Analysis of Casting Defects during Filling of AA 7075 in a Mold Cavity Using Click 2 Cast Simulation Software

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Abstract

In recent days, the manufacturers are striving regularly for attaining high productivity, good quality and overall economy in the field of manufacturing by casting. Among all the casting processes available sand casting is a commonly used technique because of its low cost and simple in process. It is often utilized in industries to make the parts that are comprised of iron, bronze, brass, aluminium and etc. However, flaws are commonly formed in sand cast parts and these flaws may affect the properties of the cast materials. In this context, click2cast simulation software is employed in order to identify and optimize the defects in sand casting such as air entrapment, porosity, cold shuts, etc. In the present work the velocity variations, pressure variations, solidification behavior and defects like porosity, cold shunts identification etc have been studied during filling of the AA7075 alloy in green sand mold. Based on the simulation results, the preventive measures to be taken in order to avoid the defects come across during the process are monitored by regulating the pressure in mold cavity through provision of vent holes properly and maintaining the pouring rate uniformly.

Keywords: Aluminium 7075, Casting, Solidification, Casting defects.

1. Introduction

Aluminium and its alloys are playing important roles in the modern manufacturing era because of its intrinsic and versatile properties of less weight, low strength to weight ratio, good corrosion resistance, electrical and thermal conductivity, etc. In case of castings, either as cast or heat treated aluminium is gradually replacing gunmetal, bronze, stainless steel and many grey iron and malleable iron castings. Aluminium alloys frequently used in engine components like diesel pistons, gear boxes, crank cases, clutch housing, pump bodies, bracket, arms and hangers for different industries, mechanical components, fittings for chemical and marine uses, railways, storage tanks, flywheel housing and propellers, artificial limbs, ornamental hardware's, ashtrays, water jugs, art metal work, molding flasks and etc. The chemical composition of AA7075 is given in table 1.

Table 1. Chemical Composition of AA7075

Zn	Mg	Cu	Cr	Fe	Si	Mn	Ti	Others	Al
5.1-6.1	2.1-2.9	1.2-2.0	0.18-0.28	0.5	0.4	0.3	0.2	0.05	Remaining

1.1. Inputs for the Simulation Software

The inputs to be provided to the software are

- The geometry of the mold cavity (3D model of the casting, feeders, and gating channels).

- Thermo physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mold material, as a function of temperature).
- Boundary conditions (i.e. the metal mold heat transfer coefficient, for normal mold as well as feed aids including chills, insulation and exothermic materials).
- Process parameters (such as pouring rate, time and temperature).

1.2. **Simulation Procedure**

The following steps are followed for the simulation

- Geometric modeling of mold
- Conversion of model to .stl file format
- Importing the geometry file to simulation software
- Ingate selection
- Meshing of model
- Material selection
- Run calculations
- Execute results

2. Design of Mold

First by using the creo software in part drawing the front view of the mold is drawn using the tools available creo parametric as per dimensions. Figure 1 showing the front view of designed model of mold. The meshed model of the casting is shown in figure 2.

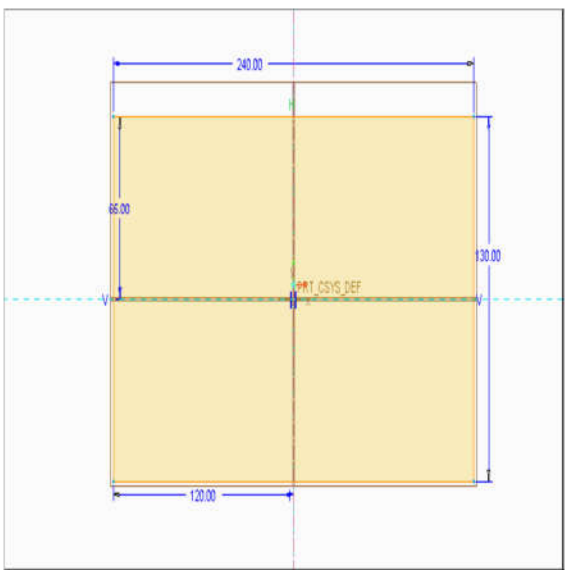

Figure 1. Front View of the Casting mold

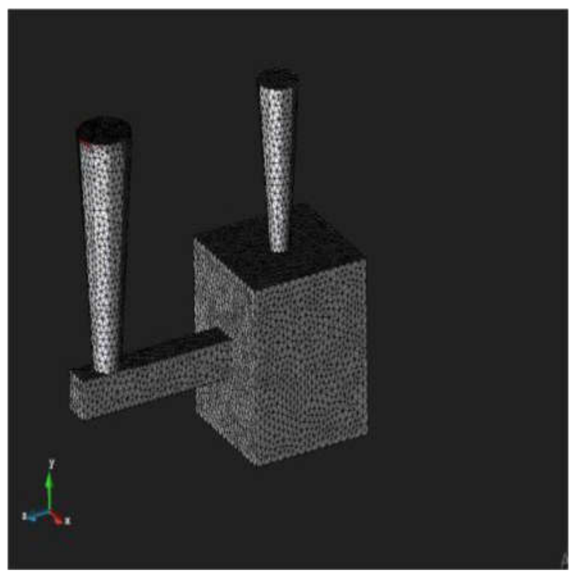

Figure 2. Meshed Model

3. Results & Analysis of Casting Simulation

The gating design has driven by the ideal mold filling time, which depends on the cast metal, casting weight and minimum wall thickness. Fast filling leads to turbulence related defects (such as mold erosion, air aspiration and inclusions). On the other hand, slow filling may cause defects related to premature solidification (such as cold shuts and miss runs). To optimize the gating design, the program simulates the mold filling and computes the total fill Time.

3.1. Variation of Velocity During Filling

The optimal filling time depends on the speed of flow of the molten metal. This mostly varies within the gating channels and the mold openings. The metal will be hot and fast at these locations and thus it leads to huge damage if the flow is not maintained properly. The speed of the molten metal depends on two factors. The metallostatic head and the ratio of cross-sections of sprue exit, runner and ingates. Figures 3, 4, 5 and 6 showing the results of rate of flow of velocity in mold cavity at various filling rates using simulation software. Pouring velocity needs to be carefully controlled during the metal casting operation, since it has certain effects on the manufacture of the part. If the pouring velocity is too fast, then turbulence can result. If it is too slow, the metal may begin to solidify before filling the mold.

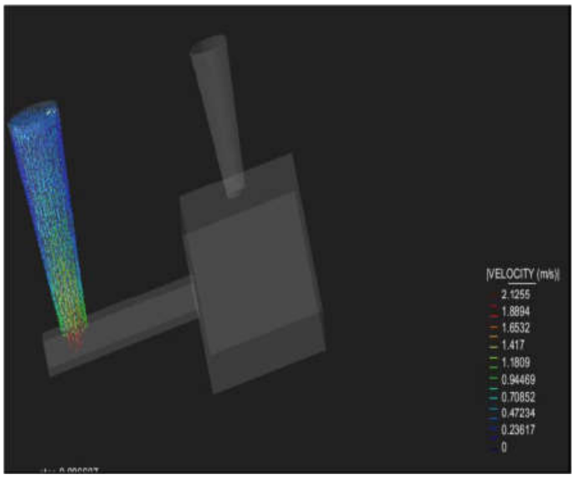

Figure 3.Velocity Variations after 25% Filling of Mold

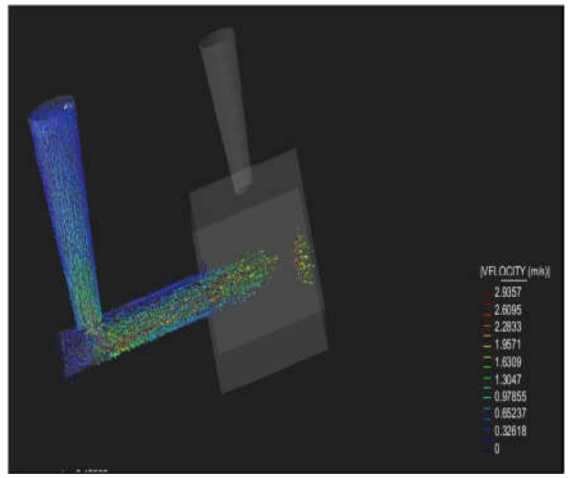

Figure 4.Velocity variations after 50% Filling of Mold

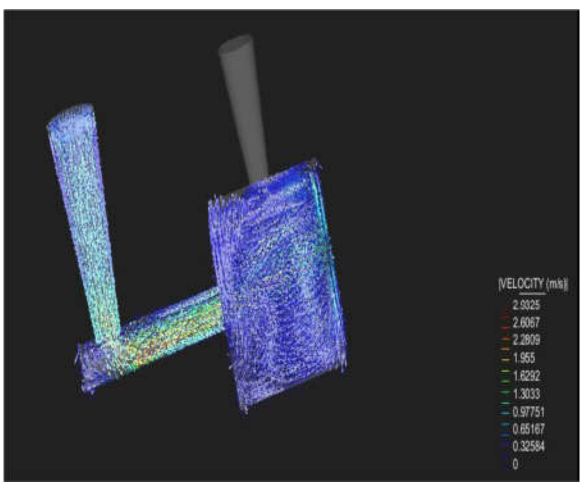

Figure 5. Velocity variations after 75% filling Of mold

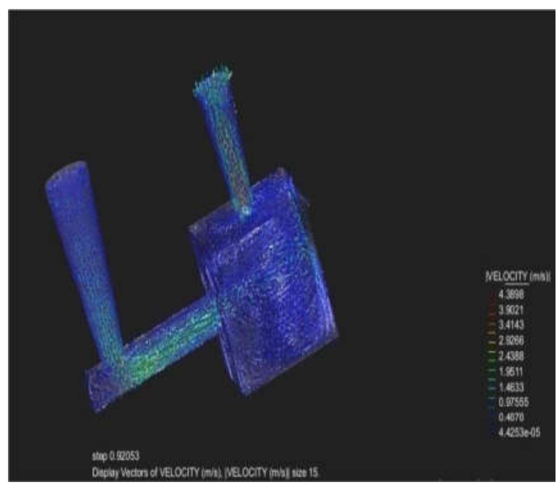

Figure 6. Velocity variations after 75% filling of mold

From the results of velocity, it is clear that the filling velocity is being increased due to effect of gravity as well as the tapering of the sprue which avoids air aspiration effect and molten metal flows into the mold cavity and also there is no sudden changes observed in the velocity variations which shows there is no defect in gating system.

3.2. Variation of Temperature during Filling

Pouring temperature refers to the initial temperature of the molten metal used for the casting as it is poured into the mold. This temperature will obviously be higher than the solidification temperature of the metal. The difference between the solidification temperature and the pouring temperature of the metal is called the superheat. Figure 7 shows the variation of temperature in mold during filling process.

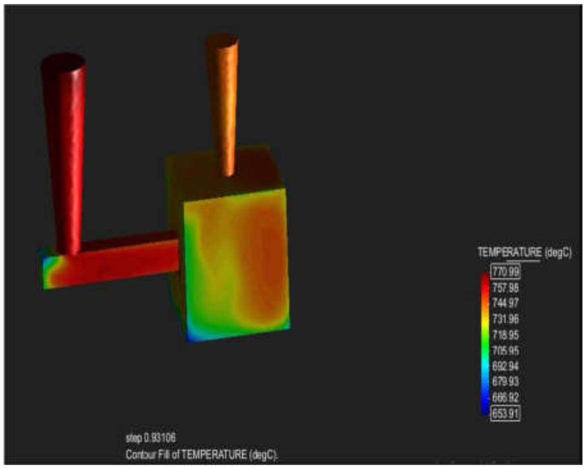

Figure 7. Variation of Temperature during Filling

From the figure 7, it has been observed that the temperature at sprue area and at its base is more due to continuous travel of molten metal which is at high temperature.

3.3. Variation of Pressure During Filling

Fluidity, a technological feature, reflects the ability of liquid metal to flow continuously even as it solidifies via a given mold passage, filling it to reproduce the detailed design. When the molten metal rises in the mold, filling can be hindered due to the backpressure created by compressed air in the cavity thereby reducing the metallostatic pressure. Venting enables to regulate the back pressure.

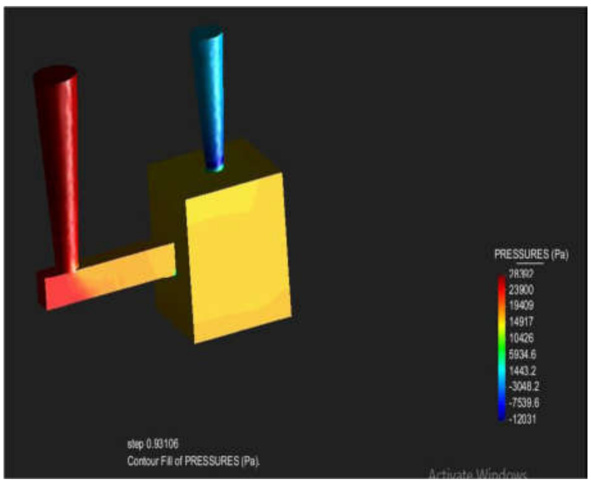

Figure 8. Variation of Pressure In Mold During Filling Process

Figure 8 showing that the pressure concentration is high at sprue and sprue base due to continuous pouring of molten metal which is at higher temperature and remaining areas like riser will have less pressure as venting enables to regulate the pressure. If the pressure concentration is more at sprue , runner , pouring basin there may be no effect on the casted object as they are trimmed and scrapped later but if the pressure concentration is high at mould cavity necessary measures should be taken and design need to be modified.

3.4. Cold Shuts Formed During Filling

Poor fluidity of molten metal gives rise to cold shut or misrun. Cold shut occurs when streams of molten metal arising from opposite direction fail to fuse completely. Figure 9 shows results of cold shuts formed in casting during filling process.

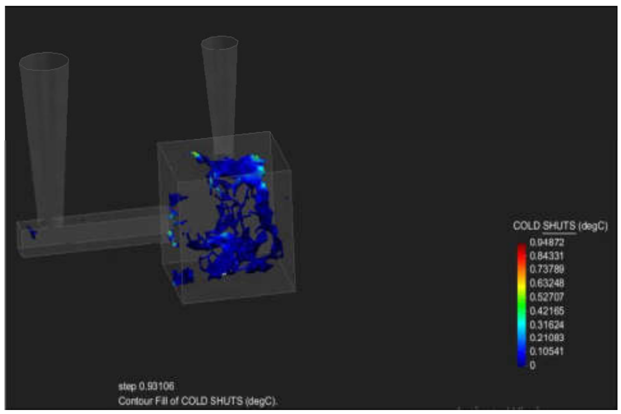

Figure 9. Cold Shunts Formation during Filling Process

From the figure it is observed that cold shuts formed at mold cavity and riser areas which are minor but it is very common as the metal enters the runner path and there on into the mold cavity the streams of molten metal arise from opposite direction may not fuse properly.

3.5. Porosity (%) Observed During Solidification

The casting voids most often referred to as porosity can be caused by gas formation, solidification shrinkage, or non-metallic compound formation, all while the metal is liquid. Large gas-related voids caused by trapped mold or core gases in the molten metal are called blows or blowholes.

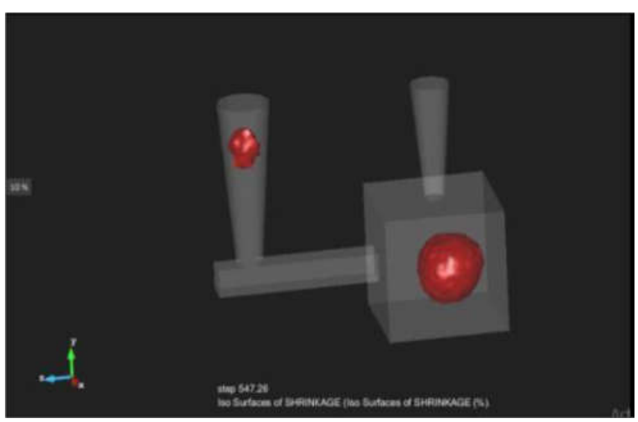

Figure 10. Porosity (%) during Solidification Process

From the results of porosity observed that the porosity at inner part of mold cavity is high due to gas formation and during solidification it is very common that the mold cavity cools slowly and inner most part of the casting may not solidify properly as shown in figure 10 and there is also increase in porosity at centre due to continuous flow of molten metal.

3.6. Macro Porosity Observed

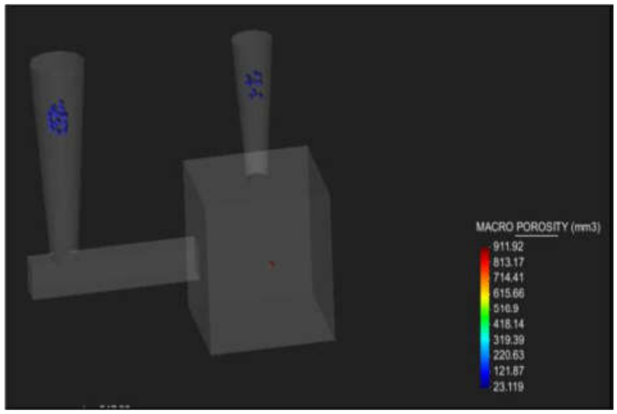

Figure 11. Micro Porosity during Solidification Process

From the results of micro porosity it is clear that the solidification shrinkage at sprue and riser will have less effect as shown in figure 11 and as the gating system is scraped later it will not influence the properties of casted metal.

3.7. Solidification Temperature Analysis

The solidification of liquid metal in the mold cavity takes place immediately after entering into the cavity. Solidification is a result of heat transfer from internal casting to external environment and the rate of solidification is not uniform throughout the casting. The solidification of liquid metal in the mold cavity starts from the edges of the casting and it progress towards the centre of the casting. The solidification front directed from the thinnest section towards the thickest section and the thinner section solidifies quicker comparison to the thickest section.

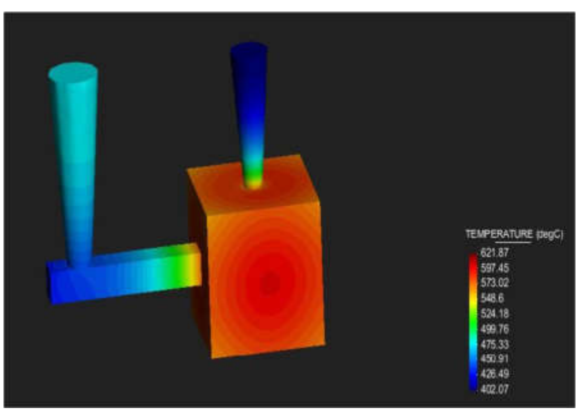

Figure 12. Temperature Variation after Filling

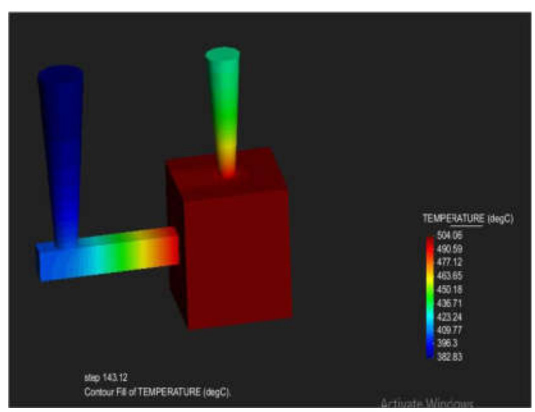

Figure 13. Temperature Variation after 25% 50% Filling

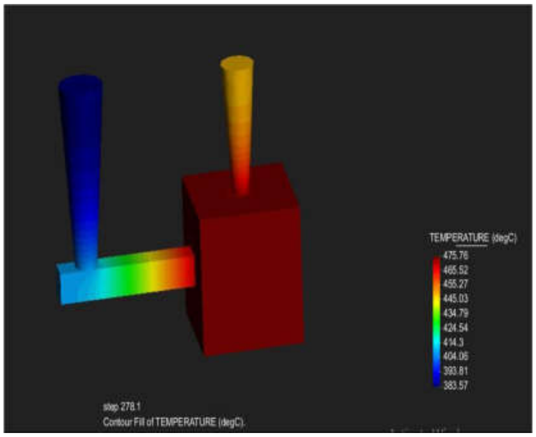

Figure 14. Temperature Variation after 75% Filling

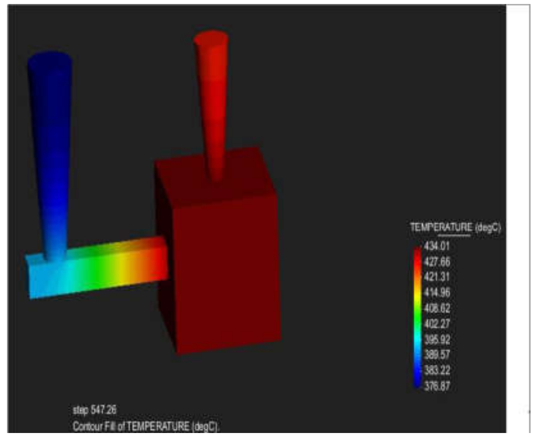

Figure 15. Temperature Variation after 100% Filling

From the figures 12 to 15, it is clear that solidification temperature will be more at the mold cavity due to no proper ventilation or absence of air and solidification time for mold cavity will be more when compared to remaining parts of gating system due to ventilation at sprue and riser and due to absence of air at mold cavity. Solidification time will be less at sprue and riser. Solidification temperature depends upon the surface area of the mold material, rate of heat transfer and temperature of liquid metal and properties of mold material.

4. Conclusions

- The application of computer aided casting simulation technologies in foundries can able to minimize the non value added time in casting development, as it reduces the number of trial casting required on the shop floor. It can also be used for prediction of various casting defects.
- The casting simulation software Click 2 cast which is based on finite element method was used in studying the solidification behavior and flow analysis in aluminium 7075 alloy castings in green sand mold. This helped in visualizing the mold filling and casting solidification. Also used to predict the related defects like shrinkage, porosity, cold shuts, and air entrapment.
- Analysis of casting process is carried out based on the results of simulation and necessary steps are taken to avoid defects by regulating pressure in mold cavity with provision of vent holes and by maintaining uniform pouring rate etc,.
- From the study it is concluded that production of reliable, economical, high accuracy cast component can be prepared by application of simulation software in casting process.

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