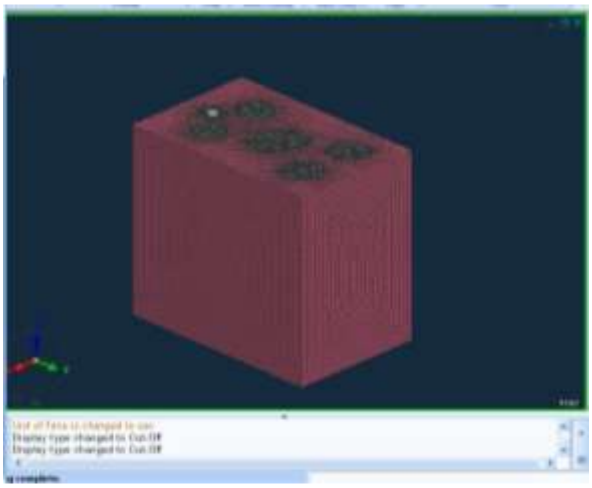


Fig4.7.3 (I): simulation parameters

Finally, the calculation parameters should be specified in the "Run parameters "list of options.

Calculation: Temperature Distribution

Figure indicates the temperature distribution over entire part. Maximum temperature at the centre of the part so that the maximum chances of porosity occurs at that region**.**

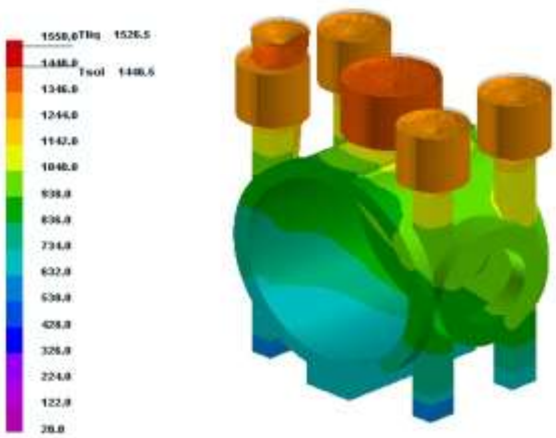
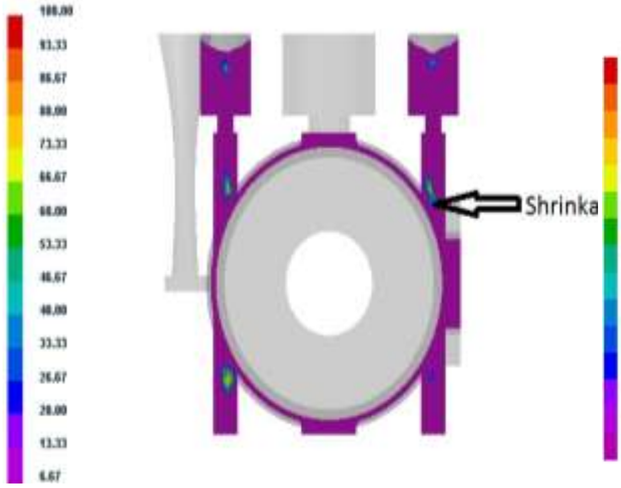


Fig: Molten state of pouring metal

Analyzing Result:



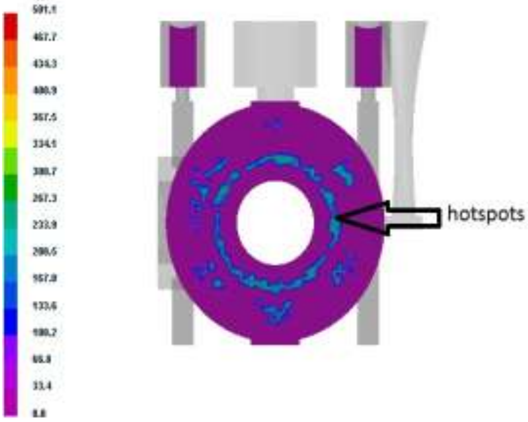


Fig: shrinkage porosity Fig: Hotspots

Solidification Analysis and Optimization using numerical simulation

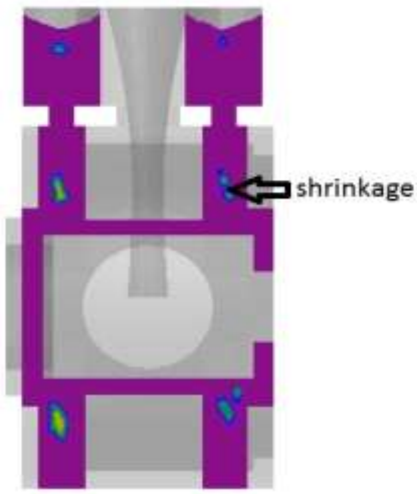
Which 3D model and simulation tools utilized to improve the design of the castings. Castings geometrics represented the meshing and volume mesh to get the new nodes and generate the tetra elements before surface mesh. Numerical simulation is the modular system to analysis the various models. It is based don numerical simulation technology, it provides a complete solution of the casting a wide range of simulation. For these purpose of the stages it will generate finite element model to setup calculations and results by analysis it will get the results.

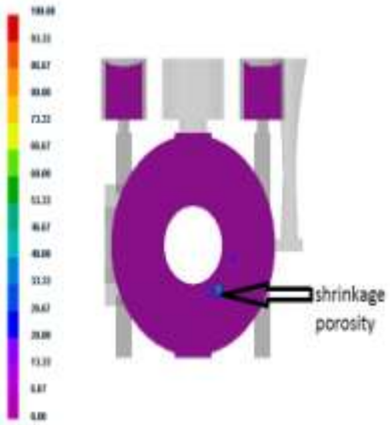
Effect of Riser Height on Shrinkage Porosity:

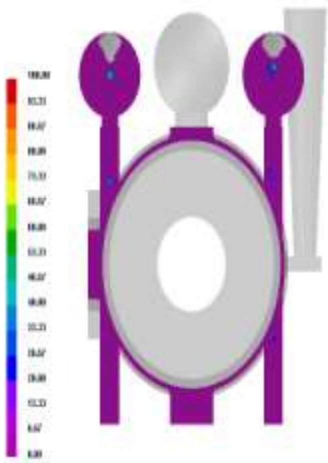
Four riser=104.25mm
Center riser=120.93mm

four risers=132.05mm
center risers=132.05mm
Copper chill with 20mm

sphere risers=28.617mm
center riser= 35.18mm







Different shrinkage porosity on riser height

Four risers=132.05mm
Center risers=132.05mm
Copper chill with 30mm

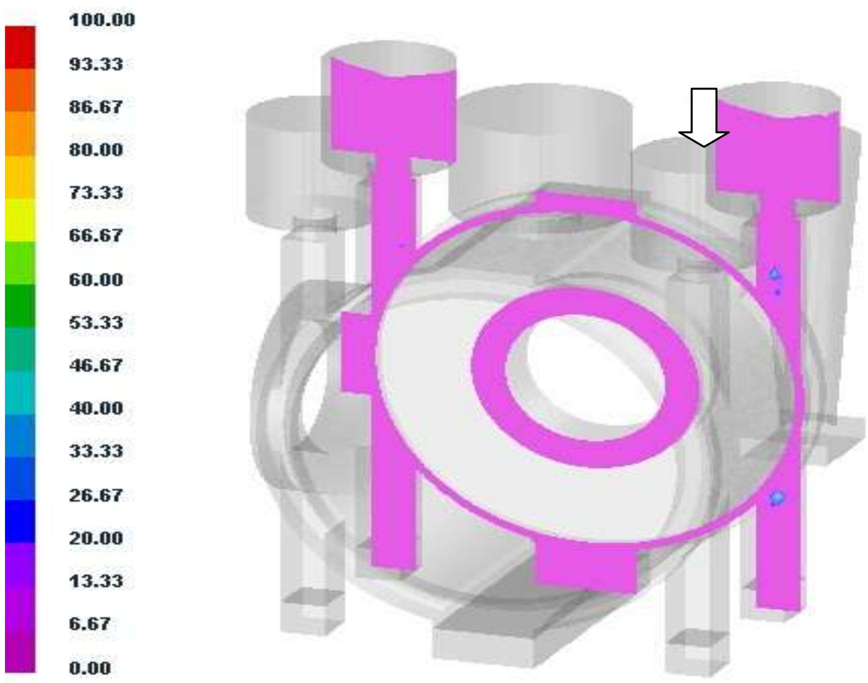


Fig: Different shrinkage porosity on riser height

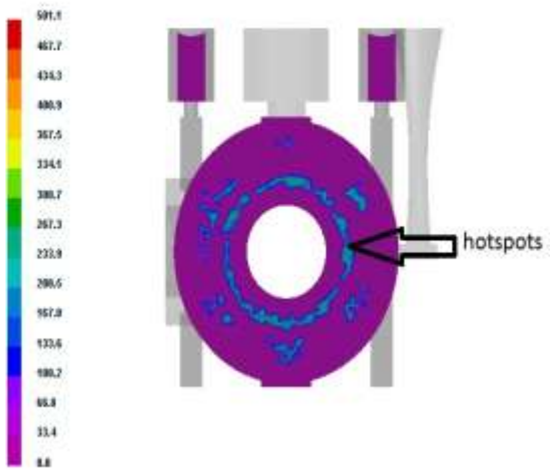
Effect of Riser Height on hotspots

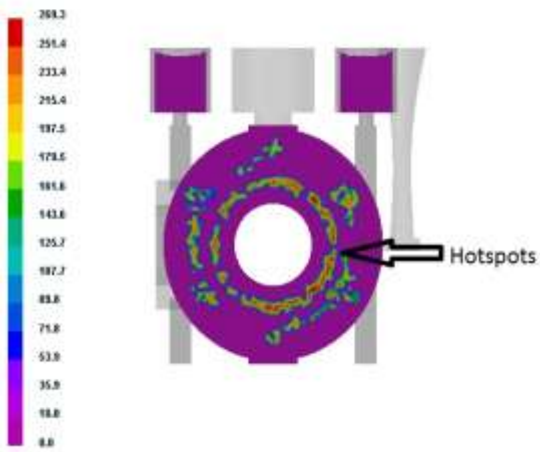
Side riser= 104mm
Center riser=120mm

Four risers=132.05mm
Center risers=132.05mm

Copper chill

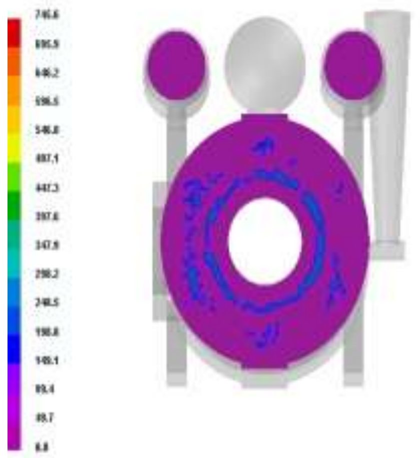
with 20mm

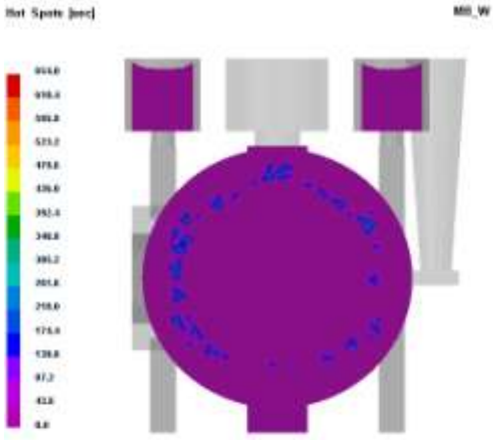




sphere risers=28.617mm
Center riser=35.81mm.

Four risers=132.05mm
Center risers=132.05mm
Copper chill with 20mm for bottom legs





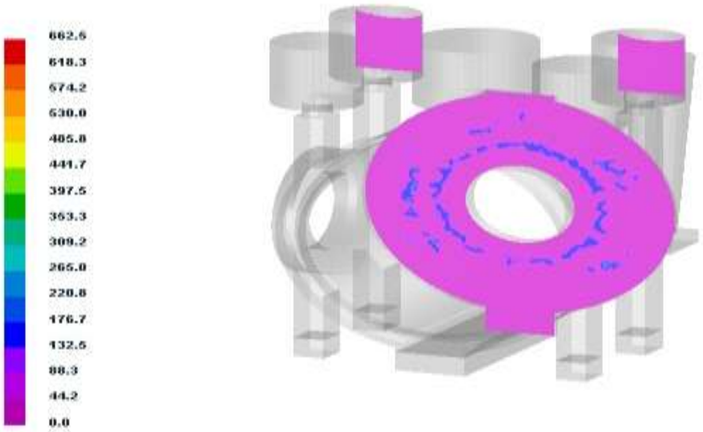
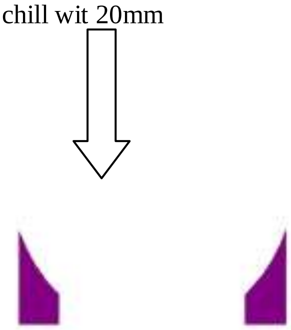


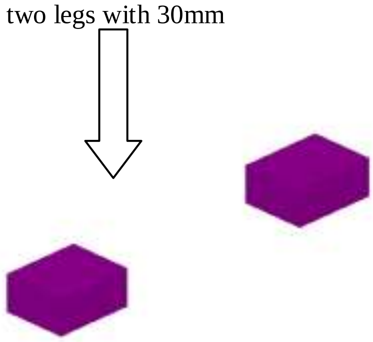
Fig: Different hotspots on riser height

Different copper chills used for simulations

Copper chill wit 20mm



copper chill for two legs with 30mm



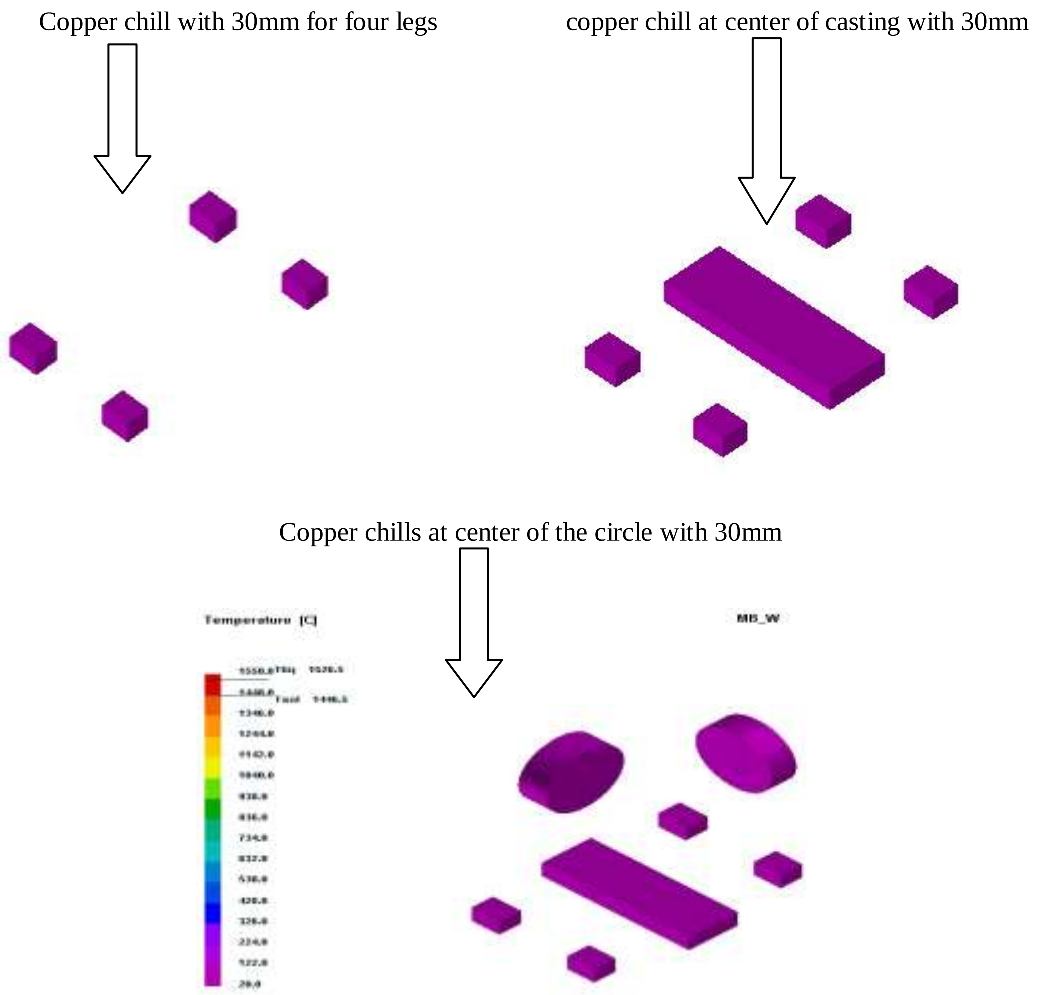


Fig: Different Copper chills

After finding individual effect on shrinkage porosity we have combined both parameter like riser height and runner for finding combined effect on shrinkage porosity and hotspots we applied 30mm copper chill at bottom of the legs and center of the circle. So with that simulation which we find the defects in casting is totally decreases y inserting copper chill

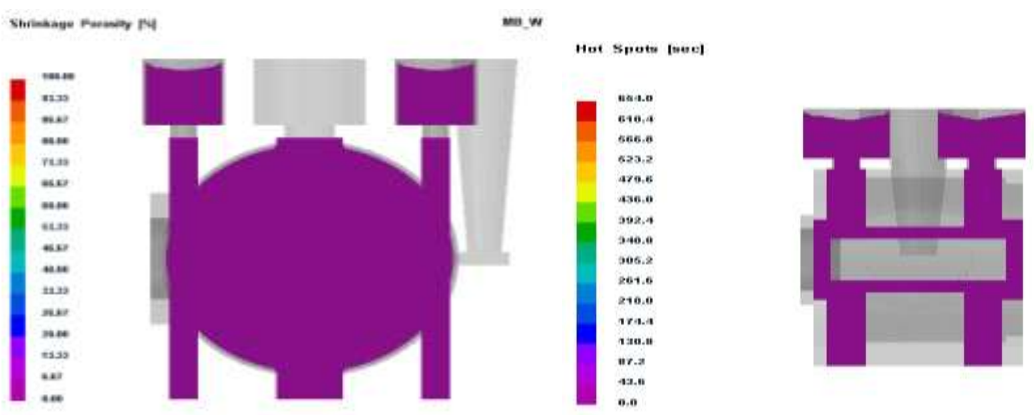


Fig: shrinkage porosity and hotspots

Experimental Work for Validation:

FIG: preparation of Reduction Gear Box Pattern

Fig Melting of low carbon steel

Fig: Pouring of low carbon steel in gear box

Fig: After solidification

V. CONCLUSIONS:

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

	Option 1		Option 2	
	Height	Diameter	Height	diameter
Side four risers	13.9*7.5mm		13.9*9.5mm	
Middle riser	13.9*8.7mm		13.9*11mm	
One spure	36.5*8.5mm			
Total dia	34.5mm			
Neck dia	20mm		28mm	

Table V: 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.

Summary:

Comes to design of the risers, gating, sprue are concerned. Although empirical relations exist a comprehensive understanding of the over-all solidification behavior of the casting cannot be visualized without employing numerical simulations. The main objective of this research is to numerically simulate reduction gear box with various risers, gates and chills in order to minimize shrinkage porosity and hot spots.

Geometry modeling of a reduction gear box was carried out using CATIA software. Numerical simulation of the entire casting with runners, risers, gating systems was performed using a FEM based commercial solidification software in order to design proper riser system and provide chills at appropriate locations such that shrinkage porosity and hot spots are minimized in the casting. Experimental work of casting molten steel of AISI 1008 in sand mold was carried out at Indy Engineering industry at Cherlapalley, Hyderabad. Following are the important conclusions.

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