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Numerical Simulation of Reverse Engineered Automotive Casting

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***Abstract* – Producing defect free casting is the main aim of foundry. To achieve this number of trials are carried out in the foundry and repeating the trials makes casting expensive and time consuming which leads to lower casting yield, time delay and higher rejections. So the casting simulation software has proved to be a practical tool for analyzing mold filling of casting, time required for solidification as well as cooling and to predict casting defects such as cold shuts, air entrainment, hot spots, shrinkage etc. Simulation software helps to make necessary changes at the design phase itself which indirectly reduces the time delay and also improves yield and quality of casting.**

The truck starter motor housing/cover is selected for the work. The selected component is scanned using reverse engineering software (geomagic QUALIFY). The point cloud data is converted into 3D CAD model. Using first principles of casting gating and risering system is designed for the component. The same is then analyzed using casting simulation software (ProCAST). The mold filling and solidification steps of casting are numerically analyzed. The casting defects such as air entrainment, shrinkage are predicted.

Key Words* – *Point cloud data; casting simulation software, reverse engineering, casting defects.

I. INTRODUCTION

Today's casting development method is basically of trial and error method. The competitive market demands for allotting shorter design time, manufacturing time, dimensional accuracy, good quality and regular change in product design, the old traditional method of casting involves dead investment which leads to scrap if component is not as per dimensions. So the casting simulation software has evolved as a useful tool for foundry which predicts the casting defects at the early stage of design itself. Thus it helps in improving design and quality of casting which is going to be produced. Therefore, the costs and the risks associated with the trial and error procedure of experimental castings are minimized. [1]

Reverse engineering is the process of duplicating an existing component by capturing the components physical dimensions. The process of duplicating an existing part, subassembly, or product, without drawings, documentation, or a computer model is known as reverse engineering. [2]

II. PROBLEM DEFINITION

Reverse engineering is carried out for existing truck starter motor housing/cover component as given in figure 2.1. CAD model is created from the point cloud generated by scanning the component. First principle of casting is used for designing the gating and risering system for the component. The designed component is analyzed using casting simulation software. Trials of numerical simulations are carried out to make defect free component.

Figure 2.1 Truck starter motor housing/cover

A. Defining the problem

Truck starter motor housing/cover component is selected. It is scanned using Baces 3D scanner for collecting point cloud data. Point cloud data of multiple scans are globally registered to obtain the surface model. Using first principles of casting gating and risering system is designed for the model. The designed model is imported into casting simulation software for analyzing various casting defects and making the component defect free numerically.

B. Objectives

Existing automotive component is selected. It is scanned using Baces 3D scanner for collecting cloud points. The component is placed at proper position and its surface is prepared by anti-reflective coating for exact surface scanning by laser scanner. The cloud point is converted to 3D model by reduction of noise in the data and deletions of stray points by reduce noise command. Uniform sampling command is used to eliminate overlapping data points. Manual registration is used to align different scan groups. Different scans are aligned by n-point registration. Further global registration is used to fine tune the alignment between different scan sets. To create a single complete polygon mesh merge the different scans together. Then the surface model is prepared to be sent to CAD/CAM packages for analysis. Using first principles of casting gating is designed for the component. Thermal and flow analysis is done for checking defects. Gating is modified, if required for defect free component. [3]

III. METHODOLOGY

A. Scanning process

The component is FG-300 gray cast iron. The first step in processing point cloud data is the reduction of noise in the data and deletion of stray points. The total number of data points obtained after scanning are 1141484 and the number of points which were deviating from scanned data are 462. Table 3.1 gives details of component and figure 3.1 shows point cloud generation process in scanning software (geomagic QUALIFY).

Table 3.1 Truck starter motor housing/cover details

Part Name	Part details		
	Application	***Material***	***Weight***
Truck starter motor housing	Automotive starter	Gray cast iron FG - 300	3.574 kg

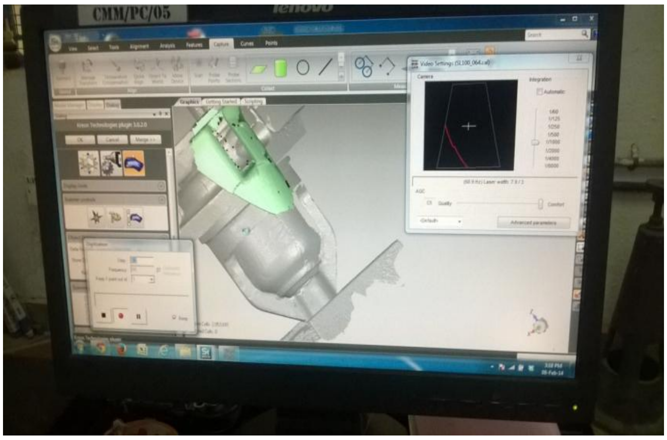
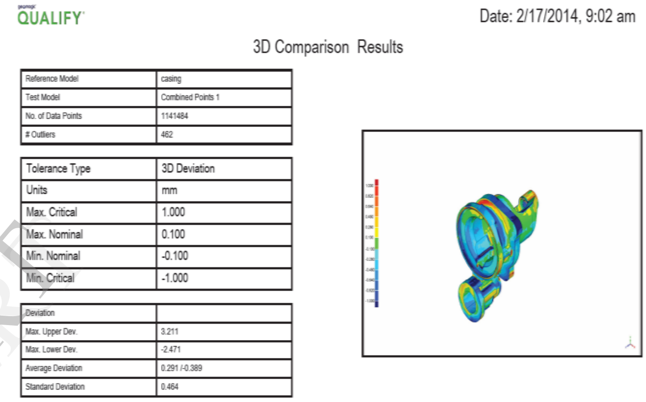


Figure 3.1 Point cloud generation

B. CAD model generation by reverse engineering



Reference Model	casing
Test Model	Combined Points 1
No. of Data Points	1141484
# Outliers	462

Tolerance Type	3D Deviation
Units	mm
Max. Critical	1.000
Max. Nominal	0.100
Min. Nominal	-0.100
Min. Critical	-1.000

Deviation	
Max. Upper Dev.	3.211
Max. Lower Dev.	-2.471
Average Deviation	0.291 / -0.389
Standard Deviation	0.464

Figure 3.2 Geomagic qualify report

After processing the point cloud data the surface model is obtained as given in the figure 3.3.

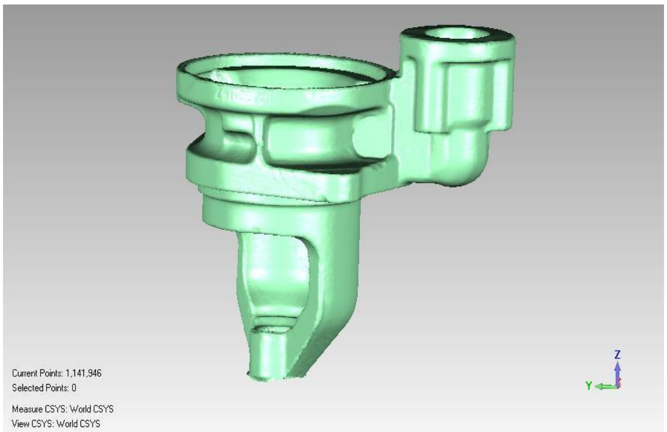


Figure 3.3 Reverse engineered truck starter motor housing/cover surface model after merging point cloud data

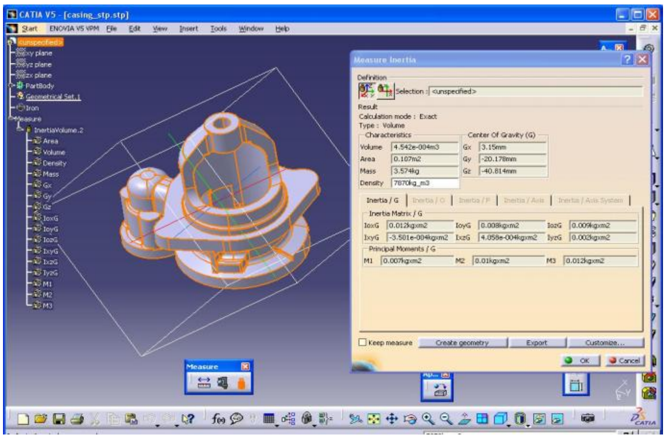


Figure 3.4 3D CAD model with properties

C. Gating and risering system design

Pressurized gating system is used since the material is gray cast iron and the gating ratio is 1:1.2:1.

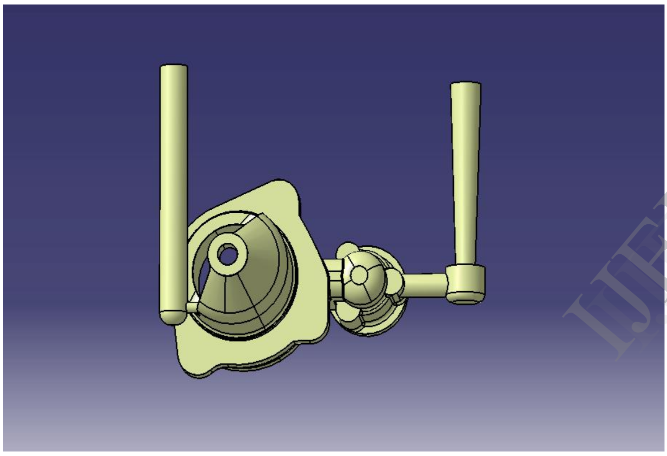


Figure 3.5 3D CAD model with design 1

The figure 3.5 shows the gating system designed for the component with side riser. The length of riser neck is 10.31mm and diameter of the riser neck is 14.434mm as per the formula in the below figure. Diameter of the riser is 4 times the modulus of riser which is 5.15508. Modulus of riser is calculated as 1.15-2 times the modulus of casting which is calculated as volume of the casting by surface area of the casting whose values are obtained from Catia software by applying material command and the material is gray iron.

Figure 3.6 shows gating system designed for the component with side and top round riser. The diameter of the riser neck is 14.434mm and length of the riser neck is 10.31mm. Diameter of the riser is 20.62mm.

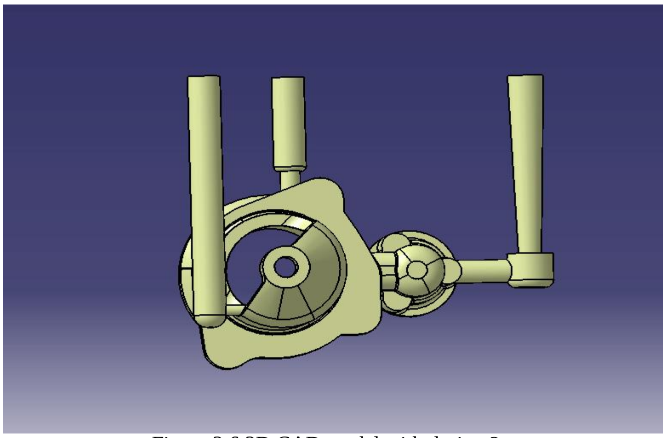


Figure 3.6 3D CAD model with design 2

The shrinkage defect still persists even after placement of top round riser along with side riser. The gating system designed for the component with top round riser as given in figure 3.7. Diameter of the riser is 20.62mm. Length of the riser neck is 10.31mm and diameter of the riser neck is 14.434mm.

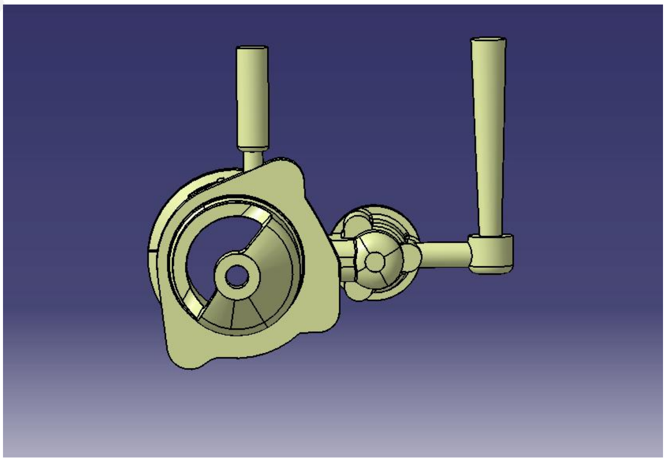


Figure 3.7 3D CAD model with design 3

D. Casting simulation process

In the present work analysis starts with the geometry of the mold cavity (3D model of the casting, feeders and gating channels). The model is imported into the simulation software in .igs format. Pre-processing is the meshing stage wherein surface and volume meshing is done. Process parameters are pouring temperature, pouring weight and pouring time. Here the pouring temperature is 1300^0 C, pouring weight is 5.1057 kg, and pouring time is 9.030 second. Major diameter of the sprue is 22.744 mm and minor diameter of the sprue is 14.608 mm. Post processing is the last stage where flow results, shrinkage results and solidification results are analyzed and modified if any defect arises in simulation result. [4, 5, 6, 7, 8]

IV. RESULTS AND DISCUSSION

After simulation process of component the following results are obtained those are temperature distribution, fraction solid, air entrainment and shrinkage. In the second trial due to side riser the cold shut problem has been eliminated. In the third trial an additional top round riser is used along with side riser.

A. *Trial 1 (without riser)*

The first trial is done without risers and in the figure 4.1(a) cold shut problems arises at the thick section of component due to premature freezing of the molten metal before fusion. [9]

In figure 4.1(b) air entrainment effects are more at the cold shut region due to large gap for release of mold gases. [9]

Figure 4.1(c) shows that fraction solid is not complete at the region where cold shut problem arises.

Figure 4.1(d) shows the shrinkage defect due to the depression in the surface caused by solidification shrinkage that restricts the amount of molten metal in the last region to

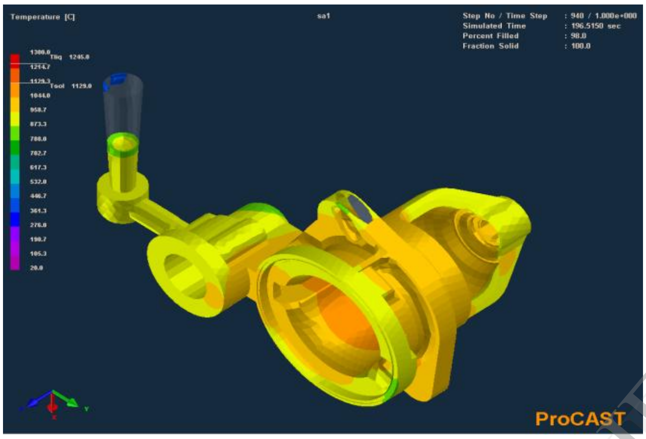


Figure 4.1(a)

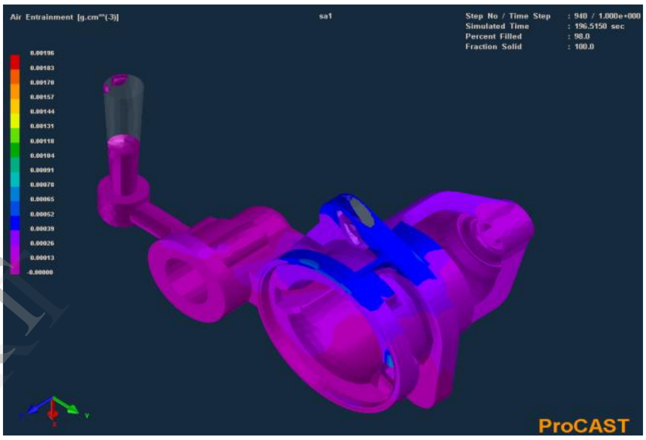


Figure 4.1(b)

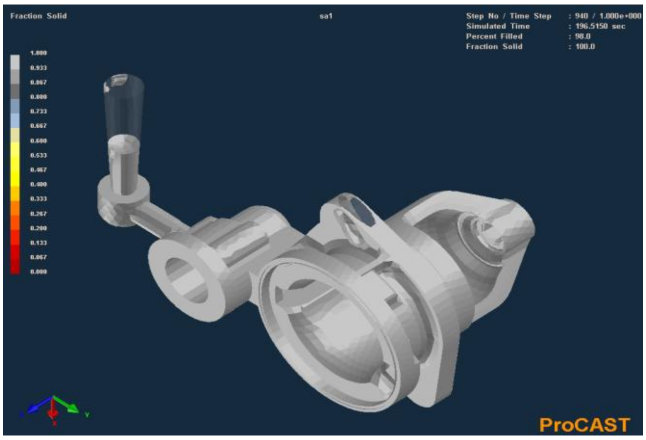


Figure 4.1(c)

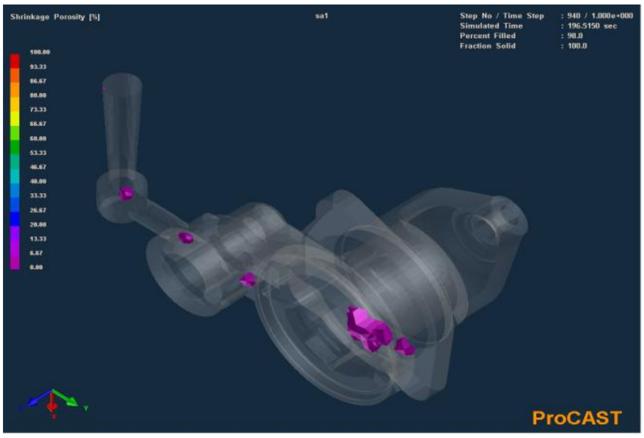


Figure 4.1(d)

B. *Trial 2 (side riser)*

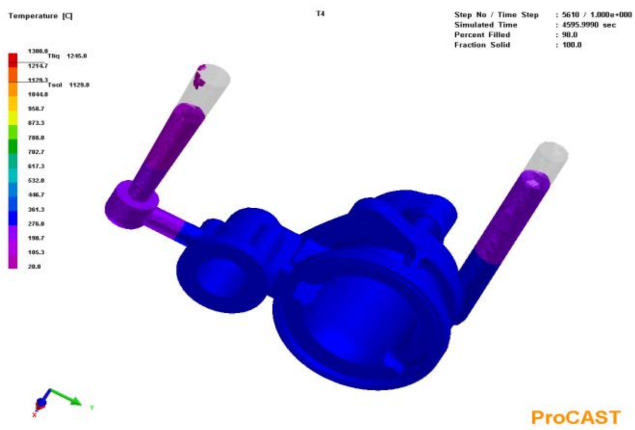


Figure 4.2(a)

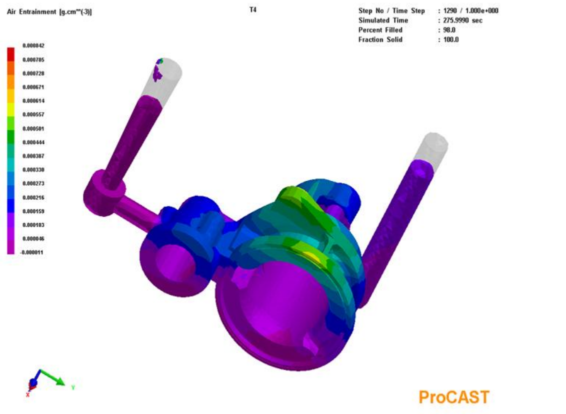


Figure 4.2(b)

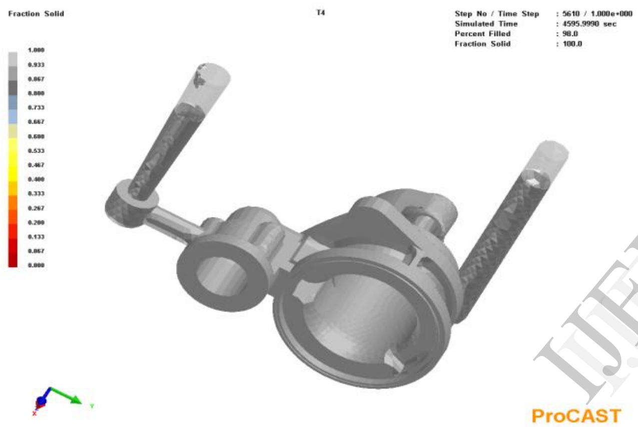


Figure 4.2(c)

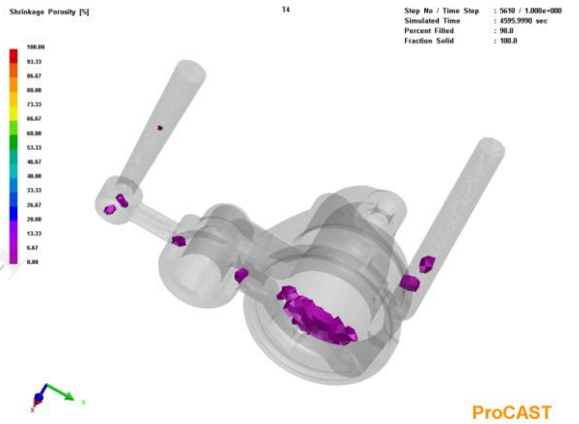


Figure 4.2(d)

Figure 4.2(a) shows the temperature distribution which is minimum compared to figure 4.1(a).

In the figure 4.2(b) air entrainment effect is minimum at the thick section compared to figure 4.1(b) but is spread over to other regions of the component.

Figure 4.2(c) shows the fraction solid completed fully.

In the figure 4.2(d) the shrinkage is present because the feeding neck of side riser is small to feed for compensating the volumetric contraction.

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C. *Trial 3 (side and top round riser)*

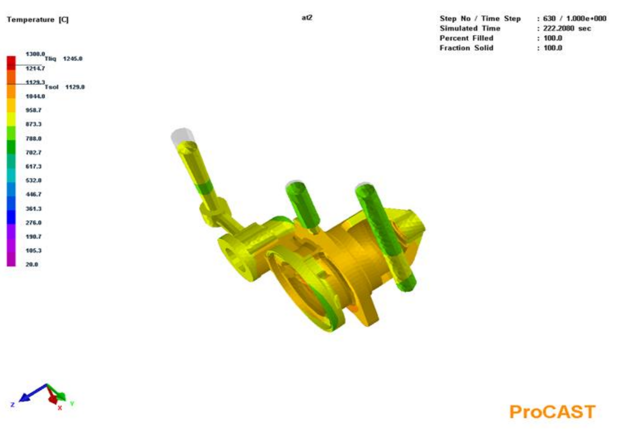

Figure 4.3(a)

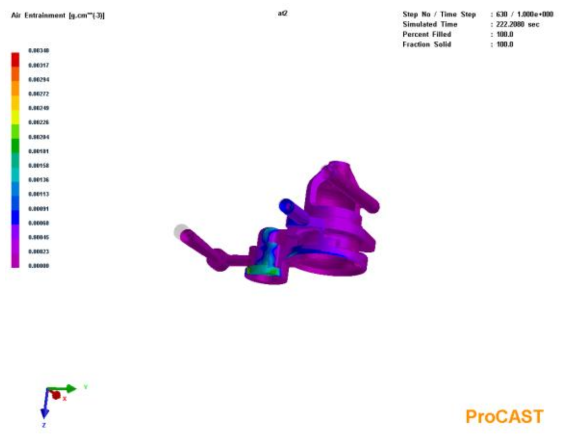

Figure 4.3(b)

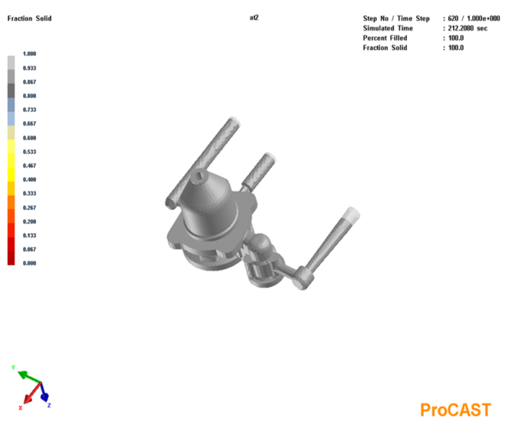

Figure 4.3(c)

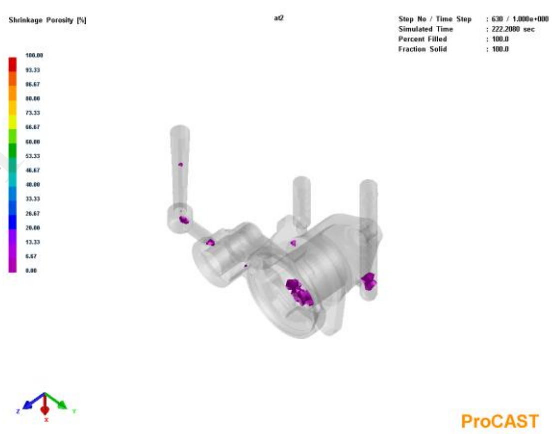

Figure 4.3(d)

Figure 4.3(a) shows the temperature distribution with side and top round riser. Temperature is more at the thick section due to slower cooling.

Figure 4.3(b) shows air entrainment which is minimum compared to figure 4.2(b) because of the placement of top round riser at the thick section of the component.

Figure 4.3(c) shows the fraction solid has occurred fully due to larger modulus of top round riser compensating for volumetric contraction.

Figure 4.3(d) shows shrinkage defect due to variation in modulus of two risers.

Trial 4 (top round riser)

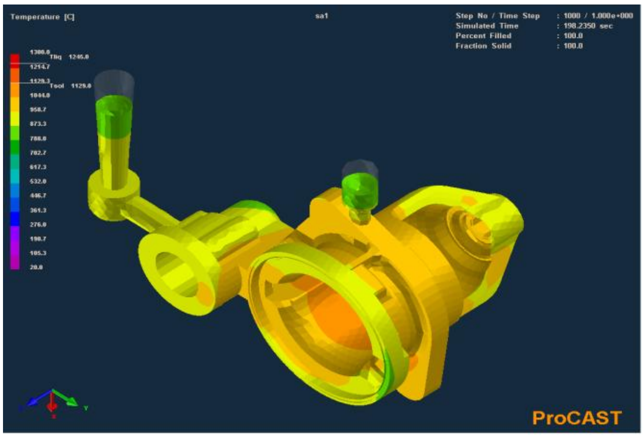

Figure 4.4(a)

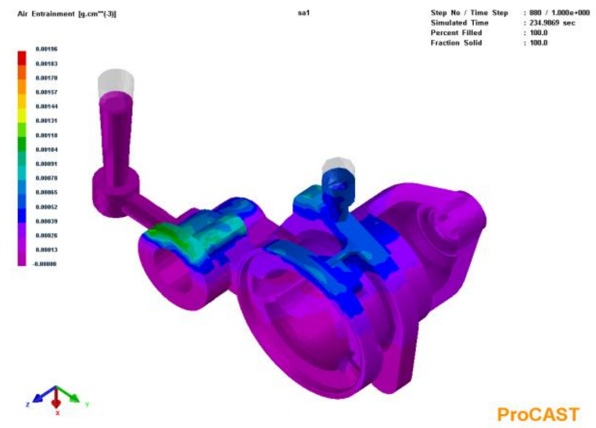

Figure 4.4(b)

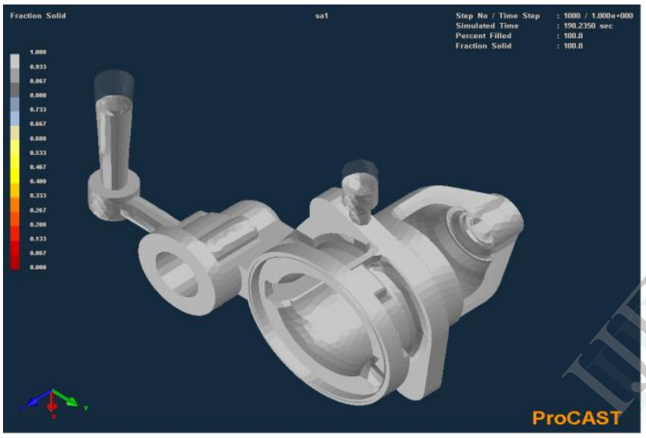

Figure 4.4(c)

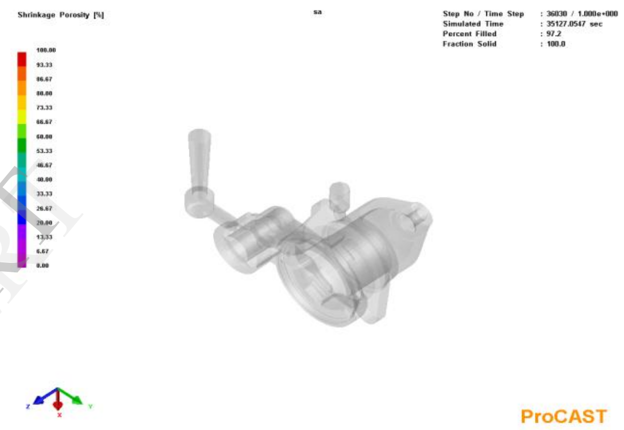

Figure 4.4(d)

Figure 4.4(a) shows temperature distribution with top round riser. Temperature is more at the thick section due to removal of side riser.

Figure 4.4(b) shows that air entrainment effect is almost similar to figure 4.3(b).

Figure 4.4(c) shows that component is in fully fractional solid condition.

Figure 4.4(d) shows shrinkage free simulation obtained for component with top round riser.

V. CONCLUSION

- Reverse engineering has been carried out successfully for the truck starter motor housing/cover component and CAD model is generated by processing the point cloud data and gating system is designed for simulation purpose.
- Simulation has been carried out successfully on various designs of gating system.
- Casting defect location is predicted at the design stage, reasons for defects are studied, need for risers are studied, proper location of risers is made in the gating design, number of risers required is decided based upon simulation results, their relative merits and drawbacks has been analyzed to arrive at defect free castings.

The benefits of the simulation software for the foundries are lead time for mold development is reduced. Shop floor trials are reduced due to prediction of casting

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defects at the early design stage which avoids the dead investment. Yield and part quality is improved. Benefit of this project is prediction of casting defect is done at the design stage and the component is made defect free.

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