Effect of Injection Moulding Process Parameter on Warpage of using Taguchi Method

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Abstract: The growth of plastic industry is increasing very rapidly in the world. Plastic industry plays important role in the development of economy of any country progress. The plastic products are light in weight in comparison to metals and nonmetals products. Metal and non-metals are rarely available on the earth. So to manufacture plastic products is beneficial for us. Generally plastic products are manufactured by injection moulding process. The process parameters which affect the product quality are necessary to control. The aim of this paper is to minimize the surface defect warpage which occur in plastic products. By controlling the process parameter we can control warpagedefect. Since handling the different process parameter is mammoth task that costs time, effort and money. The process parameter melt temperature, mould temperature, packing pressure, packing time and cooling time are studied. The Taguchi method is used by exploiting mold analyses based on two levels. Orthogonal arrays of Taguchi, Signal-to- noise ratio, the analysis of variance are utilized to find optimal the optimal levels and effect of process parameters on sink marks defect.

Keywords: Injection moulding, Taguchi method, Warpage, Polypropylene polymer

1. Introduction:

Injection molding is one of the major net shape forming processes for thermoplastic polymers. Over 30% of all the plastic parts manufactured are by injection molding. Injection molding is ideally suited for manufacturing large quantities of mass produced plastic parts of complex shapes and sizes. In the injection molding process, hot melt of plastic is forced into a cold empty cavity of desired shape called mold. Then, the hot melt is allowed to solidify. Solidified net shape product is ejected out of the mold upon opening. Although the process is simple, prediction of final part quality is a complex phenomenon due to the numerous processing variables. We can study defects on the basis of two categories in the injection moulding. One is dimensional defect and other is attributed defect.

Dimensional related defects can be controlled by correcting the mold dimensions. But, attribute related defects are generally dependent on the processing parameters. Some of the common attribute related defects are warpage, splay marks, sink marks, voids, weld/meld lines, poor surface finish, air traps, burn marks etc. Of all attribute defects, warpage marks are considered to be perennial. The warpage can be defined as the difference between the geometry of the CAD model created for manufacture of the mold and the dimensions of the molded part and the warpage are effects of variations in shrinkage. The shrinkage can be characterized by two broad classifications: volumetric and linearized. The volumetric shrinkage is the result of thermal contraction, which occurs in all polymers, and of crystallization which occurs in semi-crystalline polymers.

A great deal of research is being carried out to understand, identify critical factors and possibly the molding processes. Most of the work carried out in the last decade was based on: theoretical, computer based simulation models and practical experimental trials. **Erzurumlu and Ozcelik (2006)** used Taguchi technique to minimize warpage and the sink index. In their study they considered mold temperature, melt temperature, packing pressure, rib cross section and rib layout angle and material PC/ABS, POM,PA66. They find in their research that packing pressure is influence the factor for PC/ABS plastic products, rib cross section influence POM material plastic product and rib layout angle influence PA66 material plastic product significantly. **Baburozcelik et al (2010)** attempted to study on mechanical properties of material with using taguchi method. They consider melt temperature, packing time, cooling time, injection pressure. **Zhao Longzhi et.al.(2010)** study the sink marks defect with simulation with the help of software mold flow and did experiment with the help of taguchimethod. In their research they study on Polypropylene material and process parameter melt temperature, mold temperature, injection time, holding pressure, cooling time.**Stanek, M.etal. (2010)** study mold design with the help of Cadmould software. They explain that Cadmould software can calculates filling time, speed and vulcanization time in the mold and consequent after curing depending on the material and technological parameters.**Huang, M. Set. al. (2007)** study the cavity pressure profile in the mould of injection moulding machine. In their experimental research they find innovative switchover method yields a more uniform product weight that any traditional methods after study the filling condition in the mold. **Rezavand, S. A. M et.al. (2007)** presented a simplified wax model of gas turbine blade. Their study on the mold filling condition in the investment casting process, they explain that major steps in investment casting processes are injection molding of Wax pattern, ceramic coating, removing wax, drying and material casing. In the mold manufacturing they consider injection temperature and holding time as processing variables. They found that holding time to be more dominant than that of injection temperature. **Sahputra, I. H.et.al. (2007, December).**study on the mold flow condition of injection moulding process with the help of SIMPOL and MPI software. They compare the software result. They find MPI software generated simulation analysis report gave good results in comparison to SIMPOL software.

2. Methodology:

A. Taguchi method:

Taguchi method was developed by Dr. Genichi Taguchi of Japan. The objective of the method is to produce high quality product at low cost and time to the manufacturer. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters that affect process and the levels. Orthogonal Arrays (often referred to Taguchi Methods) are often employed in industrial experiments to study the effect of several control factors.

B. Signal-to-Noise Ratio (S/N Ratio): The S/N ratio is the ratio of mean (signal) to standard deviation (Noise), which indicates scattering around a target value. This ratio helps to identify the optimum level of process parameters. The combination of process parameters with the highest S/N ratio will be the optimum setting of process parameters. A high S/N ratio is desirable as the signal level is much higher than the random noise level that leads to best performance. The calculation of S/N ratio depends on the quality characteristics of the product or process to be optimized.Generally, there are three categories of quality characteristic in the analysis of the S/N ratio, i.e. smaller-is-better, larger-is-better, and nominal-is-better. In the present experimental design, the smaller-is-better type quality characteristics is used which is expressed as:

$S/N=-10 \log_{10}(MSD)$ -------------(1)

For smaller is better

$$MSD = \frac{1}{n}\sum_{i=0}^{n} y_i^2$$

Where MSD = Mean Square Deviation

y = Observations

n= No. of tests in a trial.

3. Experimental plan:

A. Selection of Process Parameters and their Levels:For the present experimental work the four process parameters each at three levels have been decided. Experiment has been planned according to existing data. It is desirable to have three minimum levels of process parameters to reflect the true behavior of output parameters of study. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters/factors are given in Table.1:

Table.1

Process parameter and their levels:

Melt temperature(MT)	230	235	240
Injection pressure(IP)	20	25	30
Packing pressure(PP)	12	18	24
Packing time(PT)	4	8	12
Cooling time(CT)	30	60	90

For each trial in the L27 array, the levels of the process parameters are indicated:

Table 2: Warpage height for various Experiments numbers

Run order	Melt Temperature(MT)	Injection Pressure(IP)	Packing Pressure(PP)	Packing Time(PT)	Cooling Time(CT)	Warpage Depth	S/N ratio
1.	230	20	12	4	30	.025460	31.88283
2.	230	20	12	4	60	.056458	24.96550
3.	230	20	12	4	90	.088900	21.02200
4.	230	25	18	8	30	.088617	21.04970
5.	230	25	18	8	60	.036564	28.73890
6.	230	25	18	8	90	.053858	25.37500
7.	230	30	24	12	30	.065347	23.69550
8.	230	30	24	12	60	.083950	21.51960
9.	230	30	24	12	90	.038355	28.32356
10.	240	20	18	12	30	.020054	33.95600
11.	240	20	18	12	60	.043997	27.13153
12.	240	20	18	12	90	.074100	22.60363
13.	240	25	24	4	30	.072478	22.79587
14.	240	25	24	4	60	.030481	30.31941
15.	240	25	24	4	90	.042833	27.36443
16.	240	30	12	8	30	.058235	24.69631
17.	240	30	12	8	60	.068565	23.27795
18.	240	30	12	8	90	.032409	29.78668
19.	250	20	24	8	30	.022367	33.00784
20.	250	20	24	8	60	.037175	28.59498
21.	250	20	24	8	90	.063400	23.95821
22.	250	25	12	12	30	.061962	24.15749
23.	250	25	12	12	60	.031746	29.96621
24.	250	25	12	12	90	.035834	28.91409
25.	250	30	18	4	30	.062701	24.05451
26.	250	30	18	4	60	.060334	24.38875
27.	250	30	18	4	90	.033013	29.62630

4. Response effect for signal to noise ratio (S/N) of Warpage:

A lesser value of S/N ratio is always considered for the better performance irrespective of the performance characteristics. The difference of maximum and minimum mean S/N ratio indicates the significance of process parameter. Greater will be the difference greater will be the greater will be the significance.

Table 3: Response Table for Signal to Noise Ratios Smaller is better

Level	Melt temperature(MT)	Injection Pressure(IP)	Packing Pressure(PP)	Packing Time(PT)	Cooling Time(CT)
1	25.17	27.46	26.59	26.27	26.59
2	26.88	26.52	26.54	26.50	26.54
3	27.41	25.49	26.33	26.70	26.33
Delta	2.23	1.97	0.30	0.43	.26
Rank	1	2	4	3	5

From the table 3 the overall mean for the S/N ratio of the Warpage height is found to be .53576 mm.The analysis was made using popular software specially used for design of experiment applications known as MINITAB 16

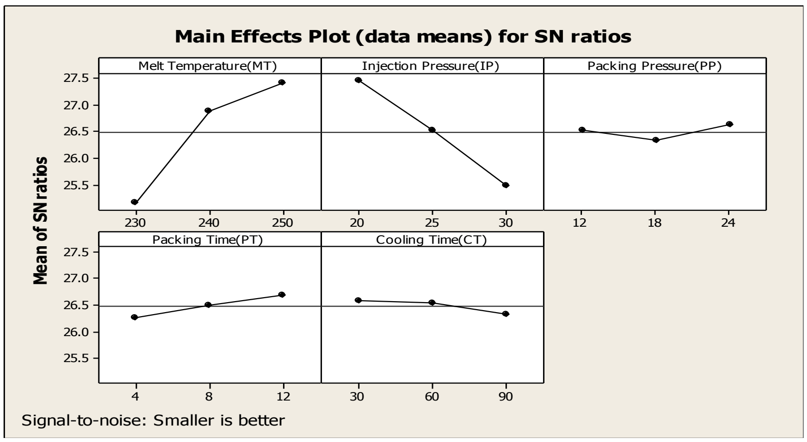

Fig: 1 Effect of control factors on Warpage Depth

5. Confirmation Test:

Once the optimal level of the cutting parameters is recognized, acquired from the analysis, it is customary to verify.

Table 4: Optimal setting for Warpage depth

Melt Temperature(MT)	Injection Pressure(IP)	Packing Pressure(PP)	Packing Time(PT)	Cooling Time(CT)
230	30	18	4	90

The confirmation experiments are performed to facilitate the verification of the injection moulding process at the obtained feasible optimal input parametric setting.

6. Conclusion:

Plastic injection moulding is quite important field in manufacturing process. There are many plastic products that produced by injection moulding. So manipulation of numerous processing variables of the injection moulding process to control defects is mammoth task that costs time, effort and money. This paper describes a simple and efficient approach to study the influence of injection molding variables on warpage using Taguchi method. Application of Taguchi approach also helps to find out optimal parameter setting. The result shows the ability of this approach to predict Sink depth for various combination of processing variables with in design space.

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