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Design And Plastic Flow Analysis Of a 16-Cavity Injection Mold For a 2-Pole Automobile Wiring Harness Connector

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Abstract- The mold design for automobile wiring harness connectors plays a important role in maintaining the quality of the automotive electronic system. This project aims at a design approach with injection molding machine selection and mold flow analysis for a newly developed 16-cavity mold for a 2-pole automobile wiring harness connector. The designed mold is validated with the Solidworks plastic simulation software to verify the flow parameters such as fill time, ease of fill, cooling channel efficiency and possible defects that might occur such as warpage and shrinking. The calculated data and the analysis results are compared. The project helps in understanding the input parameters that needs to be considered during a mold design and steps to validate the same.
Keywords: Plastic injection molding, mold flow analysis, mold design

1 1. Introduction:

Injection molding is a very crucial manufacturing technique which can be used to manufacture plastic components with complex shapes and size. The project is to design a 16-cavity injection mould to manufacture a 2-pole automobile connector component to increase production capacity from the existing 8 cavity tool. The importance of this project undertaken is to design a 16-cavity mould and to perform a simulation run on the design to validate the design. The project helps to develop a process window for the injection moulding of the component that ensures production of high-quality parts and reduced manufacturing costs, and minimized waste and provide recommendations for the design that meet the industry demand. The paper details about a 16-cavity component which is produced with PA66 material since it is a wiring harness component it is supposed to have good thermal insulation, resistance to conductivity and water resistance properties. Initially the approach for reducing production time by focusing on reduced cycle time was understood by [1]. The warpage performance of plastics and it's structural integrity of in a part was studied by [2].The approach of modern cooling system using conformal cooling technique was understood by[3] however that technique will cost more in manufacturing of mould and it's not a value for mass production. The investigation of the effect of processing temperature on incomplete filling, tensile properties failure, part mass loss of plastic was studied from [4]. The design approach and calculation for the mould was referred from [7],[8],[5]. The objectives of this project are to optimize the injection moulding process parameters for the given component by applying statistical and simulation techniques. To investigate the process variables like injection pressure, packing force and cooling time on the part's quality, warpage, and cycle time. To develop a process window for the injection moulding of the component that ensures high-quality parts, reduced manufacturing costs, and minimized waste. To provide recommendations for the design of mould tool for production of high-quality automobile plastic components for wiring harness.

2 2. Experimental study:

2.1 Methodology:

The general procedures followed for the design approach is mentioned as follows:

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- Identifying and understanding the requirement.
- Project procedure plan.
- Design calculation and CAD modeling of the mold.
- Flow simulation and analysis.
- Validation of results.

2.2 Component details:

The component was designed with the help of Creo parametric (6.0). The components overall dimensions are 30mm x 9mm x 13.4mm. The component is scaled with the appropriate shrinkage value before designing the mold and for analysis of the plastic behavior.

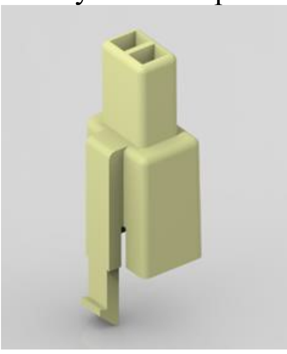

Figure 2.1 2-pole connector

Parameter	Details
Material	PA66
Density	1144 Kg/m^3
Shrinkage	1.6%
No of cavities required	16
Volume	$2.0x10^{-6}$ m^3
Wall Thickness	$1x10^{-3}$ m

Table 1 component details

2.3 Mold Design parameters:

- **Component weight**

Wc = 2.28* 10^{-3} kg

- **Shot weight**

Wn = (Wc +30% of Wc)*N..(Eq-1)

As a thumb rule the runner and gates weight is considered as 30% of the component weight.

Wn = (2.28 +(0.3*2.28)) *16

Wn= 47.4x10^{-3} kg

- **Clamping force [8]**

Cf= (area*pressure)…….(Eq-2)

Area = Area of material to be filled

Pressure = injection pressure of material

Clamping force = **19.5 Tonnes**

- **Amount of heat to be removed from the mould: [8]**

Qh =M x (Cp X (T1 – T2) + L)…(Eq-3)

Qh = **225961.596 J/Kg**

- **Coolant flow rate: [8]**

Qh = k*S*M*(Tout – Tin)..(Eq-4)

Qh = 120x10^{-3} m^3/s

Approximately taking it as **150x10^{-3} m^3/s**

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Runner size:

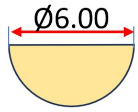
The runner length for PA66 material is kept within 150mm from the sprue centre to gates provided as a thumb rule. The design as approached for this particular tool has a runner length within 60mm. The Runner dia **[8]** is calculated with a equation

□ □

(□)= (√□n□ □$^{1/4}$)/3.7…………(Eq-5)

(d) = **5.31mm**

Round off value = **6mm**



- **Gating [8]**

The gating selected here is **submerged gating** since it is a requirement to have automatic breaking of the gates during the ejection cycle.

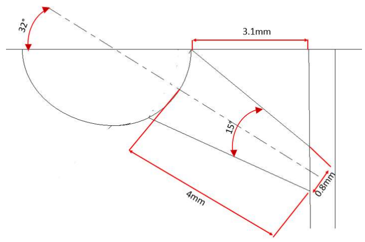


Figure 2.2 submerged gate dimensions

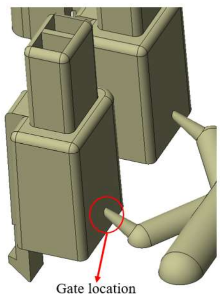


Figure 2.3 gate positioning on component

- **Layout**: **[8]**

Since it is a 16-cavity mould, the **'+' layout** is chosen mainly for space management and material saving as shown in figure xx. It also reduces the material wastage in runner and gating system. The gating is setup in a way that all cavity is at equidistance from the sprue centre and receive material equally and at the same time. This is achieved with the help of runner balancing done with the help of 'X'-shaped distributors at the gating regions.

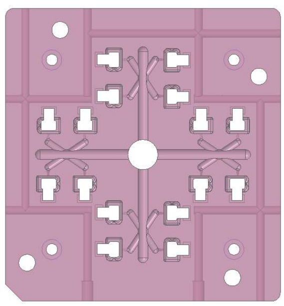


Figure 2.4 cavity Layout

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- **Machine selection data [6]:**

The machine is selected based on the calculation and also by the machine catalogue.

Description	Specification
Screw Diameter	28mm
Screw Stroke	100mm
Injection Capacity	56g
Injection Force	2190 kgf/cc
Holding Pressure	1980 kgf/cc
Heater Wattage	5.5 kW
Clamping Force	51.0 tonnes
Daylight	740 mm max
Opening stroke	270 mm
Mold Height	150mm min – 470mm max
Tie Bar distance	360 x 360mm
Platen Size	500x500mm
Ejector Stroke	70mm
Ejector Force	20 kN

Table 2 machine spec

The table xx shows the machine specifications that will be considered for the tool design.

- **Mould construction [7]**

The mould was designed using the GTTC mould standard. With a standard ejection plate system. Since the component has flat parting surface with small wall thickness it is suggested to have a plate ejection.

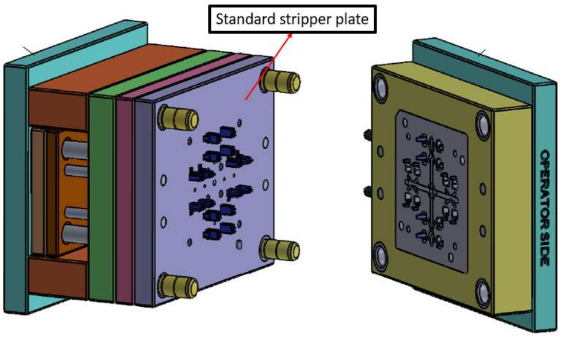

Figure 2.5 stripper plate mould

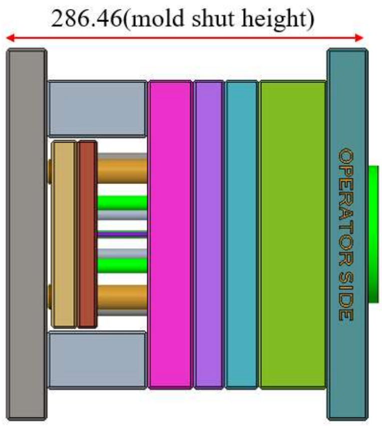

Figure 2.6 mould closed condition

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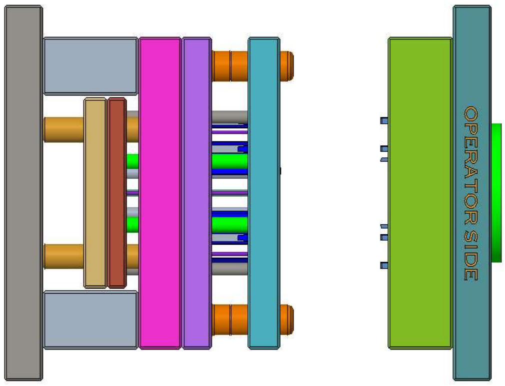

Figure 2.7 mould open condition

3 3. Flow analysis:

The mould is verified for checking various parameters such as ease of fill, fill time, cooling efficiency solidification rates, warpage, packing results etc. The software used was SOLIDWORKS as it has a built-in plastic simulation option. The parameters and inputs are adjusted as per the calculation data and used for the analysis.

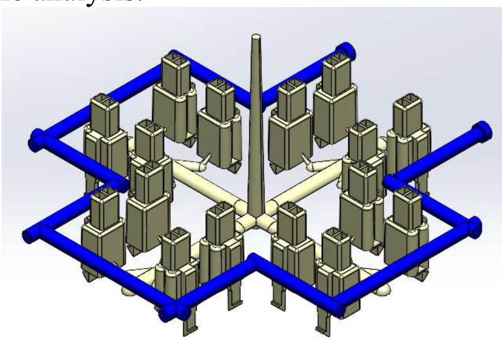
Figure 3.1 plastic shot along with cooling channel

Parameter	Value taken
Material	PA66
Mold Material	H11
Coolant Material	Water
Melt Temperature	280°C
Mold Wall Temperature	70°C
Coolant Temperature	25°C
Coolant Flow Rate	150cc
Injection Pressure Limit	100 MPa
Clamping force Limit	50 Tonnes
Simulation Type	Cool + Fill + Pack + Warp
Mesh type	Tetrahedral Hybrid
Mesh Size	0.3mm

Table 3 input parameters for analysis

3.1 Analysis steps:

- The shot is imported into the software as a step file and is checked for errors and trimmed down to only the needed bodies for the analysis.
- The study considered will be solid type with single injection material.

- The type of simulation is selected and the list of input parameters is fed manually

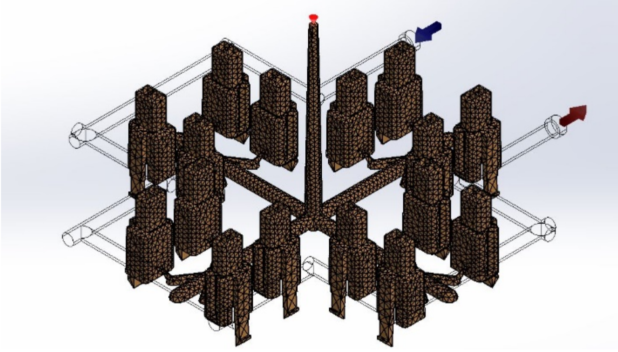

Figure 3.2 meshed model of the shot

3.2 Analysis results

Fill results:
Minimum value = 0.000140 sec
Maximum Value = 1.436087 sec

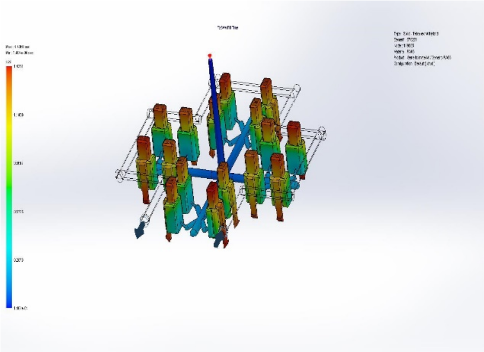

Figure 3.3 fill time gradient

3.2.1 Ease of fill:

The ease of fill data validates the runner and gate provided, making sure that there is no shot fil or fill blockage at any regions in the cavity. As shown in figure 9

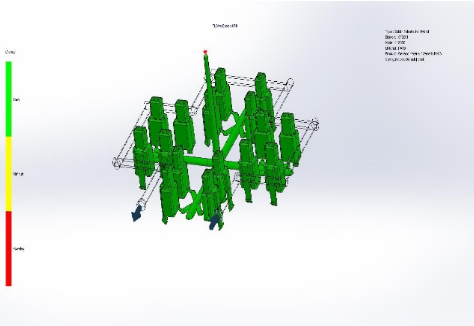

Figure 3.4 ease of fill

3.2.2 Pack results:

Clamping Force	22.3529 Ton
Max. real temperature	235.4829 °C
Max. bulk temperature	279.9130 °C
Max. shear stress	4.9646 Mpa
Max. shear rate	16.3990 1/sec
Max. residual stress	194.7522 Mpa
Mass at the end of packing	42.09 (g)

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Table 4 packing results data

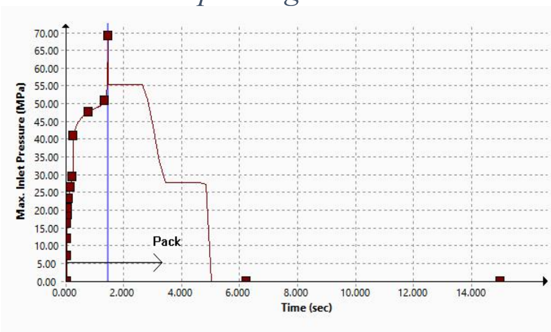

Figure 3.5 X-Y plot of Injection Pressure vs Time

The maximum inlet pressure is 69.12 MPa just before the packing phase begin. The packing force is applied for a approximate period of 4.5sec as shown in the above plot.

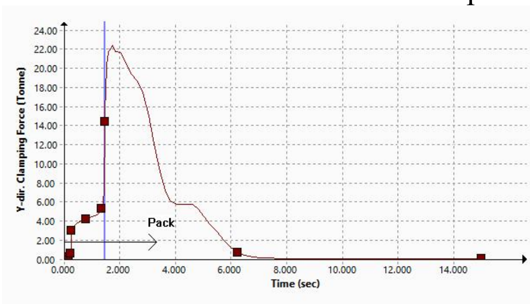

Figure 3.6 clamping force vs time

Clamping force that is required for the complete fill of the material effectively from the above graph is **22.35 Tons**.

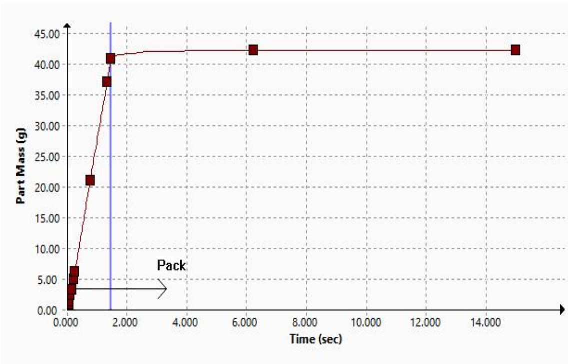

Figure 3.7 part mass vs time

The above graph shows the part mass vs time results which tells us about the amount of material filled inside the cavity with respect to time. The results tells that around 42.8g of material is filled in around 1.7sec.

3.2.3 **Warpage results:**

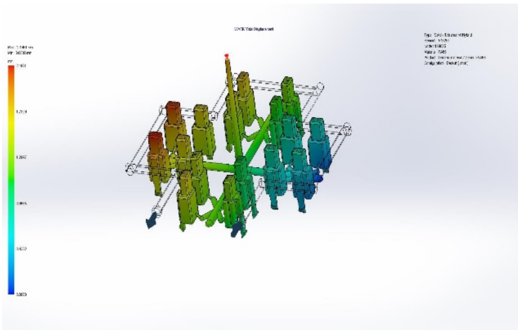

Figure 3.8 total warpage displacement

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The figure(3.80) represents the displacement of the plastic material inside the cavity due to the gravitational pull of the earth is called warpage and this defect can be overcome by setting the right amount of packing pressure and maintaining the inlet pressure of the plastic melt.

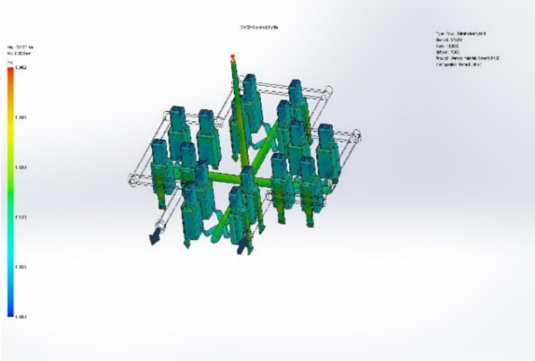

Figure 3.9 shrink mark profile

The shrink mark profile as shown in figure (3.9) tells us about the shrinkage that occurs on the plastic surfaces, the above results shows that there is very minimal shrinkage on the component region and there is high shrinkage on the runner system due to its larger surface area.

3.2.4 **Cooling results:**

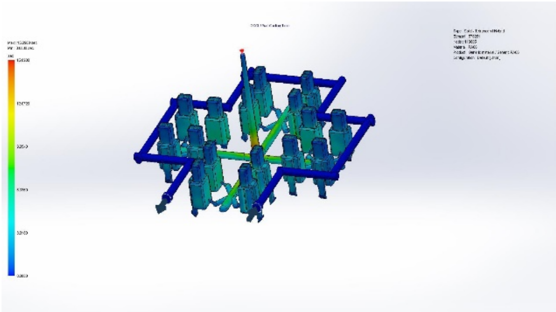

Figure 3.10 cooling time gradient

The cooling gradient image as shown in figure (3.10) represents that the part is cooled effectively within 3-6 seconds and is ready to eject out of the mould. The maximum amount of time is taken by the runner system because it further away from cooling channel. These results verify that the cooling channel provided in the mould is effective enough to cool down the part and also to keep the mould temperature at optimum levels.

4 4. Results discussion:

The results obtained from the analysis is carefully studied and compared with the manual calculations done.

Description	calculations	analysis results
Shot weight	$47.4* \quad 10^{-3}$ Kg	$42.8* \quad 10^{-3}$ Kg
Clamping force	19.5 Tonnes	22.5 Tonnes
Fill time	2.4sec	1.43sec

Table 5 result comparison

- The locking force required is slightly more than that obtained from the manual calculations.
- The filling time is reduced keeping it within 2.4seconds.
- The chosen machine does support the required injection pressure.
- The cooling system designed is adequate enough to keep the mould temperatures in check and also to effectively cool the components in all the 16 cavities and could be controlled better by regulating the water inlet temperature.

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- The packing time is around 4.5seconds for the given number of cavities to effectively pack and avoid defects such as warpage.

5 5. Conclusion:

The 2-pole wiring harness connector component that needed a new injection mold was thoroughly studied for its manufacturing requirement. Initially the component was modeled in a computer aided design software and made sure it met all the functional requirements. The mould design calculations were done and an appropriate injection moulding machine was selected according to the calculated results and model data. Mould flow analysis was performed on the newly designed 16-cavity mould to validate the design with the help of Solidworks plastic simulation. From the mould flow simulation performed, it is observed that the mould tool successfully gets filled within the calculated filling time and gets spread out evenly. The cooling channels provided is also valid as it maintains desired temperatures and cools the component as per requirement. The packing time and pressure is also within the desired range. The tool design was finally validated with the help of the simulation results, and it is safe for it to be sent for production.

6 6. Future scope of the project:

- Increasing the number of cavities for higher production rate.
- Implementing hot runner system to reduce wastage of material.
- Modifying the mold design for more cost-effective manufacturing and
- verifying the pros and cons of the same.

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