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Application of Python software in Improvement of Plastic Injected Moulded Thin Shell Components with Taguchi Method and GA

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Abstract: Plastic injection molding (PIM) is appropriate for the mass production of plastic parts having the complex geometries with a single production step. Sometimes, the difficulty in tuning the best process conditions can cause defects in the thin plastic parts, like dimensional shrinkage, warpage and short shot. In this study, optimal injection molding conditions for minimum shrinkage and warpage were determined with design of experiments technique viz. Taguchi method, and statistical technique ANOVA (Analysis of Variance) method. Step by step of Taguchi method has been explained. Granules of Polypropylene (PP) are injected in mould design for thin specimens under various processing parameters like melt temperature, injection pressure, packing pressure and packing time. S/N ratios were utilized for determining the optimal set of parameters. Python coding has been used for optimization of parameters with the Genetic algorithm..

Keywords: Plastic Injection Moulding, shrinkage, warpage, Taguchi method, Python coding , Genetic Algorithm

1. Introduction

Plastic injection molding is a manufacturing process used to produce a wide variety of plastic parts and products. It is one of the most common methods for mass-producing plastic components due to its efficiency, versatility, and precision[1-2]. The process typically employs a reciprocating single-screw extrusion machine. The machine is used for transporting, melting and pressurizing the polymeric materials, which are fed into the machine in granular form. The polymer melts within the barrel by heat conduction through the barrel wall and via the dissipation of heat generated within the sheared polymer melt. During plastication, the melt accumulates in front of the screw, which is driven back against an adjustable pressure within the hydraulic system until a desired shot size is achieved. This is followed by injection where the screw pushes forward to force the polymer melt through a runner system and into the relatively cold empty cavity of the already closed mold. In order to compensate for any shrinkage caused by the cooling of the melt within the cavity, the melt in front of the screw is held under pressure so as to force more materials into the cavity. When the gate into the mold freezes off, no more material can be supplied through the gate and product cools down further without compensation for shrinkage[4-6]. The mold temperature is regulated by water that circulates through channels in order to maintain the mold cavity walls at a temperature between room temperature and the glass transition temperature of polymer (for an amorphous polymer). When the product is cooled to a state of sufficient rigidity, which in most cases occur when all regions of the part have cooled down to below glass transition temperature of the polymer, the mold opens and the product is ejected.

2. Methods and Materials

Injection molding represents one of the most important processes in the mass production of manufactured plastic parts with complex geometries. The surface quality and dimensional stability of thin parts depends on the material characteristics, mould design and tuning of process parameters [3-4].

There are several researchers that have studied the effects of injection molding process parameters on the shrinkage of moldings [5]. Since many process parameters affect the shrinkage, parameter optimization and experimental design are needed to produce high quality parts with good surface finish. Some researchers have been conducted on optimizing shrinkage in plastic injection moldings. In thin-shelled plastic component production, few researchers used the Taguchi method to reduce shrinkage and warpage problems that were related to a variation in the process-parameters like melt temperature, cooling time and packing pressure.

Table 1 Range of parameters for virgin PP and virgin PC

Parameters	Level-1	Level-2	Level-3	Unit
Mould Temperature (A)	60	70	80	^{0}C
Melt Temperature (B)	235	255	275	^{0}C
Injection Pressure (C)	110	120	130	MPa
Packing Time (D)	4	5	6	sec
Packing Pressure (E)	60	80	100	MPa
Cooling Time (F)	10	12	14	sec

Table 2

L_{27} Run	Shrinkage (%)	Shrinkage S/N ratio (dB)	Warpage (mm)	Warpage S/N ratio (dB)
1	8.89	-18.978	6.632	-16.4067
2	7.375	-17.3552	6.282	-15.9343
3	7.34	-17.3139	6.506	-16.2395
4	8.37	-18.4545	3.58	-11.029
5	8.116	-18.1868	3.664	-11.2316
6	9.4	**-19.4626**	3.91	-11.799
7	11.45	-21.1761	2.733	-8.669
8	12.5	-21.9382	2.787	-8.84018
9	12.8	-22.1442	2.96	-9.36695
10	9.007	-19.0916	6.6	-16.3645
11	4.948	-13.8886	4.37	-12.7698
12	8.552	-18.6414	6.398	-16.0937
13	8.976	-19.0617	3.605	-11.0898
14	7.62	-17.6391	3.724	-11.3734
15	10.67	-20.5633	3.43	-10.6551
16	8.528	-18.6169	3.5	-10.8316
17	7.347	-17.3222	3.528	-10.9012
18	8.397	-18.4825	3.603	-11.0849
19	8.322	-18.4046	6.266	-15.912
20	6.264	-15.937	4.77	-13.5339
21	7.471	-17.4676	6.126	-15.7151
22	6.661	-16.4708	3.826	-11.6094
23	8.444	**-18.531**	4.64	-13.2928
24	9.414	-19.4755	6.18	-15.7916
25	11.056	**-20.872**	3.246	-10.1733
26	11.583	-21.2764	3.261	-10.2136
27	11.89	-21.5036	3.19	-10.0212

Table 3 Response table for Signal to Noise Ratios for Shrinkage of PP

Level	A	B	C	D	E	F
1	-19.45	-17.45	-19.01	-18.8	-18.74	-18.96
2	-18.15	-18.65	-18.01	-19.09	-19.11	-18.71
3	-18.88	-20.37	-19.45	-18.59	-18.62	-18.8
Delta	1.3	2.92	1.44	0.5	0.49	0.24
Rank	**3**	**1**	**2**	**4**	**5**	**6**

Table 4 Response table for Signal to Noise Ratios for Warpage of PP

Level	A	B	C	D	E	F
1	-12.17	-15.44	-12.45	-12.28	-12.35	-12.73
2	-12.35	-11.99	-12.01	-12.6	-12.95	-12.53
3	-12.92	-10.01	-12.97	-12.56	-12.14	-12.18
Delta	0.75	5.43	0.96	0.32	0.81	0.56
Rank	**4**	**1**	**2**	**6**	**3**	**5**

The ANOVA test was adopted to determine the significance of each parameter in the designed experimental study. The ANOVA results for PPfor shrinkage, and warpage . ANOVA at 95% confidence interval also shows the same results for shrinkage, and warpage as obtained by analysis of S/N ratios. Interactions between mould temperature, melt temperature and injection pressure were also considered in the ANOVA. In the analysis of ANOVA of shrinkage of PP, also shows the p-values. Since the p-values of three parameters viz. mould temperature, melt temperature and injection pressure are less than 0.05, which reflects these parameters are statistically significant. Two interactions viz., mould temperature with melt temperature and melt temperature with injection pressure also have p-values less than 0.05, which reflects their statistically significant effect on the part shrinkage at the 95% confidence level. The R^2 value and adjusted R^2 value for shrinkage model are 90.21% and 87.45% respectively.

Thus, based on the predictive equations, the following mathematical models (in coded forms) can be proposed for determining the values of shrinkage (%), and warpage (mm) for PP.

Mathematical model for virgin PP

$$\text{Shrinkage} = 229.7 - 1.686\,A + 0.0788\,B - 2.766\,C - 0.338\,D + 0.01187\,A^2 + 0.01070\,C^2 + 0.00278\,C \times D \quad (8)$$

$$\text{Warpage} = 138.7 - 0.499\,A - 0.788\,B - 0.802\,C + 2.598\,E + 0.001348\,B^2 + 0.00451\,C^2 + 0.002563\,A \times B - 0.02229\,C \times E \quad (9)$$

3. Results and Discussion

3.1 Shrinkage and warpage of virgin PP were successfully analyzed by using Taguchi technique. It provides an organized and efficient methodology for the optimization of the parameters. The standard liner graph was modified using the line-separation method to assign the parameters and various interactions in the orthogonal array.

3.2 Melt temperature, mould temperature and injection pressure with their interactions was found to perform significant role in minimization for shrinkage, and warpage for PP.

Same results were obtained with python coding with Genetic algorithm.

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The scope of this conference encompasses latest research outcomes pertaining to the "Energy" domain in the form of theoretical models, environmental impact, security and defense technology, innovative designs, enhancements and improvements in existing frameworks, sustainable technological advancement, societal welfare etc. Thus the conference intends to bring together the best minds from around the world to cover literally all aspects of energy technology from a multi-disciplinary perspective.

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