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Optimised design of injection mold for a cover plate component simulation to predict defects in castings

S. Balamurugan[1*], Vinit Nair[1], N.G.B.Kaarthick Babu[1], S.Vignesh Shanmugam[2]
[1]Department of Mechanical Engineering, SRM University, India.
[2]Mechanical Department, PSG College of Technology, India.
***Corresponding author: E-Mail: balam2007@gmail.com**

ABSTRACT

Die casting process is used to manufacture complex geometries of limited volume. The earlier methods of die casting involved trial and error methods in manufacturing. Simulators are used to predict manufacturability of castings. This helps to control process parameters and also design parameters. The process results in defect free sound castings. The design of feeding system plays an important role in manufacturing sound castings. This paper studies the effect of feeding system and tests a model for its cast ability using modern simulation tool. The model selected is a cover plate part component assumed here of ABS material. The feeding system for the material has been designed for multi cavity injection molding. The design is based on casting design rules for the gating ratio, pouring time, and gating system dimensions. Mold filling and solidification processes were simulated by using Moldex3D. The simulation results indicate its need in the feeding system design and modification and thus plays a significant role in the entire manufacturing process of castings. The entire procedure indicates a better and low cost methodology to obtain good sound castings to the traditional trial and error method.

KEY WORDS: multi-cavity, simulation, air traps, mold design, feeding system.

1. INTRODUCTION

Casting is the manufacturing process in which liquid metal is poured into mold cavity of desired shape and then allowed to solidify. Casting process is now-a-days widely used to cast products made of thermosetting polymers and some metals and alloys. With the increased use of plastics in almost all the sectors, plastic mold industry has been growing rapidly. The major casted plastic components that we see in day to day life are plastic bottles and toys.

In the design of mold there are few parameters to be considered like the complexity of geometry, filling time, overall time for production. Apart from these process parameters, design parameters like design of sprue, runner, gates etc. are to be considered.

Pouring system is designed considering laminar flow of molten metal by foundry experts. However, if turbulent flow occurs, undesired effects such as air/ gas entrapments may occur. In case of sand molds it may result in slag. These imperfections become the main reason of faulty casting. Casting contraction while cooling is yet another parameter that is taken into consideration while designing molds, however, for intricate geometries the accurate prediction of local solidification is difficult.

Earlier these computation parameters were strictly skill oriented and thus for mold design skilled labors were needed. But with advancements in the fields of science and technology the prediction of castings has become easy using simulators. Simulation of casting helps to indentify solidification course, type of flow, air entrapments, time required for filling, temperature and pressure distribution. This helps to validate the design of component, to make necessary modifications in geometry, locate overflows and thereby reduce the overall casting development cycle time.

The fundamental basis of all fluid flow calculations is based on Navier-Stokes and Newton's second law of momentum. Based on discretisation and coding the flow simulators work to give near to accurate predictions for die castings.

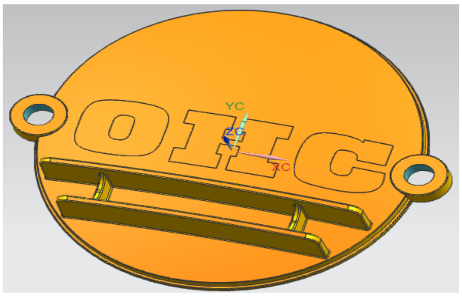

Figure.1. Toy component

Simulation Analysis of Injection Molding:

Creating The Model of Mesh: The dimensions of the component were measured physically and noted down. For modeling UNIGRAPHICS software has been used. The component is then polyhedral meshed so that the results of analysis are accurate and reliable. Mold and feeding system design for toy component were also designed in modeling software. The major three design criteria for feeding system were also considered: a) Heat transfer criteria, b) Mass transfer criteria, c) The junction criteria.

The feeding system designed consists of sprue, runner, gate and vent. The riser and overflows had purposely not been designed. The reason being that the simulation results will help understand its need and location where to apply.

Setting Technology Conditions: The material allocated to the component and feed system is Acrylonitryle Butadiene Styrene (ABS). The process parameters for the injection molding are as follows: the melt temperature is 240ºC, the mold temperature is 60ºC, the ejection temperature is 85ºC. The model after meshing is as shown in figure 2.

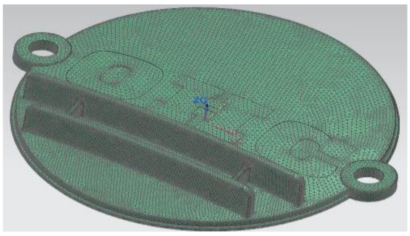

Figure.2. Meshed model of toy component

Analyzing the feeding system: Based upon the machine SP80 selected, its parameters and plasticizing rate of ABS the calculation for no of cavities came out to be two. So two components will be manufactured at the same time. The base part of the component needs to be sealed and so design of gating system in this region is not recommended. Measures are taken that the feeding system remains balanced and both components get evenly filled at the same time. Fan gates have been selected based on the geometry.

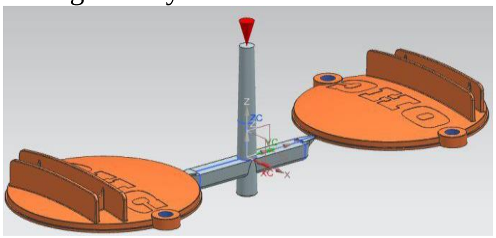

Figure.3. Feed system

On the basis of study of geometry and calculations made the feeding system is as shown in figure 3.

Flow Analysis of Injection molding:

Fill Time Analysis: Fill time analysis is the analysis of time taken by the molten plastic to reach the farthest end of the mold. The analysis is useful in predicting the nature of flow of plastic in the cavity region. This is useful to check if the feeding system is balanced or not. In case of multi variable cavity systems this helps in varying the geometry of the feeding system so as to ensure that both the cavities get uniformly filled at the same time. The fill time analysis of the component is as shown in figure 4.

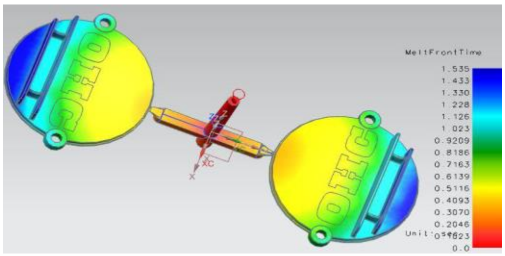

Figure.4. Melt Front time

Pressure Drop Analysis: The pressure drop results are as shown in figure 5.

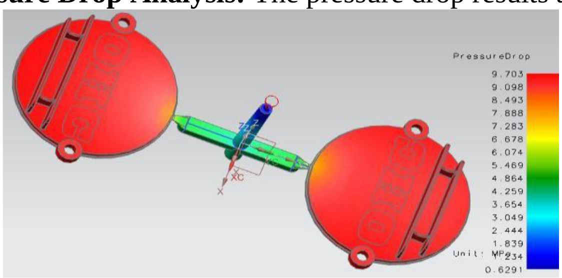

Figure.5.Pressure Drop

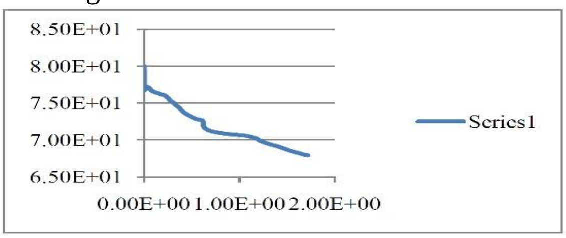

Figure.6.Drop in Pressure from set machine pressure

Air Trap Results: The air trap results are as shown in figure 7. From figure it can be seen that the air traps are distributed at the farthest end of cavity on upper thin projection. All these sir traps fall in the parting line region of the mold and on top of component.

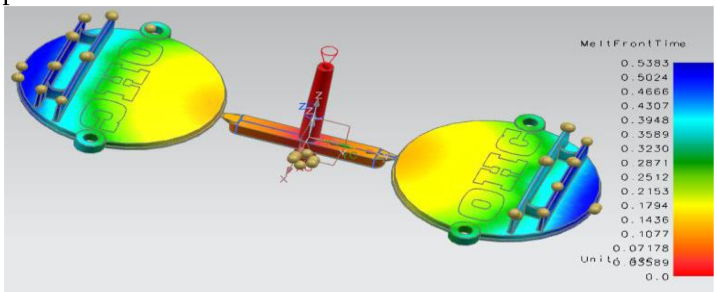

Figure.7.Air Traps

The air traps in figure are indicated by small spheres. Only the ones in the cavity region are of concern but still measure must be taken to ensure that any air bubble in the feeding system does not get into the cavity region during solidification.

Cooling Time: Based on heat transfer principles, the approximate cooling time for a component can be found out using below formula

$$tc = -0.2435 * (l^2/a) \log (\pi/4 * ((\theta - \theta_s)/(\theta_0 - \theta_s))$$

Where, l is the maximum thickness (m) of the molded product, α is temperature conductivity rate (m^2/S) of the polymer, θ is the temperature of the polymer at its center, tc is temperature at which the part can be ejected using the ejector pins, θs is mold temperature, θo is initial temperature of the polymer.

Remedy for Air traps: The air trap results indicate that they can be easily removed by venting. For the farthest end of geometry air vents will be ground on the core plate. But for the upper projections some suitable arrangement must be made as the results in this region may vary due to very thin cross section. For this region insert method is suggested and is as shown in figure 8.

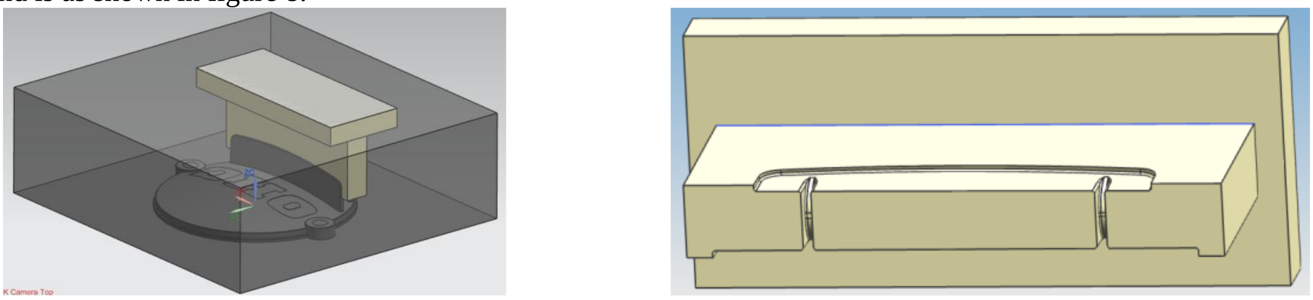

Figure.8. Inserts method

A gap of nearly 2microns will ensure that only air flows out these gaps and molten plastic will not. Thus ensuring a sound casting.

Design of Mold Structure: Based on core and cavity extractions as mentioned above the mold design is done as shown in figure 9.

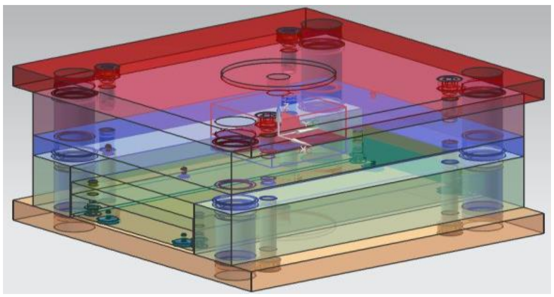

Figure.9. Mold Design

The working procedure of the mold is as follows: The molten plastic is injected in the mold cavity by the molding machine. The molten material flows into the cavity chamber through via sprue then runner and finally via gates into the cavity. After the injection is completed, depending on the ejection temperature and the cooling time calculations the mold is opened. The moving half of the mold consisting of core part moves down as being pulled by tie rods of the machine. After the set ejection distance reaches the ejector rod hits the ejector plates causing the casted component to lift from its seat. To the feeding system a small extension is provided with positive draft which keeps the feeding system pulled for some time till the casts get detached from the feed system.

If the mold consists of induction heating mechanism the feed system can again be melted as the plastic material selected is a thermoplastic. Thus the overall loss is reduced near to zero. The procedure then repeats by closing the mold. The moving half matches with the fixed half consisting the cavity plates by means of guides.

2. CONCLUSION

Thus, optimized Mold cavity design: Gating ratio, Pouring time & Gating System for Toy component has been designed using Moldex 3D software in Multi-cavity Molten Injection System. It helped to reduce investment and time on Trial and error method. Die Casting Process has be made simpler and cost effective using software simulations. Also, Flow analysis and Air trap analysis used for estimate Solidification time and best possible path for reduced defects. Further, Optimization techniques such as Design of Experiments may be used to arrive at better solutions by making trials in software itself.

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