

# OPTIMUM DESIGN PARAMETERS FOR EFFECTIVE MOLDABILITY OF GAS SENSOR

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**Abstract - In the injection molding it is important to find out the optimum design parameters for gate location, moldability, sink marks, air traps and weld lines are measure in the mould flow simulation. The design involved two-plate injection mould with edge gating system and pin ejection system is used. Creo mould flow analysis was used to define the optimal gate location, moldability, injection pressure and defects like air traps, weld lines and sink marks, in this paper Analysing the two outcomes with a relative paper, the mould flow investigations for best gate location and moldability is been analyzed, defects like sink marks, air traps, and weld line were analyzed in the mould flow. The defects are reduced by altering the processing parameters like mould temperature, melt temperature, injection pressure and fill time. After analyzing we conclude that trail two is the ideal outline.**

**Index Terms -injection molding, gas sensor, PBT material, mold analysis like gate location, fill time, sink marks, air traps, and weld lines.**

## I. INTRODUCTION

### Injection moulding

Recent plastic industries are subjected to tremendous pressure, because of the globalization of business sector, diminished life process duration for the part advancement, expanding segment extend, related with awesome order for the nature of the segment. There is a quick necessity for improving the procedure of the injection moulding with specific end goal to expand efficiency and decrease the process duration in the injection moulding. Keeping in mind the end goal to accomplish the preparing parameters, they ordinarily take after on understanding, hit and trial technique, because of which procedures isn't common sense for complex models. It is essential to embrace different propelled advances, for example data and web innovation, also CAE/CAD/CAM, concurrent engineering and so on, to successfully support the change of injection moulded product [1-2]

### Gas Sensor

Gas sensor is a comprehension of metal and plastic component, manufacturing by using injection molding process. So as to meet the steadily increasing emission regulations, which boundary the tailpipe emission of carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and hydrocarbon (HC), The necessity for a reliable "On-Board Diagnosis" (OBD) of the exhaust gas aftertreatment system applies an additional sensor downstream catalyst to monitor its functionality. However, in future cars with lowermost emissions such as indirect method might not be accurate enough to decide whether the exhaust gas aftertreatment system meets the emission requirements. Therefore, a direct measurement method using a sensor that detects the number of unburnt hydrocarbons is desirable. Such a hydrocarbon sensor can also be used for On-Board Diagnosis of close-coupled oxidation catalysts in diesel engines, also used in industry to monitor manufacturing process and energizing technologies such as Photovoltaic, Firefighting, [3]

### PBT Material

The Plastic material used in the gas sensor is PBT (Poly Butylene Terephthalate)

PBT (Poly Butylene Terephthalate) is a synthetic semi-crystalline engineered thermoplastic with similar properties and composition to polyethylene terephthalate (PET).it is part of the polyester group of resins and shares similar characteristics to other thermoplastics polyesters. Additionally, it is a high-performance material with high molecular weight and is often characterized as being a strong, stiff, and engineerable plastic. Color variations of PBT range from White to bright colors

**Table 1** properties of PBT material for gas sensor

Property	Value
Density	1.3x10 <sup>3</sup> kg/m <sup>3</sup>
hardness	1.67x10 <sup>8</sup> -1.77x10 <sup>8</sup> pa
Melting temperature	220-267 °C

Mold temperature	40-60 °C
Specific heat capacity	1.42x10 <sup>3</sup> -1.48x10 <sup>3</sup> J/kg °C
Shrinkage	0.2-0.8 %
Pressure	Up to 150MPa

**II. PROBLEM STATEMENT**

Mould is an exclusive device which is used for processing plastics. Mould design should be accurate, precise and effective in dimensions to reduce the cost and possible defect that can arise on the moulded product. Based on considering the following requirements;

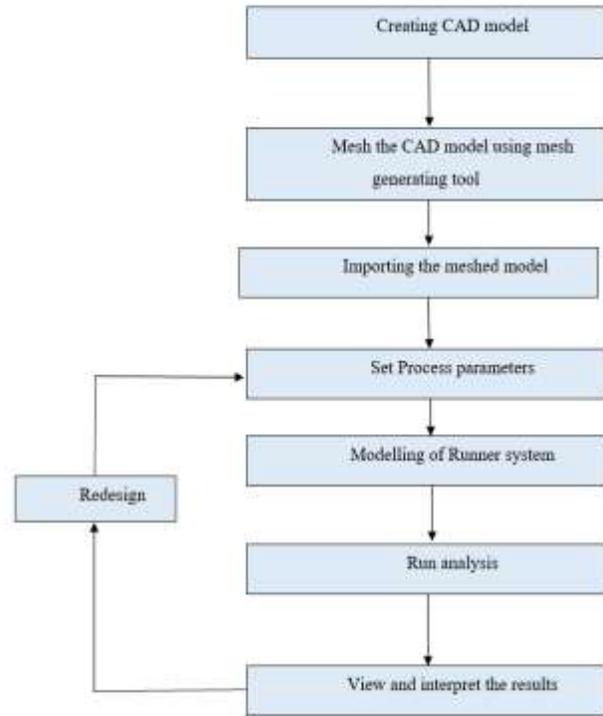
- Improper gate location results into product short fill, weld line defects
- The top surface of the part should be fine finished textured surface without any shining marks, rubbing marks and gate mark.

In this paper these problems remained overcome by using mould flow analysis which helps engineers to easily change or determine the optimum gate size, gate location, and mould strength. This also results in reduced time and cost of production.

**III. MOULD FLOW ANALYSIS FOR GAS SENSOR**

Simulation of injection molding is potentially, the best model of recreation for any injection molding procedure. The cost related with assembling an injection molding and the probability that an issue followed underway will bring about exorbitant retooling and timeless, makes molding virtual reality of high incentive to industry. This might be outstanding with other injection molding procedure, where tooling cost are much lower or issue might be overpowered by changing procedure conditions. In addition, the conjecture of shrinkage and warpage is liable to logically higher norms of precision. The relationship between process factor and article quality is amazing. It is fascinating to commentary that CAE has been significantly more fruitful in injection moulding that in different ranges of polymer preparing and material parameters as shown in the table 1.

**a) Steps followed in injection mould flow analysis**



**Figure 1.** Methodology of mould flow for gas sensor

Critical factors affecting the component quality such as gate location, shrinkage, fill time, pressure, weld lines and air traps are measured in the mould flow simulation. Mould flow programming implies a group of complete definite tools used in breaking down, improving, and favouring plastics part and mould design. The scientific approach utilized will used both time and money to dispose of vagueness and to guarantee the outline can be performed effectively.

**b) Defining of process parameters for the mould flow analysis**

the application of boundary condition is very necessary so that the Plastic flow analysis will be carried forward in the same direction as the input fed in the boundary conditions, in this analysis two trial is been conducted by varying the parameters to overcome the defects.

**Table 2.** Trial 1 parameters

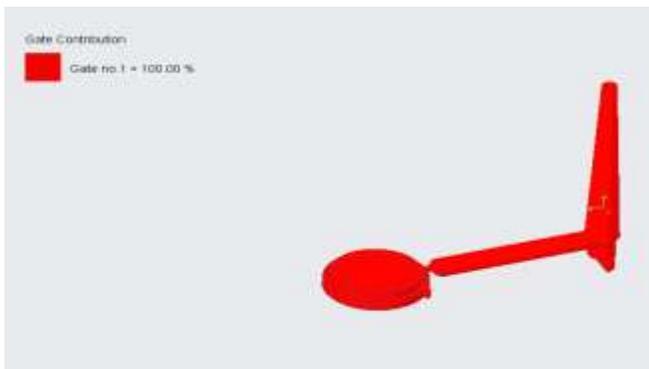
Fill time	1 second
Melt Temperature	255 °C
Mould Temperature	60 °C
Injection pressure	45 MPa

**Table 3.** Trial 2 parameters

Fill time	2 second
Melt Temperature	245 °C
Mould Temperature	50 °C
Injection pressure	55 MPa

**1) Best gate location analysis**

At first, the material conditions like PBT type, material trade name were selected and it was essential to identify the polymer injection per gate location to the cavity surface. The gate location result, rates every place on the model for its correctness for an injection location. Result showed in Figure 2, recommends the best place to enhance an injection location for Gas sensor part.[4]

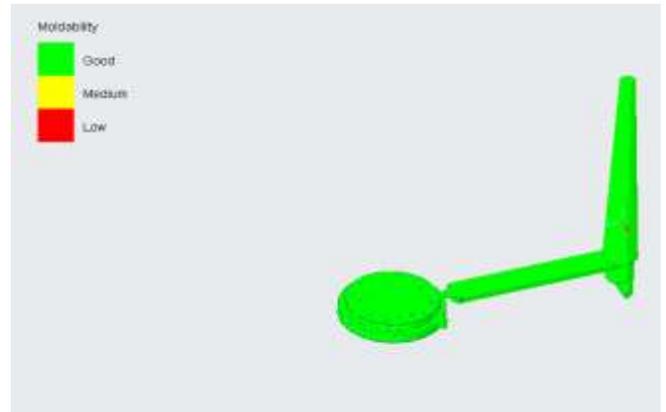


**Figure 2.** gate location

This result shows the contribution of gate. The region in the red color represents that it was filled by the plastic from the gate. The percentage of red color indicates its percentage of volume compared with the cavity. This result help determine whether the model was filled by balanced flow pattern.

**2) Moldability**

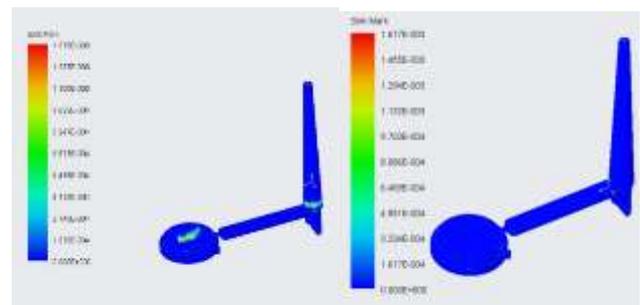
Mouldability is the parameter by which we can define the part is moldable or not with the injection mounding machine by which we can judge that the part filling of the component through all its part such as the runner, gate and the main part as shown in Figure 3. Through the plastic flow analysis, we can conclude that the part is completely moldable without any defects as its been highlighted in green.



**Figure 3.** moldability of gas sensor

**3) Sink marks**

Sink mark is defined as a depression on the surface of the part, similar to a dimple or a groove affected by extreme localized shrinkage of the polymer material once the part has cooled. They are formed by inconsistency in volumetric shrinkage. They characteristically occur on the opposite sides of surfaces to which bosses or ribs are involved and also in significantly thicker zones of parts. These sink marks can be eliminated by modifying the part thickness, expanding the size of the runners to increase the gate freeze off time, reducing mold temperature, increasing holding pressure. Figure 4, illustrates the sink mark analysis of the component, with red colour indicating the region prone to higher sink marks. As discussed, it can be observed that more sink mark is more at the undercut profile due to uneven wall thickness of the part. To reduce the sink mark defect as well as easy release of the undercut profile of the part, an Angular lifter with additional shrinkage allowances was adopted afterwards.[5]



**Figure 4.** sink marks analysis for gas sensor

**4) Air traps**

Air trapped inside the cavity of the mould leads to mould defects, thus the trapped air is released through vents. Figure 4.6 illustrates the air- trap analysis for the Gas sensor part.

They are usually located in regions that fill at last and occurs when there are unbalanced flow paths and insufficient venting. To eliminate air traps, one can modify the filling pattern by means of reducing the injection speed and enlarging venting, or insertion of proper venting in the cavity.

that it is solidify and been ejected. The sprue part is at a higher temperature cooling and as we are not concentrating on that and we require that not to cool as it should be in melt form during ejection. [7].

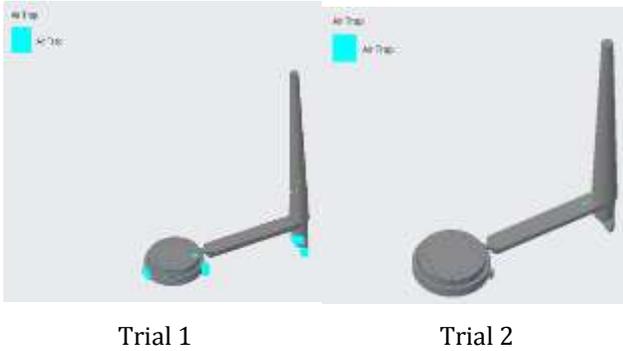


Figure 5. Air traps analysis for gas sensor

5) Weld lines

Weld line refers to the line where two melt flow fronts meet when there is the incapability of two flow fronts to "weld" during moulding process. These lines are formed around holes or obstructions and cause locally weak areas in the moulded part. Figure 6. Shows the presence and location of weld lines in the complete filled part model which we can see that the weld lines which are form are acceptable. Weld lines are considered as defects in moulding and arise when the material or/and mould temperatures are set too low. Weld line defect can be resolved by increasing the melt and mould temperature and by optimizing the runner structure design.[6].

7) Clamping force

Clamp force is the resultant value of the pressure distribution over the entire part. It holds both the mould halves together against the cavity pressure during the injection stage. Clamping force is a function of injection pressure and the projected area of the part. The projected area of the cavity is the summation of area of all the surfaces projected perpendicularly on the parting plane of mould. Figure 8 shows the graph clamping force vs fill time. The minimum clamping force required for part was approximately 2 tonnes.



Figure 6. Weld line analysis for gas sensor

6) Cooling time

The cooling time is been calculated to determine the injection cycle by determining the cooling cycle time. In the Figure 4.8 we can see the temperature distribution on the part by which we can determine the cooling of the part by which we can derive the cycle time, by the analysis we can come to a conclusion that 8 seconds is enough to totally cool the part so

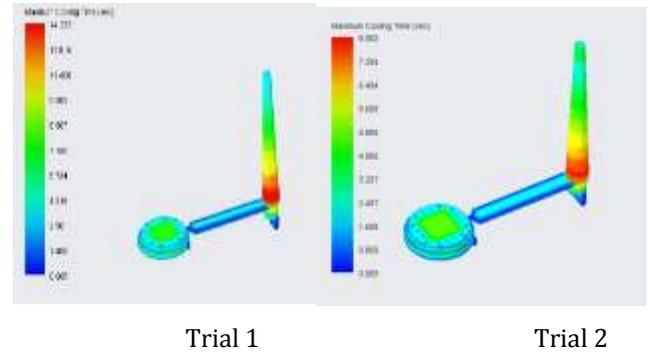


Figure 7. Cooling time calculations

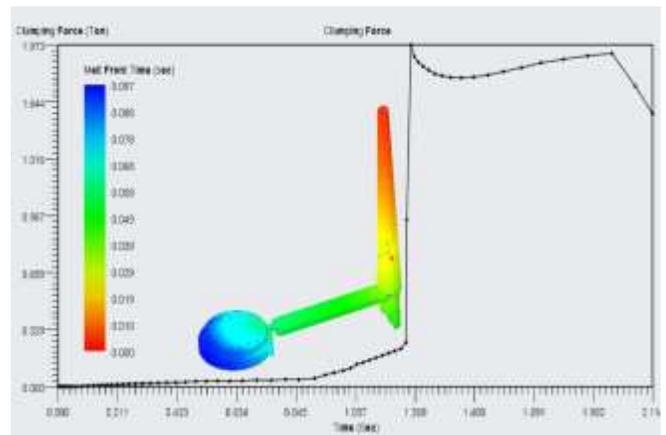


Figure 8 clamping force analysis

Clamping force calculation

By using the following formula, we can calculate the clamping force

**Cf= (projected area of the moulding including runner) x (0.5 to 0.33 of injection pressure) x number of cavities**

Where number of cavities =1

Total projected area of the component = 1.81 cm<sup>2</sup>  
(from CAD model)

Projected area of runner depends on the size of the component as it taken as 50% of projected area of moulding = 0.5 x 1.81  
=0.90 cm<sup>2</sup>

**Total Projected area** =1.81+0.90  
=2.71 cm<sup>2</sup>

Injection pressure for the material

0.5 x 1600 =800 kg/cm<sup>2</sup>

0.33 x 1600 =533.3 kg/cm<sup>2</sup>

Average area = 666 kg/cm<sup>2</sup>

Clamping force (C<sub>f</sub>) =2.71 x 666 x 1  
=1804.86 kg ≈ **2 ton**

By calculating the clamping force, we can see that both calculated and analyzed results will be 2 ton.

#### IV. COMPARISON OF RESULTS

Analysing the two outcomes with a relative report, the mould flow investigations for best gate location and moldability to be analyzed, defects like sink marks, air traps, and weld line were limited in the mould flow. Gate is located in the best area for defect less part, air traps can be limited by giving air vents in the core and cavity inserts, weld lines can be controlled by observing injection pressure, nozzle speed and maintaining the mould temperature. Sink marks can be controlled by decreasing the mould temperature and holding pressure. Cooling time is reduced by decreasing the mould temperature. Trial B is considered as ideal outline.

Table 4. Mould flow Analysis results

Sl.no	Analysis results	TRIAL A	TRIAL B
1	Sink marks	More	No sink marks
2	Air traps	More	No air traps
3	Weld lines	More	Acceptable
4	Cooling time	14.23 seconds	8 seconds

Table 5. Optimized parameters for sink marks

Analysis result	Parameters	TrialA	TrialB
Sink marks	Mould temperature	60° C	50° C
	Injection pressure	45 MPa	55 MPa

Table 6. Optimized parameters for weld lines

Analysis result	Parameters	TrialA	TrialB
Weld lines	Mould temperature	60° C	50° C
	Injection pressure	45 MPa	55 MPa
	Fill time	1 s	2 s

Table 7. Optimized parameters for cooling time

Analysis result	Parameters	TrialA	TrialB
Weld lines	Mould temperature	60° C	50° C
	Injection pressure	45 MPa	55 MPa

#### V. CONCLUSIONS

In this paper the Mould flow analysis is done through Creo mould flow revealed that the best processing conditions trial 1 were: Fill time: 2 s, mould temperature: 50, melt temperature: 245 and Injection pressure: 55 MPa, by taking these results as a ideal input for injection moulding machine we can achieve part with high accuracy.

In the first trial the cooling time is 14 seconds by decreasing the mould and melt temperature the cooling time is 8 seconds and hence, moulding cycle time is automatically decreased. And the selected area of the part for gate location is best and the moldability for these parameters is high.

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