International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Optimization of Injection Molding Process Parameter for Reducing Shrinkage by Using High Density Polyethylene (HDPE) Material

Harshal P. Kale[1], Dr. Umesh V. Hambire[2]

1Student of Government Engineering College Aurangabad, Maharashtra, India
2Assistant Professor of Government Engineering College Aurangabad, Maharashtra, India

Abstract: ***Injection molding is an important polymer processing operation in the plastic industry. In this process, polymer is injected into a mold cavity, and solidifies to the shape of the mold. Optimizing the parameters of the injection molding process is critical to enhance productivity. For process optimization, parameters must operate at optimum levels for acceptable performance. Taguchi method is one of the methods of optimization, in which orthogonal array is generated based on experimental design. Optimization of injection molding process parameters will be carried out using high density polyethylene (HDPE) as the molding material Injection molding has been a challenging process for many plastic components manufacturers and researchers to produce plastics products meeting the requirements at very economical cost. Since there is global competition in injection molding industry, so using trial and error approach to determine process parameters for injection molding is no longer hold good enough. Since plastic is widely used polymer due to its high production rate, low cost and capability to produce intricate parts with high precision. It is much difficult to set optimal process parameter levels which may cause defects in articles, such as shrinkage, warpage, line defects. Determining optimal process parameter setting critically influences productivity, quality and cost of production in plastic injection molding (PIM) industry. In this paper optimal injection molding condition for minimum shrinkage were determined by the DOE technique of Taguchi methods. The various observation has been taken for material namely HDPE. The determination of optimal process parameters were based on S/N ratios.***

Keywords: Injection molding, DOE, Taguchi optimization, design expert

1. Introduction

Optimizing process parameter problems is routinely performed in the manufacturing industry. Final optimal process parameter setting is recognized as one of the most important steps in injection molding for improving the quality of molded products [12]. Previously, engineers used trial-and-error processes which depend on the engineers' experience and intuition to determine initial process parameter settings. Subsequently, numerous engineers applied Taguchi's parameter design method to determine the optimal process parameter settings. However, the trial-and-error process is costly and time consuming, thus it is not suitable for complex manufacturing processes (Lam et al., 2004). Hsu (2004b) argued that when using a trial-and-error process, it is impossible to verify the actual optimal process parameter settings. [3]. Moreover, Taguchi's parameter design method can only find the best specified process parameter level combination which includes the discrete setting values of process parameters.

Injection molding represents one of the most important processes in the mass production of manufactured plastic parts with complex geometries. The quality of the injection moldings depends on the material characteristics, the mould design and the process conditions. Defects in the dimensional stability of the parts result in shrinkage. Severe shrinkage leads to deflection of warpage in molded parts as well as negatively influences the dimensional stability and accuracy of the parts. Many factors including materials selection, part and mould design, as well as injection molding process parameters can affect shrinkage behavior in an injection molded part. The study carried by Chang and Faison [1] reported that more shrinkage occurs across the flow direction than along the flow direction. Chang and Faison studied the shrinkage behavior and optimization of PS, HDPE and ABS parts by using the Taguchi and ANOVA methods. They stated that the mold and melt temperatures along with the holding pressure and the holding time were the most significant factors affecting the shrinkage behavior of the three materials studied. One of the main goals in injection molding is the improvement of quality of molded parts besides the reduction of cycle time, and lower production cost. For instant, poor cooling system will give rise to non uniform mould surface temperature and irrational gate location, would lead to differential shrinkage in molded parts [2],[3]. As in many manufacturing industry meeting required specification means keeping quality under control Quality problems can be material related defects i.e. black specks and splay , process related such as filling related defects i.e. flash and shots packing and cooling related defects i.e., sink marks and voids, and post, mould related defects i.e., warpage , dimensional changes. Vaatainen et al. [5] investigated the effect of the injection molding parameter on the visual quality of moldings using the Taguchi method. They focused on the shrinkage with three more quality characteristics: weight, weld line and sink marks. Factors that affect the quality of molded parts can be grouped into: part design, mould design, machine performance and processing conditions. The trial-and-error process is costly and time consuming, thus not suitable for complex manufacturing processes. In order to minimize such defects in plastic injection molding, design of experiment, the Taguchi method is applied. In experimental design, there are many variable factors that affect the functional characteristics of the product. Design parameter values that minimize the effect of noise factors on the product's quality are determined. In order to find optimum levels, fractional factorial designs using orthogonal arrays are used. In this way, an optimal set of process conditions can be obtained from very few experiments [6], [7]. This paper attempts to describe the optimization of the injection molding process parameters for optimum shrinkage performance of a plastic head light of Tata Magic which is made from Polypropylene polymer. In this paper the process parameter such as Injection temperature, Injection pressure, Packing pressure and Packing time has been taken to get best combination to optimize the process. Signal-to-noise ratio was used to obtain the optimal set of process parameters.

2. Experimental Studies

2.1 Materials

HDPE is the natural color polymer with Good process ability, very good mechanical properties.HDPE is designed to make injection molded product like industry handling, pallets and luggage shells.

Table 1: The General property of HDPE material

S. No	*Property*	*Unit*	*Value*
1	Density	g/cc	0.96
2	Melt Flow Index	g/10 min	8.0
3	Tensile strength	Mpa	25
4	Elongation at yield	%	11
5	Elongation at break	%	800
6	Flexural strength	Mpa	30

Table 2: The effective factor and levels

Factor	*Level1*	*Level2*	*Level3*
a)Melting Temperature	180	190	200
b) Injection Pressure	40	50	60
c) Packing Pressure	25	30	35
d) cooling Time	20	30	40

2.2. Experimental procedure

The experiments were performed on injection molding machine De –Tech85LNC5 to produce plastic disc of 3mm thickness and 100mm diameter. The discs were produce by HDPE of grade 080M60 material. The experiment was conducted with four controllable, three level processing parameters: melt temperature, injection pressure, packing pressure, packing time, therefore the L27 orthogonal array was selected for this study.

is the difference between the size of a mold cavity and the size of the finished part divided by the size of a mold. Usually it is expressed in percentage. Four points were marked on the specimen, and measurements were made with micrometer screw gauge (with an accuracy of 0.01 mm). For each specimen, the average thickness was calculated as the arithmetic mean of the three points. The relative shrinkage was determined as

$$S = \frac{\mathrm{Dm-Dp}}{\mathrm{Dm}} X100\% \qquad (1)$$

3. Taguchi Method

Taguchi's philosophy is an efficient tool for design of high quality manufacturing system, which has been developed based on orthogonal array experiments, which provide much reduced variance for experiment with optimum setting of process control parameters[8].The signal to noise ratio is a simple quality indicator that researchers and designers can use to evaluate the effects of changing a particular design parameter on performance of the products.[9,10] Taguchi methods [11] use a special design orthogonal array to study the entire factor with only a small number of experiments[12].It introduces an integrated approach that is simple and efficient to find the designs for quality, performance and computational cost[14]. In product or process design of Taguchi method, there are three steps:

i. System design: selection of system for given objective function.
ii. Parameter design: selection of optimum levels of parameter
iii. Tolerance design: determination of tolerance around each parameter level [15].

Taguchi method uses the signal-to-noise (S/N) ratio instead of average. The S/N ratio reflects both the average and the variation of the quality characteristics[6].As discussed by Oktem el at.[16] the S/N ratio is a measure of performance aimed at developing products and processes insensitive to noise factors. The standard S/N ratio used is as follows: Nominal is best (NB), lower the better (LB) and higher the better (HB) [4]. In this study lower value of shrinkage behavior is expected. Thus S/N ratio characteristics the lower – the-better is applied in the analysis which is given in table 4 and can be calculated by using

$$\mathbf{S/N= -log10\ (1/n\textstyle\sum yi^2)} \qquad (2)$$

Where yi is the value of the quality characteristics for the ith

Trials, n are number of repetitions.

The response table of the S/N ratio is given in table 3, and the best set of combination parameter can be determined by selecting the level with highest value for each factor. As a result, the optimal process parameter combination for. The difference value given in table 5 denotes which factor is the most significant for shrinkage of PP molding. Packing pressure was found most effective factor for PP followed by packing time, injection pressure and melt temperature.

Table 3: The Orthogonal Array

Sr. No	A	B	C	D	Shrinkage	S/N Ratio
1	1	1	1	1	3.242	-10.2163
2	1	1	1	1	3.545	-10.9923
3	1	1	1	1	3.151	-9.9690
4	1	2	2	2	3.757	-11.4968
5	1	2	2	2	4.242	-12.5514
6	1	2	2	2	4.060	-12.1705
7	1	3	3	3	3.848	-11.7047
8	1	3	3	3	4.454	-12.9750
9	1	3	3	3	4.545	-13.1507
10	2	1	2	3	4.242	-12.5514
11	2	1	2	3	4.545	-13.1507
12	2	1	2	3	4.848	-13.7113
13	2	2	3	1	4.666	-13.3789
14	2	2	3	1	4.666	-13.3789
15	2	2	3	1	4.545	-13.1507
16	2	3	1	2	4.151	-12.3631
17	2	3	1	2	3.636	-11.2125
18	2	3	1	2	2.848	-9.0908
19	3	1	3	2	3.545	-10.9923
20	3	1	3	2	3.242	-10.2163
21	3	1	3	2	3.454	-10.7664
22	3	2	1	3	3.151	-9.9690
23	3	2	1	3	2.030	-6.1499
24	3	2	1	3	1.727	-4.7548
25	3	3	2	1	2.242	-7.0127
26	3	3	2	1	0.515	5.7639
27	3	3	2	1	0.515	5.7.7639

Shrinkage is the difference between the size of a mold cavity and the size of the finished part divided by the size of a mold. Usually it is expressed in percentage. Four points were marked on the specimen, and measurements were made with micrometer screw gauge (with an accuracy of 0.01 mm). For each specimen, the average thickness was calculated as the arithmetic mean of the three points. The relative shrinkage was determined as

$$S = \frac{\mathrm{Dm}-\mathrm{Dp}}{\mathrm{Dm}} X100\% \qquad (1)$$

4. Analysis of Variance (ANOVA)

The ANOVA test was applied to determine the significance of each parameter in the designed experimental study. The ANOVA results for HDPE moldings are given in Table no 4 respectively. Since the one P-value was less than 0.05, this parameter had a statistically significant effect on the shrinkage at the 95% confidence level. The ANOVA test was applied to determine the significance of each parameter in the designed experimental study. The ANOVA results for HDPE moldings are given in Tables 4 respectively. Since the one P-value less than 0.05, this parameter had a statistically significant was

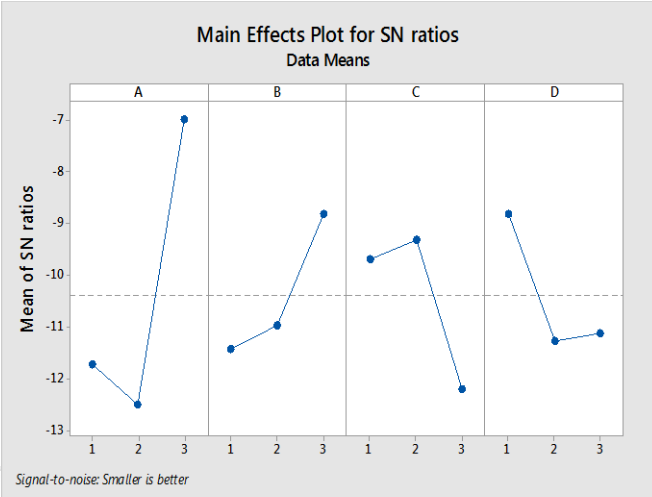

Figure 1: Main effect plot for SN rato

Table 4: ANNOVA table and result analysis

Source	Sum of square	DF	Mean square	F-value	P-value
Melting Temperature	19.75	2	9.87	37.74	0.0001
Injection Pressure	3.25	2	1.63	6.22	0.0088
Packing Pressure	5.78	2	2.89	11.05	0.0007
Cooling Time	2.75	2	1.37	5.25	0.0160
Pure Error	4.71	18	0.26		
Cor Total	36.24	26			

5. Conclusions

1. Taguchi and ANOVA methods were used to investigate the effects of melt temperature, injection pressure, packing pressure, packing time and cooling time on the shrinkage of the HDPE material.
2. In Taguchi method, S/N ratios were used for determining the optimal set of process parameters. ANOVA method gave the significance degree of the each process parameter.
3. Melt temperature is the most effective parameter.

References

[1] Chang TC, Faisen E.”Shrinkage behavior and optimization of injection molded parts studied by the Taguchi method”, polymer Engg Sci 2001; 41:703-10.
[2] H. Zhou, Y. Zhang J. Wen, D. Li “an acceleration method for minimization of shrinkage” International Journal of Advance Manufacturing Technology, 37, pp1006-1022.
[3] Mohd. Muktar Alam, Deepak Kumar, ”Reducing shrinkage in plastic injection moulding using Taguchi

method in Tata magic head light", International journal of science and research (IJSR), India onlineISSN:2319-70654.

[4] K. Krishnaiah, P. Shahabudeen,"Applied design of experiment and Taguchi method", PHI learning private limited. Delhi-110092. 2013.

[5] Vaatainen O, pentti J "Effect of processing parameters on quality of injection molded parts using Taguchi parameter design method", plastic Rubber Compos1994:21:2117.

[6] Sajjan Kumar Lal, Dr. Hari Vasudevan, " Optimization of injection molding process parameter in the molding of Low Density polyethylene (LDPE)", International journal of Engineering Research and Development, e-ISSN:2278-067X, p-ISSN:2278-800X, volume 7, issue 5, pp. 35-39.

[7] S. Kamaruddin, Zahid A. Khan and S. H. Foong, "Application of Taguchi method in the Optimization of Injection moulding parameters for manufacturing products from plastic blend", IACSIT international journal of engineering and technology, vol2, no . 6, December2010.

[8] Shi W. Lee, Seokyoung Ahn, "Effect of process parameter in plastic, metal and ceramic injection molding process", Korea-Australia Rheology journal, vol 123, No3, september2011, pp127-138.

[9] D. Mathivanan, M. Nouby and R. Vidhya, "Minimization of sink markdeffectsin injection molding process Taguchi approach", International journal of Engineering Science and Technology, vol 2, No 2, 2010, pp 13-22.

[10] M. Stanek, D. Manas, M. Manas, O Suba, "Optimization of injection molding process", International journal of Mathematics and computers in simulation, issue 5, volume 5, 2011, pp 413-421.

[11] Aliraza Akbarzadeh and mohammad Sadhegi, "parameter study in plastic Injection molding process using statistical method and IWO algorithm", International Journal of molding and optimization, volume1, No 2, June 2011, pp 141-145.

[12] M. V. Kavade, S. D. Kadam, "Parameter optimization of injection molding of polypropylene by using Taguchi methodology:, IOSR Journal of Mechanical and Civil Engineering(IOSR-JMCE), ISSN:22781684, volume 4, issue 4, pp 49-58.

[13] G. Pötsch and W. Michaeli, "Injection moulding: An introduction", Munich: Hanser Publishers, 1995.

[14] J. A. Brydson, "Plastic materials", Butterworth-Heinmann: Oxford, 1995.

[15] D. V. Rosato, M. G. Rosato, "Injection moulding handbook" Massachusetts: Kluwer Academic Publishers, 2000.

[16] M. C. Huang and C. C. Tai, "The effective factors in the warpage problem of an injection-moulded part with a thin shell feature", J. Mat. Proc. Tech. , vol. 110, 2001, pp. 1–9.

[17] M. Altan, "Reducing Shrinkage in Injection Mouldings via the Taguchi, ANOVA and Neural Network Methods", j. Mat. & Design, vol. 31, 2010, pp. 599–604

[18] Neeraj Singh Chauhan and Shahzad Ahmad "Optimization of Cycle Time of DVD-R Injection Moulding Machine" by International Journal of Engineering and Technology (IJEST)

[19] C. R. Kothari "Research Methodology" – New Age Publication

[20] James Anderson, Aaronn K. Ball "Cycle Time Reduction for Optimization of Injection Moulding Machine parameters for Process Improvements" in Session 105-039

[21] Gang XU1, Fangbao DENG2, Yihong XU"Adaptive Particle Swarm Optimization-Based Neural Network in Quality Prediction for Plastic Injection Moulding" Journal of Computational Information Systems 7:2 (2011) 462-470

[22] Taguchi G, Introduction to quality engineering. New York; Mc Graw Hill; 1990

[23] Aggarwal, Aman; and Singh Hari. 2005), Optimization of machining techniques A retrospective and literature review, Sadhana, Vol. 30, Part 6, December, pp. 699–711.

Author Profile

Harshal P. Kale received the B.E.degree in Mechanical Engineering from Bapurao Deshmukh College of Engineering in 2003. Pursuing M.E. (Production) at Government Engineering College, Aurangabad, Maharashtra, India