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Simulation and Analysis of Cold Runner Mould for Defect Minimization

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Abstract
Most of the thermoplastic resins were molded by using Injection molding with Cold Runner System. Cold runner system is widely used in many of the plastic industries due to its simplicity in design and less investment cost in tooling. It doesn't require highly skilled manpower and gives moderate quality component. The product quality can be confirmed through simulation results for cold runner system. This paper covers the design and simulation of concealed box using mould flow software. The essential material properties for the application of concealed box are fire and heat resistant, insulator, high rigidity and dimensional stability. ABS (Acrylonitrile Butadiene Styrene) material offers most of these hence can be suited for electrical appliances widely. Simulation of the component with respect to various process parameters such as Injection pressure, mould temperature, shear stress, cycle time are discussed so as to minimise the mould defects such as sink marks, weld lines and air traps in moulded component. This paper elaborates suitability of cold runner system for ABS as a better substitute for such applications with better productivity.
Key words: *Injection moulding, Cold Runner system, ABS, simulation, Moldflow software*

1. INTRODUCTION:

Concealed box used for the application of Electrical parts to hold socket , switches is considered for the analysis. The part used is manufactured by using material Acrylonitrile Butadiene Styrene (ABS). The component is moulded by Injection moulding using Cold Runner System. The simulation is carried out using mould flow software and material properties, process parameters with their effect on moulding defects is studied. Simulation of mould using CRS system plays an important role in defining its process parameters and primary estimation of mould defects.

2. LITERATURE REVIEW:

Mr. P. Vinod, Mr. K. Vijaykumar [1] have designed multicavity injection mould with HRS and CRS. They studied the effect of runner systems, mould cooling and venting by comparison of both the designs with its simulation in ANSYS.

Rashi A. Yadav, S. V. Joshi, N. K. Kamble [2] have done the review of the recent research in designing and determining process parameters of injection molding. A number of research works based on various approaches have been performed in the domain of the parameter setting for injection molding. They have Determined optimal process parameter settings critically influences productivity, quality, and cost of production in the plastic injection molding (PIM) industry.

Gurjeet Singh, Ajay Verma [3] have studied primary processing conditions of moulding from concept development to manufacturing of the product. They studied effect of various factors on the basis of processing parameters. Since quality and productivity are the two important contradictory objectives in any machining process. Some extent of quality has to be compromised while assurance giving for high productivity. It is concluded that productivity get decreased while the efforts are channelized to enhance quality. Machining parameters need to be optimized to ensure high quality and productivity. Authors have studied various responses of quality of injection moulding process on the basis of performance parameters and methods.

Lee and Lin et al. [4] Built a multi-cavity mould runner and gating system. Use Finite Element Theory (FEM) network. Optimal runner unit parameter used to minimise injection mould warp, FEM, Taguchi phase and adductive framework. Processes during mould filling, enhancing moulding condition. Model injection mould simulation at steady flow rate. Finite differences method offers strong consent for methodological solutions.

Different gate sizes and locations using flow simulation have been detected for defects reduction such as weld lines and air traps, air traps and warpage can be managed by varying process parameters

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Different gate sizes and locations using flow simulation have been detected for defects reduction such as weld lines and air traps, air traps and warpage can be managed by varying process parameters [5].
Part flow-reducer studied using Autodesk Mould Flow tools. The mould flow analysis is used to predict the piece's deformation and change the design accordingly. [6].
Experimentation: Component Name - Concealed box
Application: Electrical parts to hold socket, switches etc.
Material: ABS (Acrylonitrile Butadiene Styrene)
Component is manufactured using plastic injection moulding with cold runner system

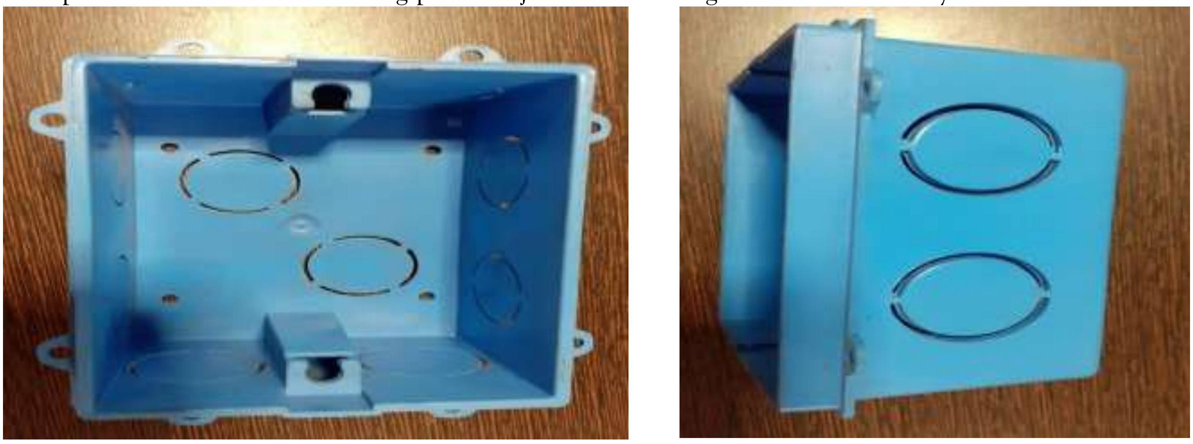

Fig 1: Component model for concealed box

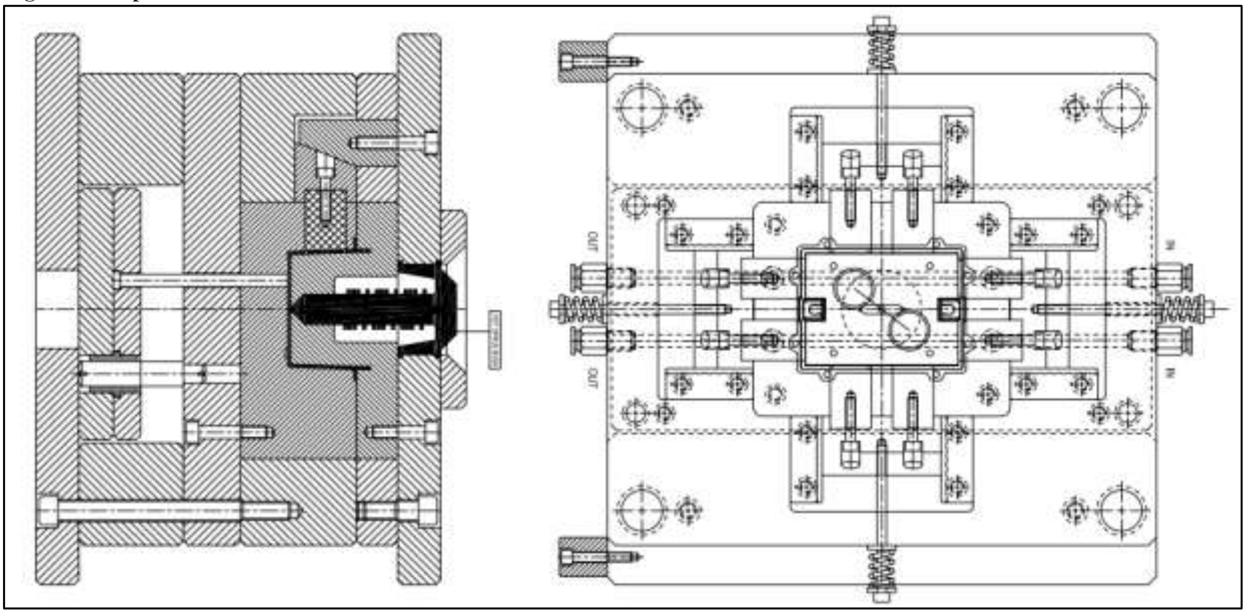

Fig 2: Mould design for Concealed box

3. Simulation for CRS using mould flow software

Input Parameter:
Name: Concealed box, Volume: 57.19 (cm3), Mass: 63.01 (G)
Size: X: 116.90 (mm), Y: 90.90 (mm), Z: 93.40 (mm)
Material Name = ABS (Acrylonitrile Butadiene Styrene)

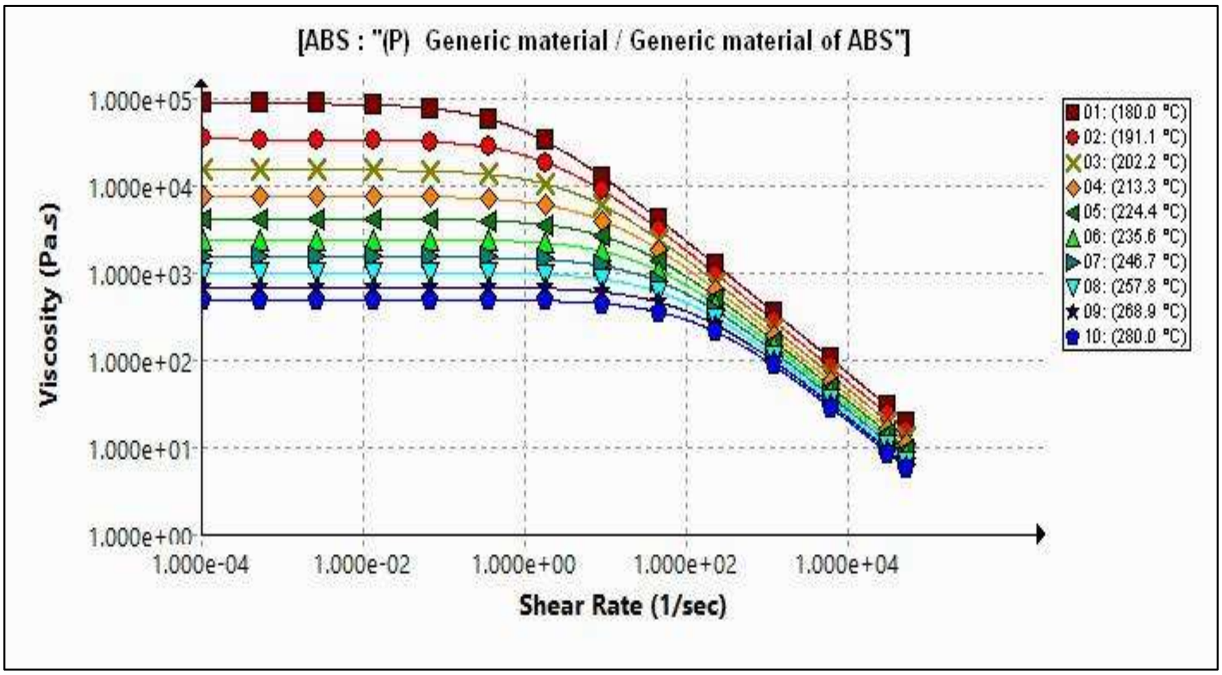

Fig 3: Shear rate Vs Viscosity

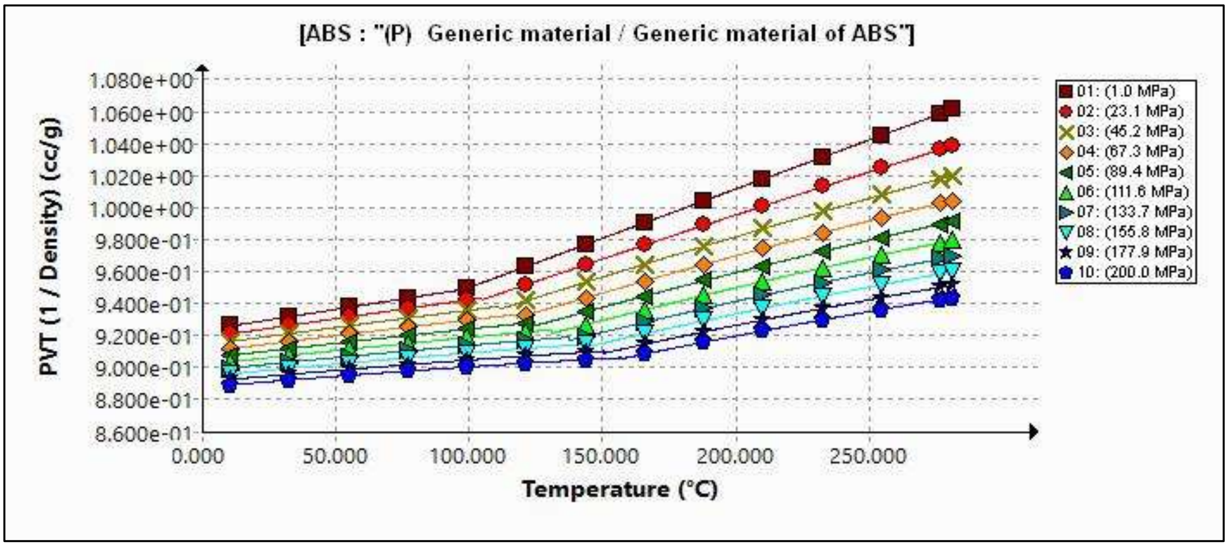

Fig 4: Temperature Vs Specific Volume

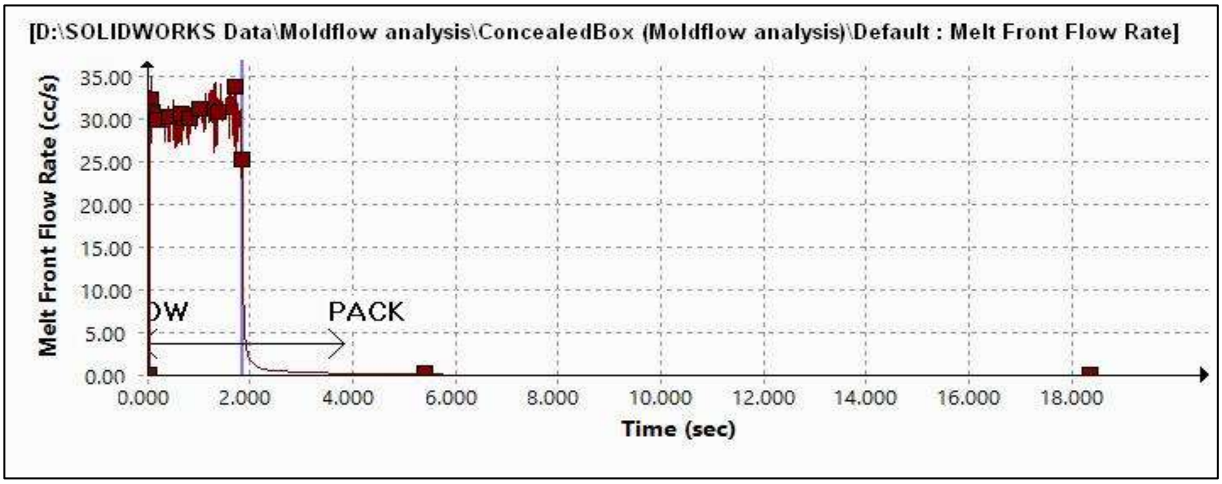

Fig 5: Time Vs **Flow rate**

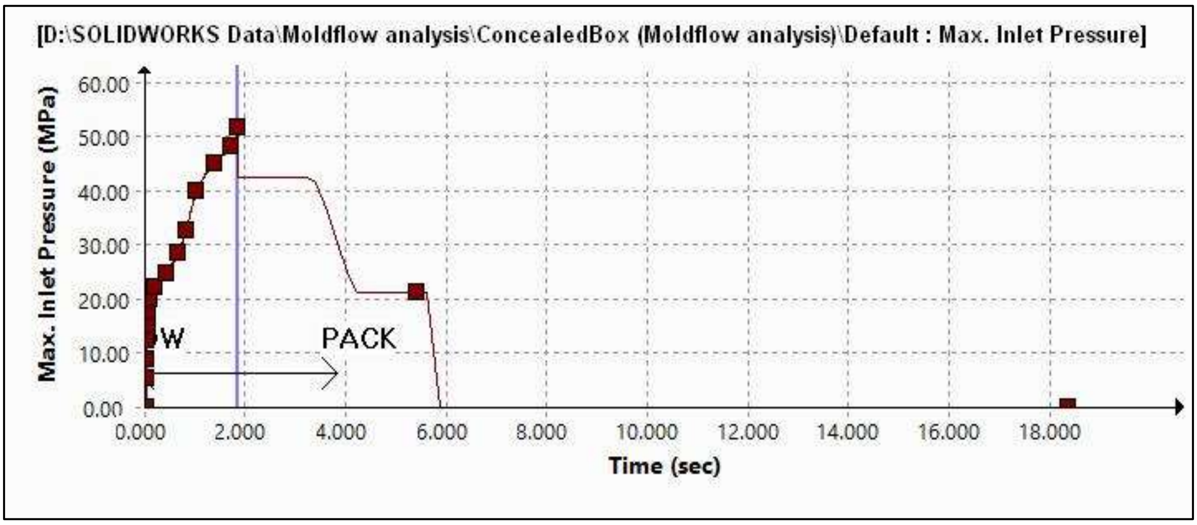

Fig 6: Time Vs Flow rate

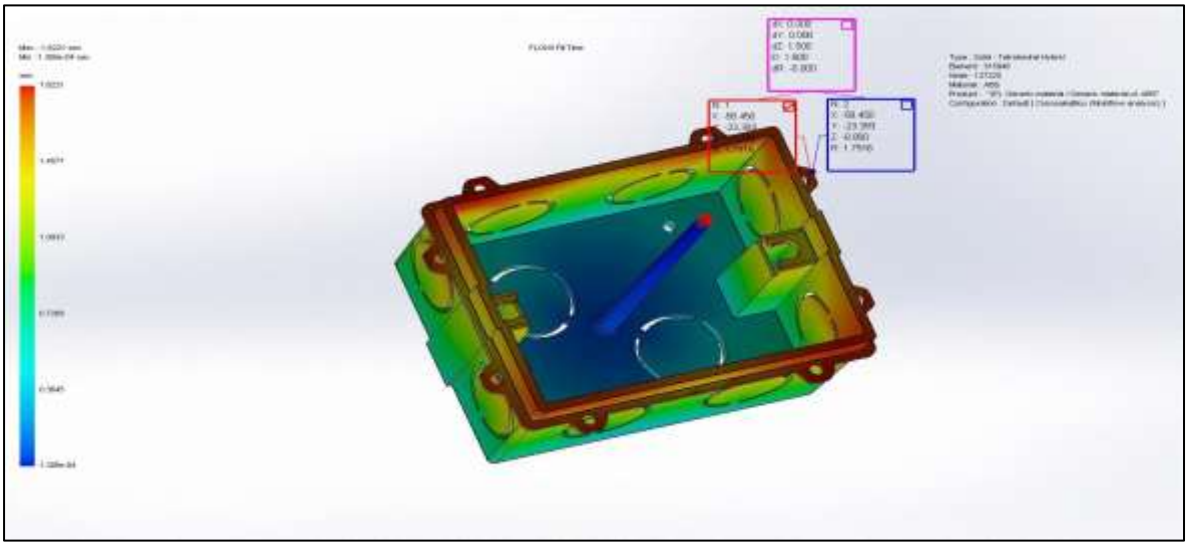
Fig 7: Mould filling

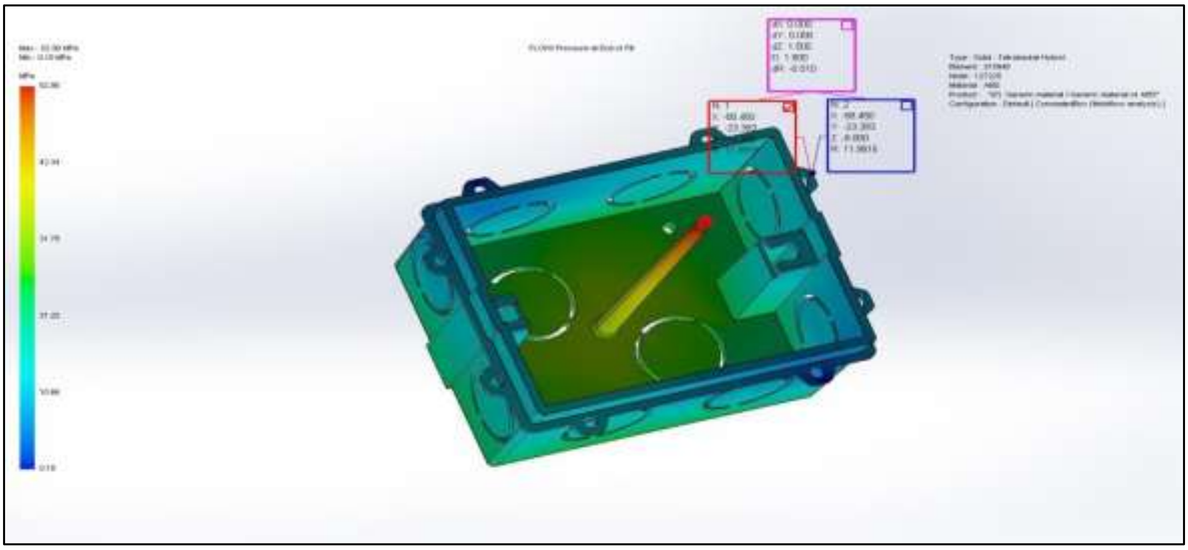
Fig 8: Inlet Pressure

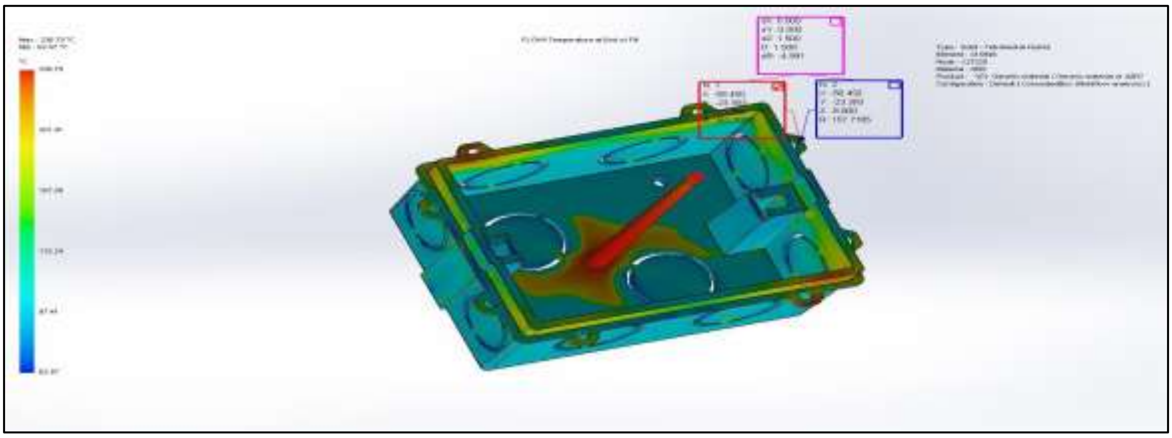

Fig 9: Temperature at end of filling

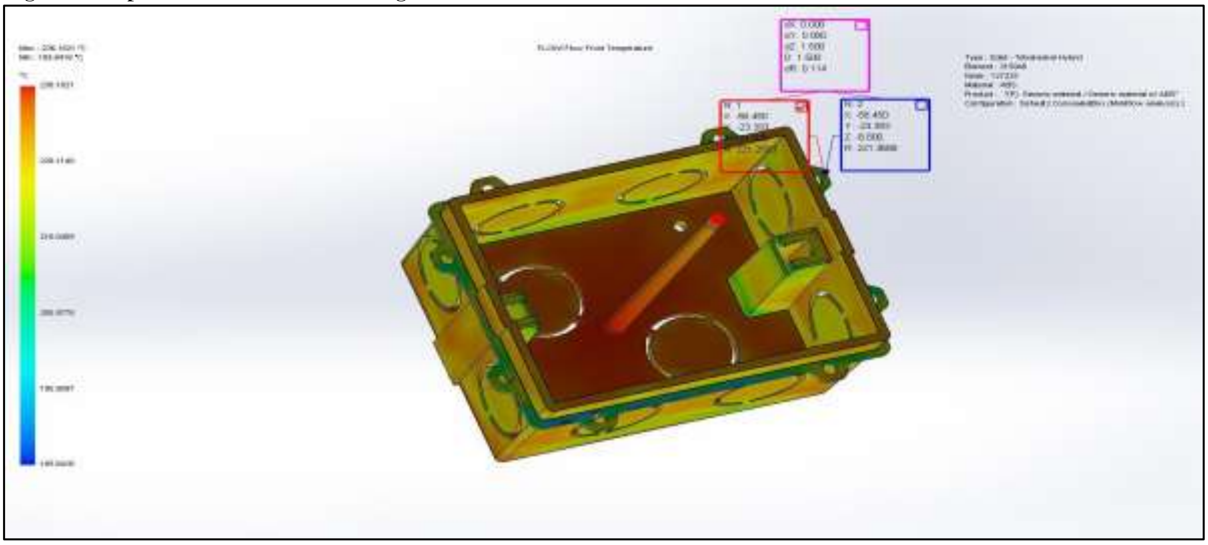

Fig 10: Flow front Temperature

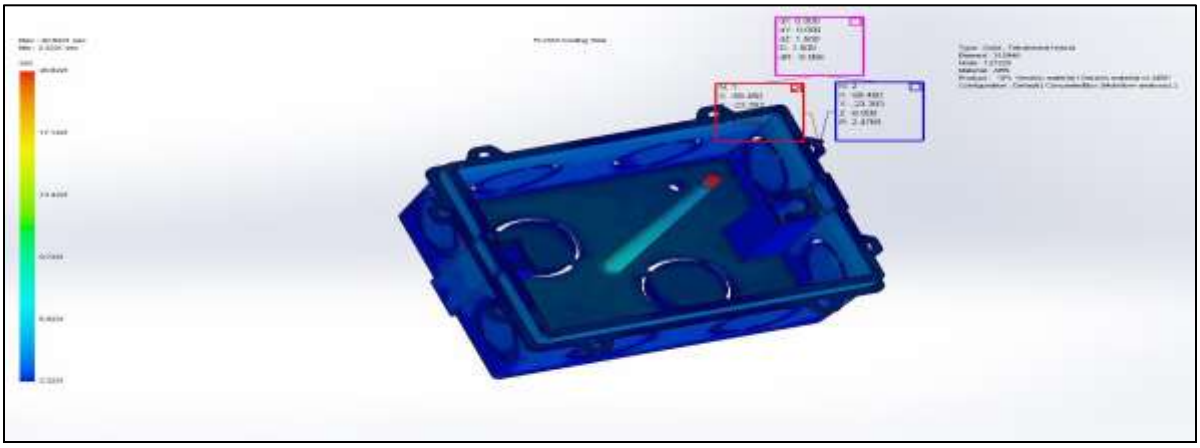

Fig 11: Cooling Time

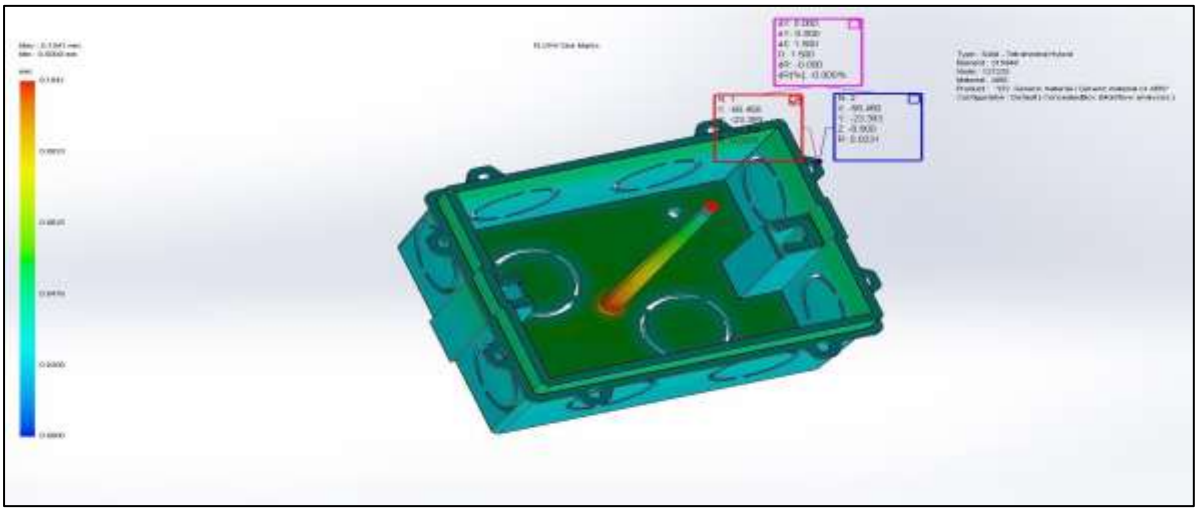

Fig 12: Sink marks

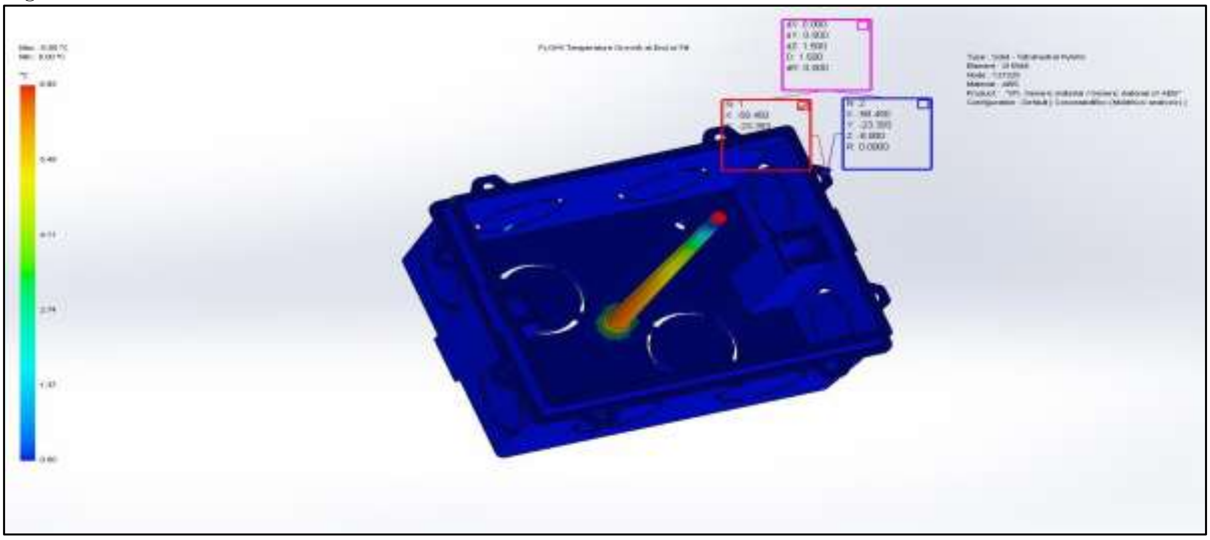

Fig 13: Temperature growth at the end of fill

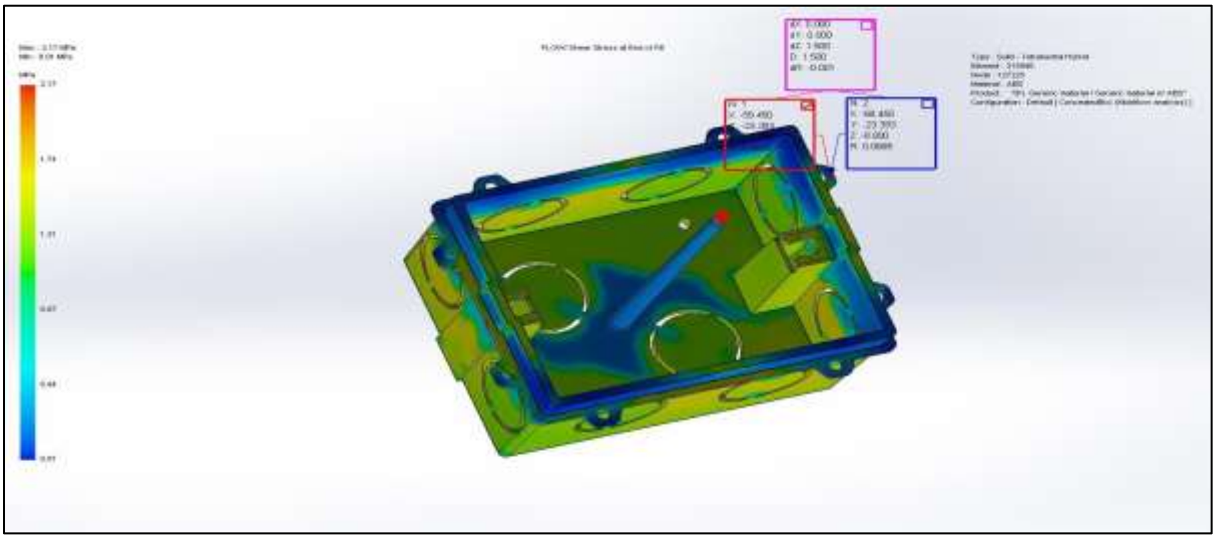

Fig 14: Shear stress at the end of fill

The simulation of the component by considering cold runner mould is carried out and the results for process parameters and mould defects can be summarised as follows:

Viscosity: Viscosity is measured within temperature range of 180° to 280° in the interval of 10° each. Graph of viscosity Vs shear rate has been plot and is been observed that viscosity is constant up to shear rate of 1.000e + 00 per sec. and then it starts decreasing as shear rate increases.
Specific volume: Specific volume is with respect to temperature in the range from 0° to 250° and it is measured at various pressure levels from 1 MPa to 200 MPa and it is found that specific volume increases slowly with increase in temperature up to 100° and then it increases gradually with increase in temperature.
Flow rate: Flow rate is observed as maximum but in varying nature during initial 2 sec of the process and then it gets dropped drastically to zero.
Maximum Inlet Pressure: It is observed that inlet pressure increases for the initial time period of 2 secs, reaches to 50 MPa and then starts decreasing till the end of the moulding process.
Pressure at end fill: Fig indicates pressure at different mould locations. Mould flow pressure is maximum at gate and it gradually decreases as we go away from gate area.
Temperature at the end of fill: Mould temperature is maximum, in the range of 235°C at gate area and it decreases gradually up to 62°C as we go away from gate location.
Flow front temperature: The result shows the changes in the temperature of the flow front during filling. Gate area shows maximum temperature in the range of 236°C and it gradually decreases as we go away from gate region and drops up to 185°C during filling process.
Temperature growth at the end of fill: It shows at how much rate faster the temperature drops and mould is getting cooled. Sprue remains at higher temperature in the range of 6°C to 1°C where maximum temperature is in area of gate and it takes more time to get cooled.
Shear stress at the end of fill: Shear stress is a measure of the tension created between molecules within the plastic, caused by the plastic layers flowing relative to each other and tugging on each other. Too much stress causes the molecules to break. The maximum shear stress a material can withstand is generally estimated at 1% of tensile strength. This result shows the recorded peak value of shear stress of each element during the filling process. It is observed that, shear stress is maximum in the range of 2MPa at gate location and is dropped to zero in sprue region. Shear stress is moderate in the component region
Volumetric shrinkage at end of fill: Volumetric shrinkage is caused by thermal contraction, which affects all polymers, and/or crystallization for semi-crystalline polymers. It describes the extent to which the material changes in volume as it changes from a liquid to a solid. In general, plastics can shrink up to 25% during the injection moulding process. In this case, the actual shrinkage is in the range of 4% to 6 % in the component area which is in allowable limits.
Freezing time at end of fill: Freezing time gives the time required for solidification and ultimately it gives total process time required. It shoes the critical region which takes more time to get solidified and its freezing time is in the range of 1 to 2 sec approximately.
Cooling time: Cooling time in injection moulding is a critical part of the production process. It is the amount of time the molten plastic takes to solidify. An adequate cooling system is required to transfer heat away from the mold and maintain a stable cooling rate, ensuring the highest quality final products. In this process, cooling rate is sufficiently good near about 2.5 sec.
Sink mark: Sink mark is a depression on the surface of a moulded part. Although sink marks do not affect the part strength or function, they are perceived to be serious quality defects. The sink mark occurs when the inside plastic shrinks and the solidified surface layer deforms due to inner pressure of shrinkage at the cooling process. Sink mark result shows the possible sink mark displacement across the entire cavity surface. A higher value indicates a high degree of sink. You can eliminate sink mark by decreasing the filling time to compensate the plastic shrink. In this component, sink marks in the range of 0.04 to 0.06 mm are observed.
Frozen area at the end of fill: The Frozen layer fraction at end of fill result represents the thickness fraction of the frozen layer at the end of filling. It ranges from 0.0 to 1.0. A higher value indicates a thicker frozen layer (or thinner flow layer) and higher flow resistance. A polymer is considered frozen when the temperature falls below the transition temperature During filling, the frozen layer should maintain a constant thickness for those areas with continuous flow, because the heat loss to the mold wall is balanced by the hot melt coming from upstream. Once the flow stops, the heat loss through the thickness is completely dominant in that area. The frozen layer fraction generally will be very low near the injection

location and the end of fill. The maximum frozen layer fraction at the end of fill should be less than 0.20–0.25. None of the part should have a frozen layer fraction higher than 0.20–0.25 at the end of fill. A faster injection time will reduce the frozen layer fraction.

Weld lines: Weld lines are caused by the inadequate bonding of two or more flow fronts when there is partial solidification of the molten plastic. Knit lines in injection molding are undesirable, especially when surface appearance and part strength are significant concerns. The existence of weld lines in our component is appear to be almost nil.

Air traps: Air Traps occur when a bubble of air is trapped as plastic flow fronts coincide. The air bubble, or air trap, can cause various defects in a plastic part such as blemishes on the surface, incomplete filling and packing. Following are the areas where air traps are likely to occur. The results can be tabulated as follows:

Table 1: Simulation results of mould flow analysis

Sr. No.	Parameter	Cold Runner System	Sr. No.	Parameter	Cold Runner System
1	Material name	ABS	16	Clamp force limit	100 Tonne
2	Melt temperature	230° C	17	Ambient temperature	30° C
3	Mould temperature	50° C	18	X-dir clamping force	10.2239 Tonne
4	Ejection temperature	90° C	19	Y-dir clamping force	13.2053 Tonne
5	Transition temperature	100° C	20	Z-dir clamping force	16.4450 Tonne
6	Filling time	1.7 sec	21	Required injection pressure	52.8989 MPa
7	Main material melt temperature	230° C	22	Max. real temperature	236.8954° C
8	Mold wall temperature	50° C	23	Max. bulk temperature	236.9998° C
9	Injection pressure limit	100 MPa	24	Max. shear stress	2.1743 MPa
10	Flow rate limit	194 cc/s	25	Max. shear rate	4783.9760 1/sec
11	Pressure holding time	3.8 sec	26	CPU time	19058.05 sec
12	Total time in pack stage	16.98 sec	27	Cycle time	27.64 sec
13	Cavity initial air pressure	0.101 MPa	28	Filling time	1.82 sec
14	Cavity initial air temperature	30° C	29	Cooling time	20.82 sec
15	Temperature criteria for short shots	100° C	30	Mould open time	5.00 sec

5. CONCLUSION:

Component is manufactured using cold runner system. Analysis of the component is done with Mould flow software. It is observed that initially viscosity is constant and decreases as shear rate increases. Specific heat, thermal conductivity, Young's modulus, Poisson's ratio are constant through the process. Flow front temperature is distributed in the range of 230°C to 185°C with respect to distance from gate location. Variation in freezing time is seen in the range of 1 to 2 sec approximately. Cooling time is near about 2.5 sec and is constant through the process. Sink marks and weld lines are observed because of changes in temperature distribution. Air traps are also likely to be appear in some of the region of component. Based on the results of analysis, if simulation of hot runner system will be carried out and the comparison of both will give better solution regarding scrap and process optimization of moulding process. Hot runner system can be more compatible as that of cold runner system which need to be studied in future.

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