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# Optimization of Fill Time in Multi Cavity Plastic Injection Molding Through Simulation

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***Abstract*— Injection molding is a complex process regulated by many factors (injection speed, injection pressure, melt temperature, mold temperature, and others). Despite, process control and parameter optimization, it is often difficult to replicate thermoplastic components with adequate dimensional accuracy, especially in the case of geometries with high aspect ratios. For these reason, there is a need for study of fill time on other parameters . In this paper simulate the fill the effect with the help of the simulation work and with DOE approach. Data analysis evidenced the greater quality of work pieces obtained by mould flow adviser.**

***Index Terms*— Injection molding, DOE approach, Mould Flow**

## I. INTRODUCTION

This type of molding stages is initiated for getting of food to polymer type to tray keeping material to gun pipe followed by heating with enough temperature for making it moving liquid , then the made liquid by heat soft, readily bent which was gone slowly will be kept within high pressure vessel for forming whole process within one's knowledge as in original name, after this process i.e. injection molding is sent in name for both platens moving and fixed in injection molding machine in order to place in ship for goods the vessel for forming person used by another together after output as result product put to somewhat cold that helps in the solidification process. Polymers play an important role in injection molding. Types of polymers: Thermoplastic, thermosets and elastomers. Further types of Thermoplastic: crystalline and amorphous .Polymers are the combination of numbers of small organic repeating monomer shaving high resistivity to chemicals. Thermoplastic materials generally soften Due its weak inter molecules force when they are come contact to heat and return to their previous condition when cooled polymer process of forming polymer. Due recyclable property it is used in a wide range of applications such as insulation, Food packaging, credit cards holder and automobile bumpers.

## II. LITERATURE REVIEW

**Shunliang Jiang *et al.* [15]** told injection molding is one of the most widely used manufacturing processes for producing thin soft, readily bent parts. It is chiefly of vessel for forming, packing, and making somewhat cold stages.

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The air entrapments and weld-lines occurred in the vessel for forming stage has one influence on the quality of thermal product. Material used is molten polymer, which is used for thin plastic products. Main problems occur in filling is resin transfer molding (RTM) and vacuum assist resin transfer mold (VARTM). Analysis and case studies conclude that computing time and complexity solving temperature were less. Material used is molten polymer.

**According to J.G. Kovacs and B. Siklo [12]** in warpage developing many parameters influence at the corners of injection molded plastic parts. Main cause of this deformation is the asymmetrical cooling of the injection mold. This study presents an injection molding analysis of the heat flow developing in injection molds. The analysis shows that significant temperature difference appeared between the two sides of the mold after the hot polymer melt had filled the cavity. It was highlighted that the unevenness of the cooling should be considered during the mold design in order to avoid the warpage of the parts.

**T.Barriere, *et al.* [13]** says the MIM (metal injection moulding) process is combination of powder metallurgy technology and IM (Injection molding) to produce small and integrating parts to get exact same as per requirement. 3D software is used for efficient injection in cavity. Bi-phasic model is used to describe the flows of the metallic powder and plastic blinder so that can predict the accurately the powder segregation in injection. Powder segregation ins main problem. Software permits to optimize the mould design and processing parameters to get required components

In this study consist of the effects of injection parameters and weld line on the mechanical properties of polypropylene (PP) moldings were studied. To produce weld line at PP specimens, the obstacles having edge angle of 0°, 15° and 45° were designed. These obstacles were located at the center of the mold. The effects of both obstacles angles and the injection molding parameters such as melt temperature and packing pressure on the mechanical strength were investigated. Mechanical properties such as tensile strength and Izod impact strength (Notched) of the specimens were measured by test methods. The effect of molecular orientation on the mechanical properties of the specimens was discussed by Finite Element Analysis. Weld line tensile strength of injection molded specimens having obstacle edge angle (OEA) of 15° was obtained higher than the other obstacle edge angles. The cavity of the mold was manufactured in the CNC machine. A test part was injected by a plastic injection machine. Which had a clamping force of 490 kN and an Injection pressure of 275 MPa**Ching-Piao Chen *et al.* [5]** deals with the application of computer-aided engineering integrating with statistical technique to reduce warpage variation depended on injection molding process.

For this purpose, a number of Mold-Flow analyses are carried out by utilizing the combination of process. In the meantime; apply the design of experiments (DOE) approach to determine an optimal parameter setting.

In this regression models that link the controlled parameters and the targeted outputs are developed, and the identified models can be utilized to predict the war page at various injection molding conditions. The melt temperature and the packing pressure are found to be the most significant factors in both the simulation and the practical for an injection molding process of thin-shell plastic objects.

## III. Problem Identification

In this study the problem focused to improve productivity of thick plastic products and this is done by applying CAE methods in plastic injection molding process. Five controlling factors named mold temperature, melt temperature, injection pressure, packing pressure and runner diameter were used with three levels. For design of experiment Taguchi tables were used which are discussed in detail in the next chapter. In the analysis of the product main responses from all experiments were volumetric shrinkage and fill time. The design set up of the product consisting of sprue, gate, cooling channels and runner used in this study is shown in figure 1 and 2.

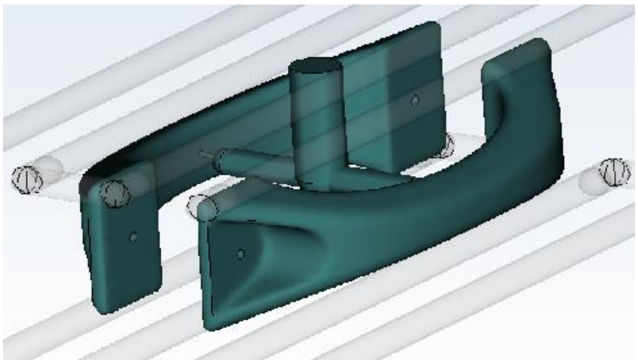


**Fig 1 design set up of the product**

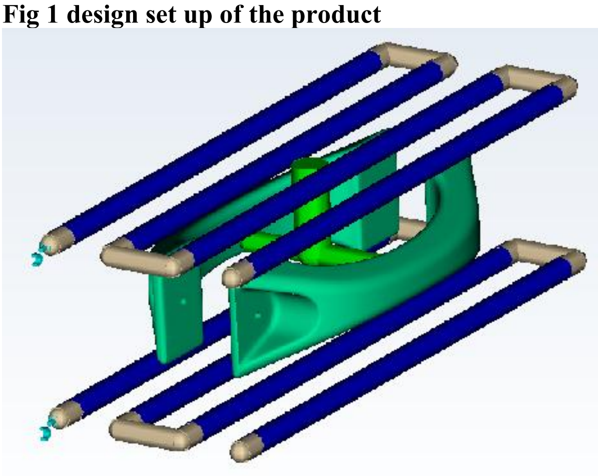


**Fig. 2 design consisting of sprue, gate, cooling channels and runner**

## IV. Design of Experiment

In Plastic injection molding process quality of the product is always affected by its process parameters like injection pressure, injection speed, mold temperature, melt temperature, packing pressure, packing time, cooling time and many more. During the last decade the effects of these parameters were studied by various researchers. For such kind of studies DOE (Design of Experiment) is a scientific technique which is being generally used by researchers now days. By using DOE the important factors which affect the output results are identified. For a particular experiment DOE finds.

One simple plastic product i.e. car handle with sprue and runner arrangement was used in this study which is shown in figure 4.1 and DOE was applied to find the optimum value of input parameters that affects the output results for plastic injection molding product. It was very difficult to choose proper technique for experiments design as DOE is very vast and complicated subject. From literature review it was revealed that DOE based on Taguchi methods was used by various researchers and for this reason that this technique was also used in this study and the detailed discussion related to this technique is given in the next section.

Research problem plays a vital role in the preparation DOE experiments. Some important steps which were followed by researchers during DOE designing were shown below.

**Define the problem Statement**. Developing a good problem statement plays an important role in the analysis and make sure that researchers are studying the right variables in the right direction. At this step, identify the logical questions and that will be answered rightly.

**Define the objective of study**. A well-defined and planned objective will make sure that the designed experiment answers the right questions and yields practical and useful information. At this step, the goals of the experiment are being defined.

**Develop an experimental plan** that will provide meaningful and worth full information. Much relevant and useful background information, such as theoretical principles and knowledge are gained through literature of previous research papers. The factors or process conditions which affect process performance and contribute to process variability need to be identified by Researchers. Once the process is already established and the factors influencing the process have been identified, you need to determine optimal process conditions.

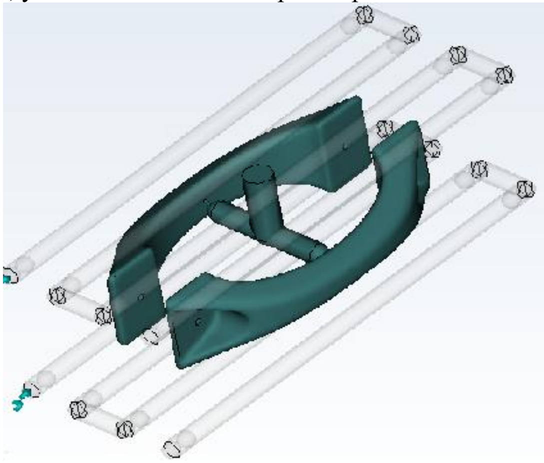


**Fig. 3 Sprue Location for the Car Handle Design**

## V. Factors and Levels

By selection of proper factors and their levels makes the possibility of Design of DOE table. In this study five factors were selected with three levels for each product and were shown in table 1.

**Table 1 Summary Table of Factors and Levels**

| Levels | P1 (Mould Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr. %) | P5 (Runner Dia.) (mm) |
|---|---|---|---|---|---|
| 1 | 70 | 280 | 30 | 20 | 10 |
| 2 | 80 | 290 | 40 | 25 | 12 |
| 3 | 90 | 300 | 50 | 30 | 14 |

## VI. Result and Discussion:

**Taguchi Method**

To determine the effect of fill time in this study the Taguchi method was applied and five process parameters used as input variables. Fill time and volumetric shrinkages simulated values are shown in table 2.

**Table 2 Shrinkage and Fill Time Values**

| No. of Exp. | P1 (Mold Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr) | P5 Runner Type | Fill Time |
|---|---|---|---|---|---|---|
| 1 | 70 | 280 | 30 | 20 | 10 | 1.668 |
| 2 | 70 | 280 | 30 | 20 | 12 | 1.667 |
| 3 | 70 | 280 | 30 | 20 | 14 | 1.502 |
| 4 | 70 | 290 | 40 | 25 | 10 | 1.489 |
| 5 | 70 | 290 | 40 | 25 | 12 | 1.332 |
| 6 | 70 | 290 | 40 | 25 | 14 | 1.333 |
| 7 | 70 | 300 | 50 | 30 | 10 | 1.329 |
| 8 | 70 | 300 | 50 | 30 | 12 | 1.165 |
| 9 | 70 | 300 | 50 | 30 | 14 | 1.167 |
| 10 | 80 | 280 | 40 | 30 | 10 | 1.165 |
| 11 | 80 | 280 | 40 | 30 | 12 | 1.658 |
| 12 | 80 | 280 | 40 | 30 | 14 | 1.658 |
| 13 | 80 | 290 | 50 | 20 | 10 | 1.502 |
| 14 | 80 | 290 | 50 | 20 | 12 | 1.5 |
| 15 | 80 | 290 | 50 | 20 | 14 | 1.337 |
| 16 | 80 | 300 | 30 | 25 | 10 | 1.332 |
| 17 | 80 | 300 | 30 | 25 | 12 | 1.332 |
| 18 | 80 | 300 | 30 | 25 | 14 | 1.167 |
| 19 | 90 | 280 | 50 | 25 | 10 | 1.825 |
| 20 | 90 | 280 | 50 | 25 | 12 | 1.66 |
| 21 | 90 | 280 | 50 | 25 | 14 | 1.66 |
| 22 | 90 | 290 | 30 | 30 | 10 | 1.494 |
| 23 | 90 | 290 | 30 | 30 | 12 | 1.495 |
| 24 | 90 | 290 | 30 | 30 | 14 | 1.495 |
| 25 | 90 | 300 | 40 | 20 | 10 | 1.335 |
| 26 | 90 | 300 | 40 | 20 | 12 | 1.336 |
| 27 | 90 | 300 | 40 | 20 | 14 | 1.337 |

**Regression Equation**

In this study regression equations for responses fill time were developed.

**Regression Equation for Fill Time**

**Fill time = 6.096 -0.00547*A -0.01646*B-0.00004*C-0.000620*D-0.0134*E**

**Fill Time Contours**

The time which requires filling the resin in cavity is called Fill time. Fill time basically depends on properties of material, injection pressure limit and gating system for resins. It was not possible to show here all 27 experiments fill time contours, so only few good and worst combinations of process parameters based results are discussed here.

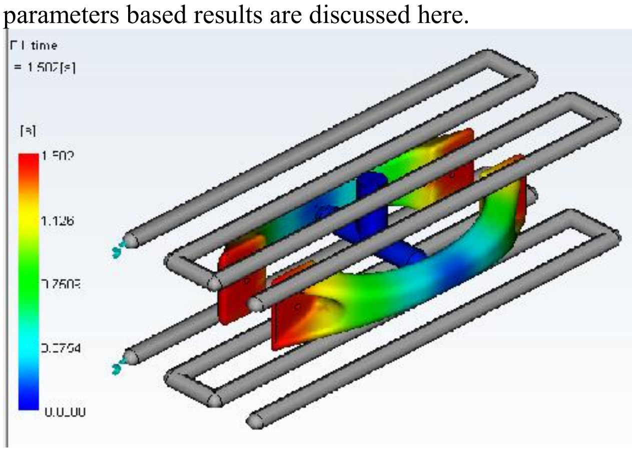


**Fig. 3 Fill Time for Experiment 3**

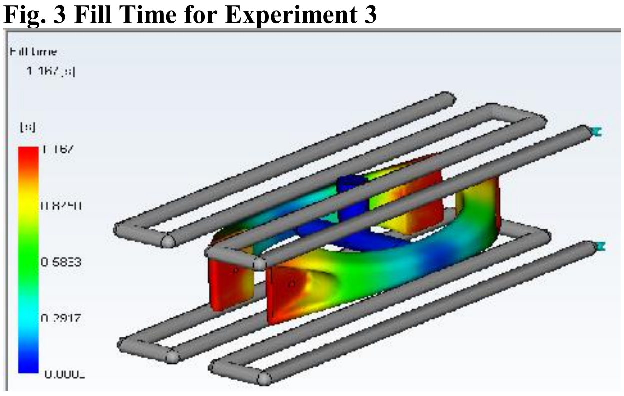


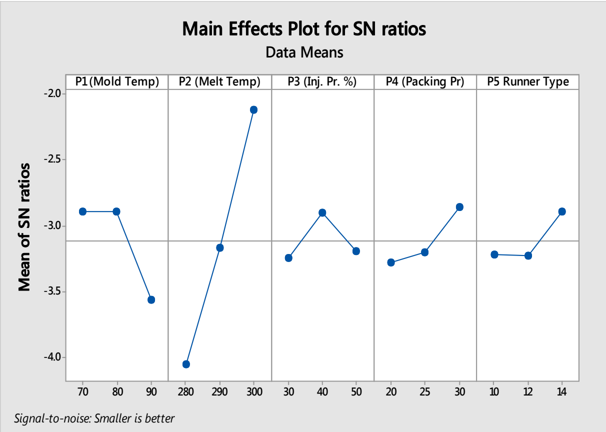
**Fig. 4 Fill Time for Experiment 9**

**Taguchi Analysis: Fill Time versus P1 (Mold Tem, P2 (Melt Tem, P3 (Inj. Pr., ...**

Response Table for Signal to Noise Ratios

Smaller is better

| Level | P1 (Mold Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr) | P5 Runner Type |
|---|---|---|---|---|---|
| 1 | -2.889 | -4.062 | -3.246 | -3.282 | -3.216 |
| 2 | -2.890 | -3.166 | -2.900 | -3.200 | -3.230 |
| 3 | -3.561 | -2.112 | -3.194 | -2.858 | -2.894 |
| Delta | 0.672 | 1.950 | 0.345 | 0.425 | 0.336 |
| Rank | 2 | 1 | 4 | 3 | 5 |




## VII. CONCLUSION

The aim of this study is to optimize the runner system of multi-cavity plastic injection molding process. This study utilizes L27 orthogonal array for data analysis for three different runner diameter but runner location was fixed. In this study Analysis of variance (ANOVA), Signal to Noise ratio and regression analysis was main key techniques to show response and factor relations with each other. Results are summarized as follows:

1. Best parameter combination for design was following.

**Summary of Best Cases for Designs**

| Case | P1 (Mold Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr) | P5 Runner Dia. (mm) |
|---|---|---|---|---|---|
| 1 | 70 | 280 | 40 | 30 | 14 |

2. Response optimization for the fill time as following.

| Solution | P1 (Mold Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr) | P5 Runner Dia. (mm) | Fill time fit |
|---|---|---|---|---|---|---|
| 1 | 70 | 280 | 40 | 30 | 14 | 1.493 |

3. Model equations for fill time was predict accurately with Minitab software and show 95% good prediction for responses and can be used by any plastic injection molding process manufacturer.
4. Signal to noise ratio predict a rank for most responsible factors for fill time was following for both design respectively

**Table 3 The Response Table of S/N Ratio**

| Levels | P1 (Mold Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr) | P5 Runner Dia. (mm) |
|---|---|---|---|---|---|
| 1 | -15.08 | -14.84 | -15.10 | -14.37 | -15.27 |
| 2 | -15.09 | -15.10 | -15.10 | -15.11 | -15.08 |
| 3 | -15.13 | -15.36 | -15.11 | -14.83 | -14.95 |
| rank | 4 | 2 | 5 | 1 | 3 |

## VIII. FUTURE SCOPE

In this design was studied using orthogonal array concept, design modification was based on runner diameter and locations. In this study runner diameter was change but runner location was fixed for all simulation case. For future scope it will be a good approach to study factor change based on geometrical change of runner design, runner location and runner feeding system.

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