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OPTIMIZATION OF RUNNER SYSTEM OF MULTI-CAVITY INJECTION MOLDING PROCESS: A CASE STUDY FOR ELECTRICAL SWITCH BOX

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Abstract - *Plastic made products are essential part of human life. Small and large scale both industries are work in this area. Plastic products qualities are dependent on their process parameters as well as material selection. In present study process parameters are used for research purpose. Aim of present study is to minimize the plastic injection molding defects using hot feeding system. A finite element method approach is used to simulate the electrical switch box by helping of "Autodesk Mold-flow Adviser" Software. All experiments are designed according design of experiment technique. Taguchi method is used in current study. Total five factors are selected with three levels each. According to taguchi method total 27 experiments are required to gain some meaning full outcomes. Two responses are selected in present study. ANOVA analysis is also performed in present study using commercial software MINITAB. Linear modeling equations are developed for both responses using regression modeling analyses. This study is useful for small scale industries worked for electrical switch box manufacturing.*

Keywords: FEM, Autodesk MFA, Taguchi method, ANOVA, Linear Modeling equation etc.

1. INTRODUCTION

Injection molding is used at large scale in India for Polymeric fabrication process for thermoplastic materials. This process is like die casting but difficulties are more than simple metal casting. The reason behind is plastic high viscosity of liquid plastic than molten metal. Due to high viscosity high range of pressure is required to overcome the defects made during injection process. In injection molding two pressures are most important part of the succession of plastic injection molding, first one is injection pressure and second is packing pressure required to pack the final product. Injection molding process is a cyclic operation involved during injection like transformation of plastic pellets into molten liquid than filled in cavity and in last again solidifies in molded part. Electrical energy operated machines are more dominant in today's era. The main components of a typical injection molding machine are the following clamping unit, the plasticizing unit, and the drive unit; they are shown in Fig.

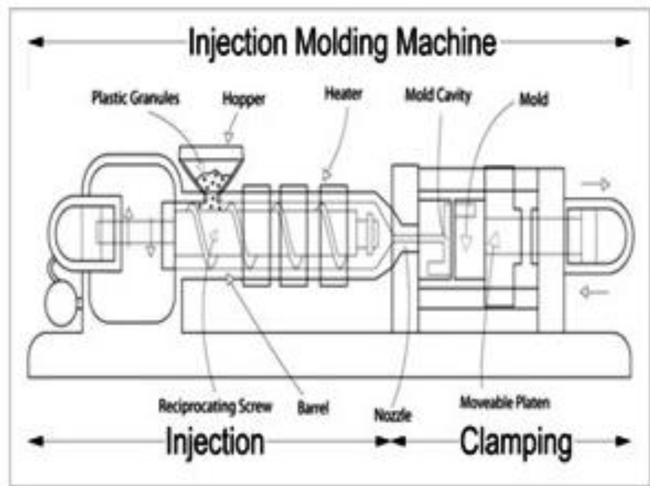

Fig. 1. Plastic Injection Molding Machine

2. NUMERICAL SIMULATION

Autodesk Simulation Moldflow (2014), MFA is a complete suite of definitive tools for simulating, analyzing, optimizing and validating plastics part and mold designs in plastics injection molding. MFA address the broadest range of manufacturing issues and design geometry types associated with plastics molding processes. Thus, MFA can work to reduce or eliminate time delays, improve part quality, and deliver projects within budget constraints. With MFA analysis modules, filling, packing, and cooling stages of the plastic, the injection molding process can be simulated. MFA also predict post-molding phenomena such as shrinkage sink mark, air trap, weld line, and war page of the products. In addition, MFA offers an expanded material database, which includes over 9300 unique plastic materials for use in plastic injection molding process simulation software in order to ensure that users have access to the highest quality material data for plastic simulation.

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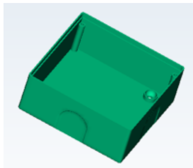
Step 1
Import a CAD model, which was created in Auto-desk Inventor 2014.



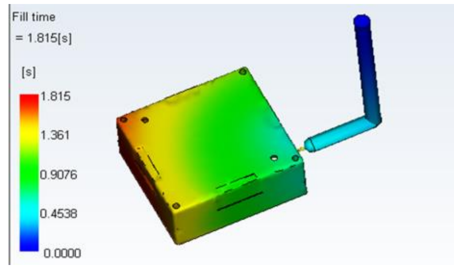
Step 2
Mesh the CAD model

Step 3
Material Selection: Globalene 6331: Taiwan P

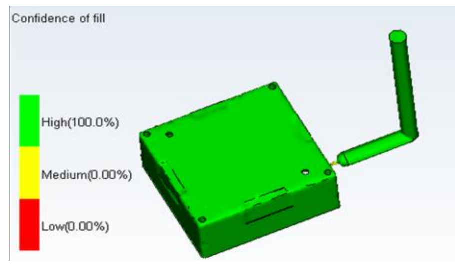
Step 4
Simulation type selections

Step 5
Process parameters selection
Melt Temperature
Mold Temperature
Injection Speed
Packing Pressure
Gate Diameter

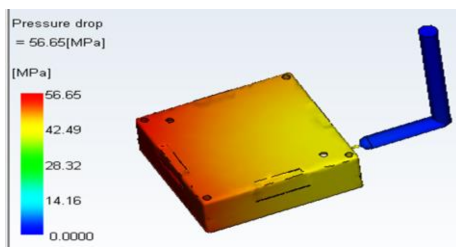
Step 6
Results



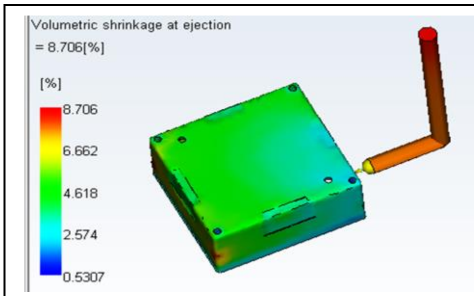
Material Fill time in Second



Confidence of fill of the product



Pressure drop of product



Volumetric Shrinkage at Ejection

3. MATERIAL USED

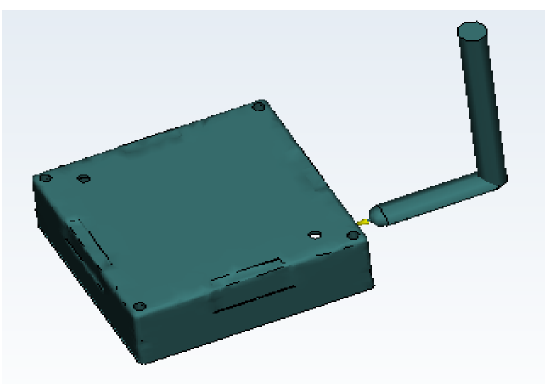
In this study a common material was selected for product making and selection was based on literature review and material name was Globalene 6331. Required material properties were shown in table 1.

TABLE – 1: Material Properties of Globalene 6331

S.NO.	PROPERTIES	VALUE
1	Specific Heat (C_p)	3100 J/kg C
2	Elastic Modulus	1340 MPa
3	Poisson's Ratio	0.392
4	Shear Modulus	481.3 MPa
5	Melt Temperature	254.5 C
6	Density	0.92889 gm/cm^3
7	Thermal conductivity	0.17 W/m-C
9	Energy Usage Indicator	3

4. PROBLEM DESCRIPTION

The problem focused in this study was to apply CAE methods in plastic injection molding process to improve productivity of thick plastic products. In this study five controlling factors named mold temperature, melt temperature, injection pressure, packing pressure and one geometrical factor named gate diameter were used with three levels by application of taguchi tables were used for design of experiment.



Gate Location of the design

5. DESIGN OF EXPERIMENT METHODOLOGY

The product quality made from plastic injection molding process 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. The effects of these parameters were studied by various researchers from last decades. It was very difficult to design, experiments for any type of research and here a scientific approach is helpful for researchers which is known as "DESIGN OF EXPERIMENT". This technique was adopted by researcher for this study. By use of DOE techniques any researcher can determine important factors which are responsible for output result variation of experiments. DOE can found optimum solution for particular experiments.

6. FACTORS AND LEVELS

Design of DOE table was only possible by selection of proper factors and their levels. In this study five factors were selected with three levels for each product and were shown in table 2.

TABLE - 2: Summary table of Factors and Levels for used product

Levels	P1 (Mold Temp)	P2 (Melt Temp)	P3 (Inj. Pressure)	P4 (Packing Pr. %)	P5 (Gate Dia.)
1	35	210	75	60	1
2	40	220	85	70	1.5
3	45	230	95	80	2

Outcome parameters for this study were fill time and volumetric shrinkage (%) shown in below table 3. After selection of factors and levels for current study it was important to select accurate orthogonal array and for this task MINITAB software was used for making of orthogonal array of factors and their levels.

7. RESULT AND DISCUSSION

Single cavity plastic injection molding process was simulated in this study for mouse family. Autodesk mold flow adviser ultimate FEM package was used for simulation purpose. All experiments were designed according to DOE technique (Taguchi orthogonal array table), which were discussed in table 3. Main outcomes focused in this were following:

Injection Pressure, Fill Time, Volumetric Shrinkage, Analysis of variance (ANOVA).

Signal to noise ratio was simple method to predict the effect of changing of factors according their levels to find effect on product quality. In this study "smaller is better" was adopted as quality indicator for S/N ratio.

The response tables for both design cases were shown in table 3 and table 4 respectively. S/N ratio gives best combination of input parameters for both cases.

TABLE - 3: L27 Orthogonal Array with Result Parameter of Hot Runner

Ex. No	A (Mold Temp)	B (Melt Temp)	C Inj pressure	D (Inj. Speed %)	E (Packing Pr. MPa)	Shrinkage %	Fill time (sec)
1	35	210	75	60	1	8.706	1.815
2	35	210	75	60	1.5	8.997	1.815
3	35	210	75	60	2	9.137	1.798
4	35	220	85	70	1	8.745	1.645
5	35	220	85	70	1.5	9.293	1.633
6	35	220	85	70	2	8.363	1.636
7	35	230	95	80	1	9.008	1.489
8	35	230	95	80	1.5	9.521	1.477
9	35	230	95	80	2	9.838	1.461
10	40	210	85	80	1	7.856	1.774
11	40	210	85	80	1.5	8.437	1.76
12	40	210	85	80	2	8.727	1.751
13	40	220	95	60	1	9.262	1.654
14	40	220	95	60	1.5	10	1.639
15	40	220	95	60	2	9.755	1.641
16	40	230	75	70	1	9.538	1.488
17	40	230	75	70	1.5	10.13	1.477
18	40	230	75	70	2	8.403	1.933
19	45	210	95	70	1	10.42	1.469
20	45	210	95	70	1.5	8.904	1.917
21	45	210	95	70	2	9.153	1.767
22	45	220	75	80	1	8.607	1.626
23	45	220	75	80	1.5	9.229	1.614
24	45	220	75	80	2	9.539	1.606
25	45	230	85	60	1	12.79	1.654
26	45	230	85	60	1.5	10.98	1.488
27	45	230	85	60	2	10.98	1.488

"Signal to Noise" ratio was simple method to predict the effect of changing of factors according their levels to find effect on product quality. In this study "smaller is better" was adopted as quality indicator for S/N ratio.

From Table 4 it is concluded that melt temperature is most important parameter whereas packing pressure is less important parameter. On the basis of mean ratio it is concluded that it also showed same results like S/N ratio

TABLE – 4: Response table for S/N ratio

Levels	(Mold Temp)	(Melt Temp)	(Inj. Press)	(Packing pres.)	Gate Dia.
1	-16.27	-16.15	-16.35	-17.11	-16.54
2	-16.31	-16.39	-16.65	-16.40	-16.65
3	-17.10	-17.15	16.70	-16.17	-16.49
delta	0.83	1.0	0.35	0.94	0.16
rank	**3**	**1**	**4**	**2**	**5**

TABLE -5: The response table for mean value

Levels	(Mold Temp)	(Melt Temp)	(Inj. Press)	(Packing Pr.)	Gate dia.
1	5.354	5.345	5.414	5.867	5.530
2	5.401	5.416	5.611	5.440	5.573
3	5.846	5.841	5.576	5.296	5.499
delta	0.492	0.496	0.197	0.571	0.074
rank	**3**	**2**	**4**	**1**	**5**

Response table for plastic product were show that input Parameter melting temperature, was most critical responsible parameter for shrinkage and fill time outcomes.

Rank was also show based on response table. Most critical parameter was melting temperature whereas less important parameter was packing pressure because level values were high and show no effect in product quality variation. Figure 8 and 9 show graphical presentation of S/N ration and also show best cases for all experiments.