Effect of Process Parameter on Plastic Parts Using ANOVA with Moldflow Simulation

Kalpit Jain, Devendra Somwanshi, and Akshay Jain

Abstract This research work has been conducted on polypropylene (PP) material using Moldflow Adviser (MFA). Moldflow Adviser (MFA) has been used to contemplate and confirm the impact of procedure boundaries and advance the volumetric shrinkage and fill time. Streamlining of procedure boundaries is finished using L27 design of experiments (DOE). Further, analysis of variance (ANOVA) has been conducted. Ideal blend of procedure boundaries is represented by ANOVA. Two unique combinations of sprue and sprinter framework are utilized for simulation. Analysis of variance shows that packing pressure is most huge variable for volumetric shrinkage in both of the cases. Regression model conditions for volumetric shrinkage and fill time are likewise created in this investigation. It will assist little with micro industry in improving nature of an injection molded plastic parts.

Keywords Volumetric shrinkage · Regression model equations · ANOVA

1 Introduction

For building up the thermoplastic materials on higher production rate, plastic injection molding (PIM) is most significant method which has gigantic dimensional control[1]. PIM is most critical methodologies for assembling the plastic items due to top part surfaces, short product cycles, and lightweight [2]. In PIM, a framework is a client intelligent framework giving a well-disposed condition to the end-client for providing essential data from the framework [3]. The location of the gate for filling of the mold cavity is very significant effects on warpage. The effect of melt temperature, injection time, and packing pressure is more significant as compared to mold temperature and packing time on fill time [4]. Timon-3D v.6.11 CAE programming was utilized to complete the simulation. The runner, sprue, and gate are

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the segments of the conveyance framework [5]. The metering size, melt temperature, injection rate, and injection pressure influence the thickness of the article [6]. Natural fiber composite material is one of the suitable materials to manufacture window frame [7]. To examine the warpage, the melt temperature and packing pressure are most significant boundaries [8]. The intensity of packing pressures influences the volumetric shrinkage which occurs near the gate at the end of fill location. Lower shrinkage is indicated by higher packing pressure, and high volumetric shrinkage is a result of low packing pressure [9]. Conformal cooling channel is the most appropriate cooling framework for the plastic part among other cooling channels. Flow simulation for various gate size and locations was broke down. Air traps can be limited by giving air vents in center and hole embeds [7]. Holding pressure was the fundamental factor impacting all injection molding procedures and creating varieties of the TR up to 9% for IM, 3.5% for ICM, and 5.5% for VIM. Injection speed was additionally the second most significant factor [8]. PIM is most commonly used method for developing thermoplastic materials [9]. Plastic injection molding machine can be a used to obtain molded product by melted plastic material by heat into a mold. Parametric optimization of machining input parameter is required to get the desired optimized results [10–14].

2 Research Methodology

First step is the planning of simulation-based design of experiments. In the second step, apply Autodesk Moldflow Adviser (MFA) software to conduct MFA simulations based on the planned DOE. To identify most or least significant factors, ANOVA is used as third step.

In the fourth step, regression analysis has been done to find out the statistical relationship between input and output parameters. Once the regression has been done, modeling equations for output parameters have been generated using residual analysis.

In this investigation, a typical material was chosen for item making and determination depended on absolutely writing audit and statistical surveying, and material name was polypropylene (PP). L27 orthogonal array has been used for data analysis on two different sprue and runner locations. In this investigation, five input parameters with three levels have been used. L27 OA has been used for design of experiment. Primary reactions from all tests were volumetric shrinkage, and fill time of item chose. Two designs of sprue and runner were utilized in this investigation, which are shown in Fig. 1a and b.

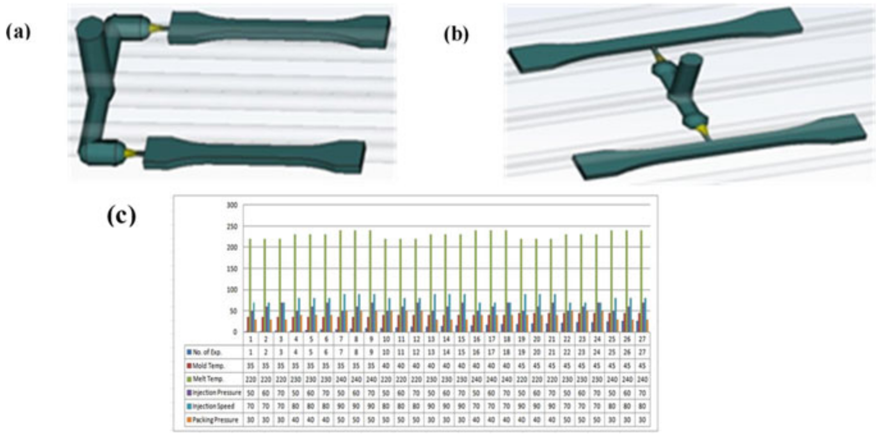

Fig. 1 **a** Sprue location at side for Case 1**, b** sprue location at center for Case 2, **c** orthogonal array for Case 1 and Case 2

2.1 Factors and Levels Along with Orthogonal Array

Design of experiments table was just conceivable by determination of proper factors and their levels. In this research work, five input parameters with three levels have been used which have been shown in Table 1.

Response parameters for this investigation are volumetric shrinkage (%) and fill time (s). Here, L27 has been used for five parameters and their three levels for each parameter.

3 Experimental Result and Analysis

The simulated values of fill time and volumetric shrinkages have been shown in Fig. 2a and b for both cases 1 and 2, respectively.

Table 1 Factor and level for case 1 and Case 2

Levels	Mold temp.	Melt temp.	Injection pressure	Injection speed	Packing pressure
1	35	220	50	70	30
2	40	230	60	80	40
3	45	240	70	90	50

Units: temperature in °C, pressure in Mpa, injection speed in %

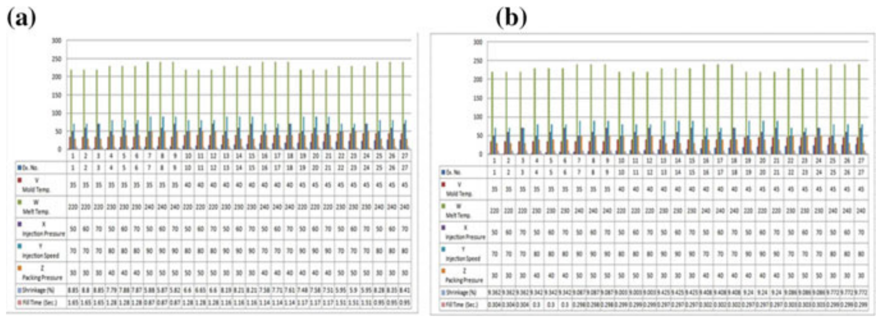

Fig. 2 **a** Shrinkage and fill time values for Case 1, **b** shrinkage and fill time values for Case 2

3.1 Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) was determined for the two cases, and results were appeared in Tables 2 and 3. F-test was directed for contrasting a model variance and a residual variance in ANOVA examination. *F* esteem was determined by isolating a model mean square by residual mean square value. On the off chance that *f* esteem was drawing closer to one method, the two differences were same, concurring F esteem most noteworthy was ideal to discover basic input parameter.

From literature review, it has been found that *P* esteem has exceptionally little (under 0.05) at that point the terms in the regression model have a huge impact to the reactions.

Table 2a and b has shown one important result that F-value for regression models is very high (Table 2 *F*-value was 73.20 for Case 1, and like Table 3, *F*-value was 358.92 for Case 2) than P-value is very less (approx. 0.0000) suggested that all parameters are significant.

3.2 Regression Equation

In this study, regression equations were also obtained from Minitab for both cases, for both responses volumetric shrinkage and fill time.

Regression equation for shrinkage for Case 1

$$\begin{aligned} \text{Shrinkage} = 18.45 - 0.0245 * \text{V} \ - 0.01905 * \text{W} \ + 0.00118 * \text{X} \\ - 0.01358 * \text{Y} \ - 0.11627 * \text{Z} \end{aligned} \quad (1)$$

Table 2 Comparison analysis of ANOVA results of shrinkage for Case 1 and Case 2

	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
Source	DF		Adj. SS		Adj. MS		*F*-value		*P*-value	
Regression	5	5	25.5921	1.228	5.1184	0.2456	73.2	58.77	0	0
V	1	1	0.2699	0.04712	0.2699	0.04712	3.86	11.28	0.063	0.003
W	1	1	0.6532	0.21912	0.6532	0.21912	9.34	52.43	0.006	0
X	1	1	0.0025	0	0.0025	0	0.04	0	0.851	1
Y	1	1	0.3318	0.00541	0.3318	0.0054	4.75	1.29	0.041	0.268
Z	1	1	24.3346	0.95634	24.3346	0.95634	348	228.85	0	0
Error	21	21	1.4685	0.08776	0.0699	0.004179				
Total	26	26	27.0605	1.31576						

Table 3 Comparison analysis of ANOVA results of fill time for Case 1 and Case 2

	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
Source	DF		Adj. SS		Adj. MS		*F*-value		*P*-value	
Regression	5	5	1.27532	0.000163	0.255064	0.000033	29.9	358.92	0	0
V	1	1	0.01491	0.00004	0.01491	0.00004	1.75	46.35	0.2	0
W	1	1	0.65677	0	0.656773	0	77	1.38	0	0.254
X	1	1	0	0	0	0	0	0	1	1
Y	1	1	0.59809	0.000158	0.59809	0.000158	70.12	1746.36	0	0
Z	1	1	0.00554	0	0.005544	0	0.65	0.5	0.429	0.489
Error	21	21	0.17912	0.00002	0.00853	0				
Total	21	26	1.45444	0.000165						

Regression equation for shrinkage for Case 2

$$\text{Shrinkage} = 7.416 + 0.01023 * V + 0.01103 * W - 0.000 * X - 0.00173 * Y - 0.02305 * Z \quad (2)$$

Regression equation for fill time for Case 1

$$\text{Fill time} = 7.376 - 0.00576 * V - 0.01910 * W + 0.00 * X - 0.01823 * Y - 0.00176 * Z \quad (3)$$

Regression equation for fill time for Case 2

$$\text{Fill time} = 0.32902 - 0.000097 * V - 0.000008 * W + 0.0 * X - 0.000297 * Y + 0.000005 * Z \quad (4)$$

Residual results for regression equations have been shown in Fig. 3a and b, respectively. The residual result shows the differences between simulation and predicted results.

Figure 4 shows that the normal probability plot is near to the straight line, so it is residual.

4 Conclusion

The point of this investigation is to advance MFA simulation results for mold flow plastic injection process. This investigation uses L27 orthogonal array for informative investigation on two distinctive sprue and location of runner. In this investigation, analysis of variance (ANOVA) and regression analysis were principle input strategies to explain reaction and factor relations emphatically.

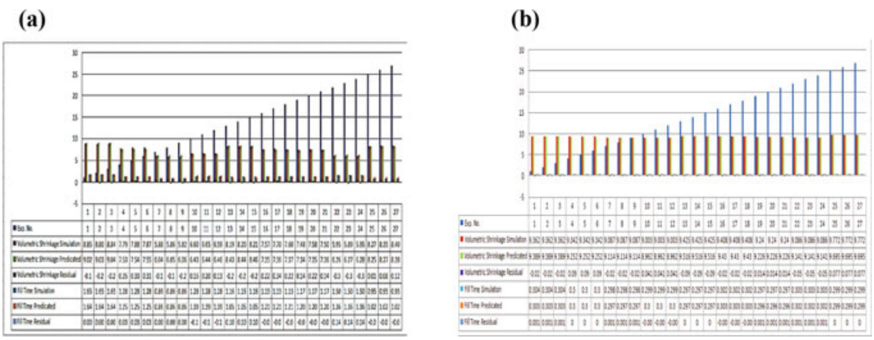

Fig. 3 **a** Residual results for Case 1, **b** residual results for Case 2

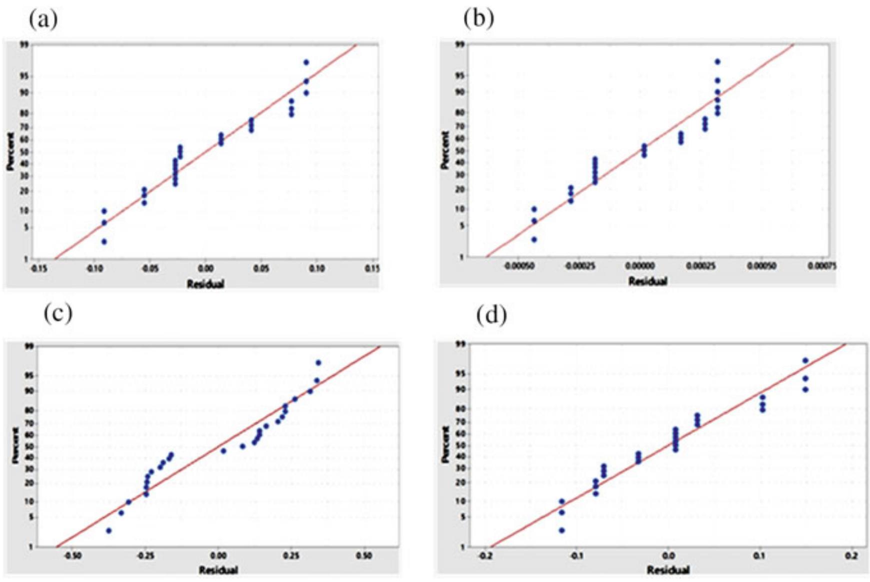

Fig. 4 **a** Case 1 shrinkage normal probability plot, **b** Case 1 fill time normal probability plot, **c** Case 2 shrinkage normal probability plot, **d** Case 2 fill time normal probability plot

ANOVA outcomes demonstrate that the packing pressure is major noteworthy factor for volumetric shrinkage for Case 1 and packing pressure with melt temperature was most critical element for volumetric shrinkage for Case 2. Like that for fill time, melt temperature and injection speed were most critical variables for Case 1, and for Case 2, mold temperature and injection speed were most noteworthy elements.

Model conditions related to fill time and shrinkage were anticipated precisely with Minitab programming and show 90% great forecast for reactions and can be utilized by any plastic injection molding procedure producer.

5 Future Scope

In this investigation, two cases were examined utilizing symmetrical cluster idea, structure change depended on sprue, and location of runner, yet in this investigation, sprue and runner were fixed for all reproduction cases for both cases. For future work, it will be a great way to deal with study factor change dependent on geometrical difference in sprue and runner framework.

ANT colony and response surface optimization can be used for prospect investigation to get the better consequences of process related to plastic injection molding.

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