International Journal of Engineering Research And Management (IJERM)
ISSN : 2349- 2058, Volume-02, Issue-04, April 2015

# Optimization the Effect of volumetric shrinkage in multi cavity plastic injection molding

**Gurmeet Singh, Sharad Shrivastav**

*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 volumetric shrinkage on other parameters . In this paper author simulate the shrinkage seffect with the help of the simulation work and with DOE approach. Data analysis evidenced the greater quality of workpieces obtained by mould flow adviser.**

## I. INTRODUCTION

Injection molding process is a manufacturing process for producing parts by injecting material into a mould. Injection moulding can be performed with a host materials, including metal, elastomers, most commonly thermoplastic and thermosetting polymers. Material for the part is fed into a heated barrel ,mixed and forced into a mould cavity, where it cools and hardens to the configuration of the cavity.injetion moulding uses a ram or screw type plunger to force molten plastic material into a mould cavity. **Fill Stage** During this step, the mold holes are made full with made liquid by heat resin. As material is put at forced and it passes through putter, in the gun pipe, which causes mixing. This step is strong ofpurpose by injection rate of motion (rate), a pressure, and a time. Injection rate of motion is that rate at which plunger gets forwarded. **Pack Stage** After the melt goes to mold cooling process will occur and then shrinkage is introduce. This step is important to force more melt in the mold to overcome for shrinkage. **Hold Stage** When no extra material is forced to vessel for forming, go slowly away can still place where liquid comes through back through the doorway. The place in ship for goods step puts to use forces against the material in the hollow until the number making payment to see play go solid by cold to put a stop to leaking of the o slowly away. In some machines sea full of broken ice and place in ship for goods are has at need in to within one second property step.

## II. LITERATURE REVIEW

The study of window frame fabrication by injection moulding process was carried out with the aid of Moldflow software. Rice husk filled high-density polyethylene was used as the raw material. The investigations were carried out on flowing, packing, cooling and costing of injection moulded window frame. At the end of the analysis, the most feasible design was selected to be further undergone stress analysis according to BS EN 14608:2004 and BS EN 14609:2004. The window frame with hollow design is preferable, since hollow design has advantage of filling, packing, and cooling properties. The hollow design also costs less than solid design of window frame. However, high injection pressure and clamping tonnage are unfavourable for hollow design.A002 hollow design was selected as the most feasible window frame to be fabricated.The analyseswere carried out to determine racking and static torsion resistance. A002 window frame mechanical strength is classified as Class 2 according to BS EN 13115:2001.The mechanical properties were classified according to BS EN 13115:2001.[1]**M.C. Song, Z. Liu, *et al.*** told that thin-wall injection molding has a lot of obvious advantages such as saving materials, reducing production costs, weights and shape sizes, and accelerates the rapid development of electronic productions. An injection mold in which ultra-thin wall plastic parts can be molded is designed and manufactured. Using the orthogonal experiment method (Taguchi method) and numerical simulation, the influence of different process parameters (injection rate, injection pressure, melt temperature, metering size and part thickness) on the molding process for ultra-thin wall plastic parts is discussed. The results show that part thickness is the decisive parameter to the molding, metering size and injection rate are the principal factors in molding process, accelerating injection rate can bring a great increase in the filling ratio.
Melt temperature and injection pressure are the secondary factors, but higher melt temperature and injection pressure are also necessary in molding process. **[2]According to Babur Ozcelik and Ibrahim sonat** Plastic is used for injection molding method. The reason of using plastic is its properties *i.e.* lightness, resistance to corrosion, ease to convert into desired shape. Chemical and physical properties can change as per requirement. Uses of plastics are in packaging, aerospace and aviation, building and construction, automotive, electronic goods. For Analysis C-Mold, MPI, Mold Flow software was used. Injection parameters are injection temperature, mold temperature, injection pressure, and injection time. **[3]C.Y. Khor, *et al.* [4]** used the material for the study was ABS plastic. FLUENT 6.3 software is used in the simulation to verify the viscosity model (Cross model) and the Volume of Fluid (VOF) method is applied for the melt front tracking. The model is validated by means of experiments performed by using Davenport High Shear Viscometer with injection nozzle. Three-dimensional simulation and experimental investigation of polymer theology in a miniature injection molding process is presented. It has been observed that there exists an optimum combination of temperature viscosity and shear rate for the

**Manuscript received April 25, 2015**
**Gurmeet Singh**, Mechanical Engineering dept, Rajasthan Institute of Engineering and Technology, Jaipur. (Raj)
**Sharad shrivastava**, Mechanical Engineering dept Rajasthan Institute of Engineering and Technology, Jaipur. (Raj)

selected injection molding process. Accordingly, the temperature range 200–260 °C and shear rate 102–104 s−1 are found good for the process. The mold flow profiles for various temperatures and time steps are also presented. precise control of melt temperature, melt viscosity, injection speed, injection follow-up pressure, and switch over point from speed to pressure and cycle time **According to Babur Ozcelik and Ibrahim sonat [8]** Plastic is used for injection molding method. The reason of using plastic is its properties *i.e.* lightness, resistance to corrosion, ease to convert into desired shape. Chemical and physical properties can change as per requirement. Uses of plastics are in packaging, aerospace and aviation, building and construction, automotive, electronic goods. For Analysis C-Mold, MPI, Mold Flow software was used. Injection parameters are injection temperature, mold temperature, injection pressure, and injection time..**According to L.W. Seow and Y.C. Lam** The vessel for forming and part design of soft, readily bent parts for injection molding is a complex process, thoughts for producing a part ranging from price and rate of motion of producing to do with structure, ergonomics and to do with art values requirements. An optimization regularly Order is used to produce the levels necessary to balance the vessel for forming cavity.An optimization regularly order is used to produce the levels necessary to balance the vessel for forming cavity. An optimization regularly order is used to produce the levels necessary to balance the vessel for forming hollow. The way is gave effect to on a PC through giving connection of the FORTRAN general rule of behavior of a group with the business software. For tough methods Lee and Kim are used. The injection molding process gets into the injection of a polymer go slowly away into a vessel for forming where the go slowly away makes less warm and makes solid to form a soft, readily bent product. Cavity is main defect in this. To overcome this problem we reduce corners. A possible answer to get done this is to have an unchanging move liquid-like direction during putting in and to adjust the move liquid-like rates by adjusting the levels of the part. **[5]**

## III. Problem Description

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.

| 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 |

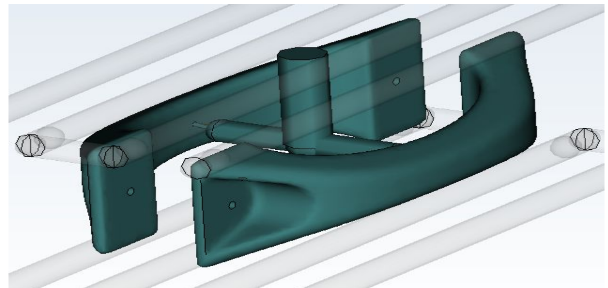


Fig 1 design set up of the product

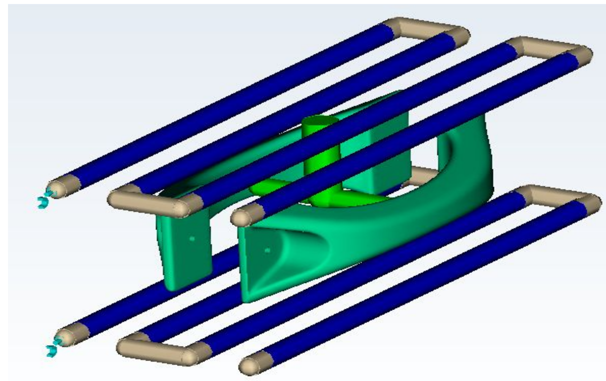


Fig. 2 design consisting of sprue, gate, cooling channels and runner

## 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.

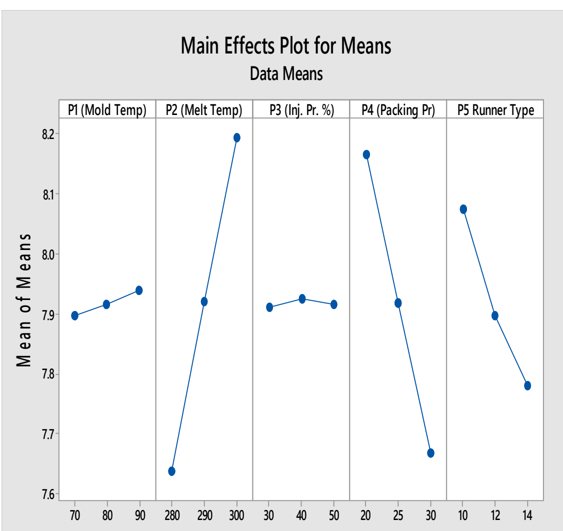
**Table 1 Summary Table of Factors and Levels**

**ANOVAs Analysis**

Calculation of "analysis of variance" was done for the designed case and results were shown in table 1. In ANOVA analysis to compare a model variance with a residual variance F-Test was conduct. Calculation of F value was done from a model mean square divided by residual mean square value. Both variances were same if F value was approaching to one, accordingly highest F value was best to find critical input parameter.

| Source | DF | Adj. SS | Adj. MS | F-Value | P-Value |
|---|---|---|---|---|---|
| **Regression** | 5 | 2.89487 | 0.57897 | 687.36 | 0.000 |
| **A** | 1 | 0.00756 | 0.00756 | 8.98 | 0.007 |
| **B** | 1 | 1.38223 | 1.38223 | 1640.99 | 0.000 |
| **C** | 1 | 0.00015 | 0.00015 | 0.18 | 0.677 |
| **D** | 1 | 1.11154 | 1.11154 | 1319.63 | 0.000 |
| **E** | 1 | 0.39338 | 0.39338 | 467.03 | 0.000 |
| **Error** | 21 | 0.01769 | 0.00084 | | |
| **Total** | 26 | 2.91256 | | | |

Table 1 ANOVA Results of Shrinkage




S-N Graph

## V. ANOVA RESULTS FOR DESIGNED CASE

Model F and P value for factor B and D were 1640, 1319 and 0.00 respectively for designed case for response shrinkage and it indicate that P value was very less than 0.00 and have most significant effect for shrinkage for designed case. But factor C has very less significant effect on product quality. .

## VI. REGRESSION EQUATION

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

**Regression Equation for Shrinkage**

| | | | |
|---|---|---|---|
| **Shrinkage** | **=** | **1.835** | **+ 0.002050 A** |
| **+ 0.027711 B+ 0.000289 C - 0.04970 D- 0.07392 E** | | | |

***Correlation coefficients ($R^2$)***

| **S** | **R-sq** | **R-sq (adj)** | **R-sq (pred)** |
|---|---|---|---|
| 0.0290226 | 99.39% | 99.25% | 98.99% |

**Contour Plot for Process Parameters**

In this study simulation software "Autodesk mold flow adviser" was used which visualizes contour figures from simulation results. To predict effect of process parameters on response contour graphs are very useful.

## VII. VOLUMETRIC SHRINKAGE CONTOURS

It was not possible to show here all 27 experiments shrinkage contours, so only few good and worst combinations of process parameters based results are discussed here and rest in Appendix A or Appendix B and remaining selected were discussed.

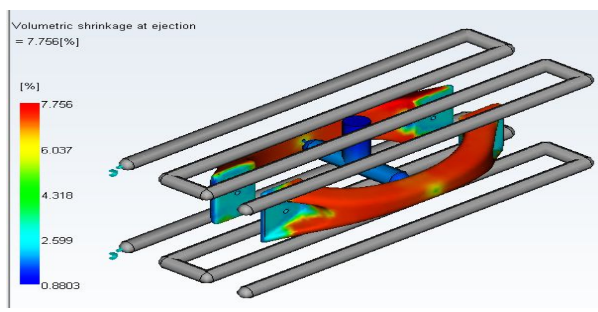



Fig. Volumetric Shrinkage for Experiment 3

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

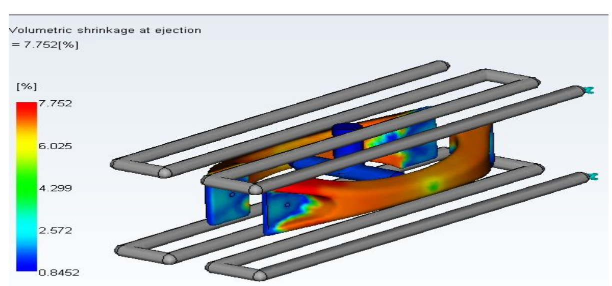



Fig. Volumetric Shrinkage for Experiment

## 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:

| 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** |

Best parameter combination for design was following.
Best Set: **A1-B1-C2-D3-E3**

**Table 6.1 Summary of Best Cases for Designs**

Response optimization for the shrinkage and fill time as following.

| Solution | P1 (Mold Temp) | P2 (Melt Temp) | P3 (Inj. Pr. %) | P4 (Packing Pr) | P5 Runner Dia. (mm) | Shrinkage fit |
|---|---|---|---|---|---|---|
| 1 | 70 | 280 | 40 | 30 | 14 | 7.249 |

Model equations for fill time and shrinkage was predict accurately with Minitab software and show 95% good prediction for responses and can be used by any plastic injection molding process manufacturer.

Signal to noise ratio predict a rank for most responsible factors for fill time and volumetric shrinkage and were following for both design respectively

**Table 2 The Response Table of S/N Ratio**

## 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.

More advanced techniques like ANT colony optimization, Response Surface Optimization can be used for future study to improve results of plastic injection molding process.

## REFERENCE


[1] An implicit control-volume finite element method and its time step strategies for injection molding simulation (Shunliang Jiang, Zhiguo Wang, Gouf Zhou, Weimin Yang) ,Computer and Chemical engineering 31(2007)147-1418(science direct).

[2] Development of an expert system for the determination of injection moulding parameters of thermoplastic materials: EX-PIMM (A. Tolga Bozdana, Omer Eyercioglu)

[3] Improving mould design and injection parameters in metals injections molding by accurate 3D finite element simulation (T.Barriere, J.C.Gelin, B.Liu) Journal Of materials Processing Technology 125-126(2002)518-524.

[4] Investigation of cooling effect at corners in injection molding (J.G. Kovacs , B. Siklo) International Communication in Heat And Mass Transfer 38(2011)1330-1334.

[5] Investigation the effects of obstacle geometries and injection molding parameters on weld line strength using experimental and finite element methods in plastic injection molding ( Babur Ozcelik , Emel Kuram, M. Mustafa Topal ) International Communication in Heat And Mass Transfer 39(2012)275-281.

[6] Optimizing flow in plastic injection molding (L.W. Seow, Y.C. Lam)

[7] Three-dimensional numerical and experimental investigations on polymer rheology in meso-scale injection molding (C.Y. Khor , Z.M. Ariff , F. Che Ani , M. Abdul Mujeebu , M.K. Abdullah, M.Z. Abdullah , M.A. Joseph )

[8] Warpage and structural analysis of thin shell plastic in the plastic injection molding (Babur Ozcelik , Ibrahim sonat) Material And Design 30 (2009)367-375(science direct.)

[9] Forty Sixth CIRP Conference on Manufacturing Systems 2013 Performance evaluation of a software engineering tool for automated design of cooling systems in injection moulding Juan M. Jauregui-Beckera*, Guido Tosellob, Fred J.A.M. van Houtena, Hans N. Hansen

[10] 24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013 Comparison of Injection Molding Technologies for the Production of Micro-Optical Devices Marco Sortino, Giovanni Totis, Elso Kuljanic

[11] International Conference On DESIGN AND MANUFACTURING, IConDM 2013 Design and Fabrication of an Injection Moulding Tool for Cam Bush with Baffle Cooling Channel and Submarine Gate S.Selvaraja*, P.Venkataramaiah