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Determining the Optimum Parameters of Plastic Injection Moulding for the Production of Bottle Cover

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Abstract: ***Today's the plastic injection moulding process is the widely used manufacturing process for the production plastic products. The main aim of this paper is to study the effect of different parameters on polypropylene work material for a plastic injection moulding process during manufacturing of bottle cover. The optimization of different parameters like melting temperature, injection pressure and cooling time are done which mainly affects the mechanical properties of the bottle cover. The taguchi method, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to analyse the effect of process parameters of plastic injection moulding on the tensile strength of the bottle cover of polypropylene material.***

Keywords: ANOVA, plastic injection moulding, polypropylene, S/N ratio, taguchi method, tensile strength

1. Introduction

Plastic is known to be a very versatile as well as economical material and is used in many applications. The popularity of the plastic is increase speedily due to its wide variety of industrial applications is the tremendous range of properties exhibited by plastic and there ease of processing [1]. The injection moulding process is one of the most widely used manufacturing process for the production of plastic products. Injection moulding is the most important method for manufacturing varieties of plastic components. It is based on the ability of thermoplastic materials to be softened by heat and to harden when cooled [2]

Plastic injection moulding uses plastic in the form of pellets or granules as a raw material. It is then heated until a melt is obtained. Then the melt is injected into a mould where it is allowed to solidify to obtain the desired shape. The mould is then opened and the part is ejected. The process parameters such as cycle time, fill time, cooling time, injection time, injection speed, injection pressure, holding pressure, melting temperature, mould temperature and so on need to be optimised in order to produce finished plastic parts with good quality. Various studies have been conducted to improve and optimise the process, so as to obtain high quality parts produced on a wide range of commercial plastic injection moulding machines [3-5].

The work material used in this research is Polypropylene. Polypropylene is a thermoplastic polymer having chemical formula $(C_3H_6)_n$ and chemical name of poly(1-methylethylene). It is a very versatile material; it offers very great combinations of properties such as light weight, strong, high heat resistance as well as stiffness and flexural retention. By these properties polypropylene is easily fabricated. The polypropylene has many variants but the material used is homopolymer polypropylene [6].

2. Experimental Planning

The plastic injection machine setup used for the experimentation is shown in the fig. 1. The injection moulding machines are of three types on the basis of their driving system which are hydraulic, mechanical and electrical; they can also be divided into two categories according to the position of their injection unit which are horizontal and vertical. There are large verities of injection moulding machine in the market but the most commonly used are horizontal hydraulically driven injection moulding machine. The material used for the manufacturing of bottle cover is polypropylene. The polypropylene has many variant in the market but the material used in this research is homopolymer polypropylene of H110MA grade. The universal testing machine (UTM) is used for the tensile test having load limit of 140 tones.

3. Design of Experiment

In the design of experiment the best set of the parameters of different factors are identified by using the taguchi method. Taguchi techniques were developed by Dr. Genichi Taguchi. Taguchi developed the foundations of robust design and validated its basic philosophies by applying them in the development of many products (Phadke, 1989). Taguchi method can be used for optimization methodology that improves the quality of existing. The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimisation. It has been widely used for product design and process optimisation worldwide.

The plastic injection moulding process has many parameters which affects the tensile strength of the product. But the most effecting parameters are injection pressure, melting temperature and cooling time. The four levels are considered

for the parameters according to the thermal properties of the polypropylene are shows in table 1

The L_{16} (4^3) orthogonal array is used in this research. In an L_{16} (4^3) orthogonal array four levels of each parameters are conducted where the selection of the array is because of its suitability for three parameters with four levels. The used orthogonal arrays for the injection moulding parameters in the research are shows in table 2.

The tensile test of the specimen produced during the above tests is completed on the universal testing machine. The tensile strength of each test specimen produced according to trials of orthogonal array is shown in table 3. By this obtained tensile strength the S/N ratio is calculated are shown in table 3.

To analyse this values the analysis of variance (ANOVA) is used for which the percentage distribution of the impact of the parameters over the tensile strength of the material is determined.

4. Result and Discussion

The tensile strength of any material is necessary, higher is the strength which means higher the quality, therefore the S/N ratio for larger-the-better is used for which the formula is give as follows:

$$\eta = -10 log_{10} \left[\frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_i^2} \right]$$

Where, η is the S/N ratio in dB,
n is the number of replication of i_{th} experiments,
y_i is the response value or quality characteristics at i_{th} experiments.

Similarly the S/N ratio is calculated for the tensile strength. So the S/N ratio for all the parameters at the different levels is shown in table 4. which is the average of S/N ratios for each levels.

The graphs are plotted for each of the parameters with the S/N ratio to show the best result of combinations of the parameters to obtain higher strength of the product. The graphs for the parameters are shown in fig 2-4.

From the fig. 2-4 the desired combinations of parameters are obtained for the higher strength of the material which are 215 ^{0}C, 65 MPa and 5 sec.

Form the ANOVA method the percentage distribution of these parameters is obtained which are shows in table 5. The percentage contribution of the parameters to improve the strength are 68.46% of melting temperature, 3.73% of injection pressure and 9.19% cooling time, which describes that the melting temperature is the most significant parameter to improve the tensile strength of the bottle cover.

5. Figure and Tables

Figure 1: Plastic injection moulding machine

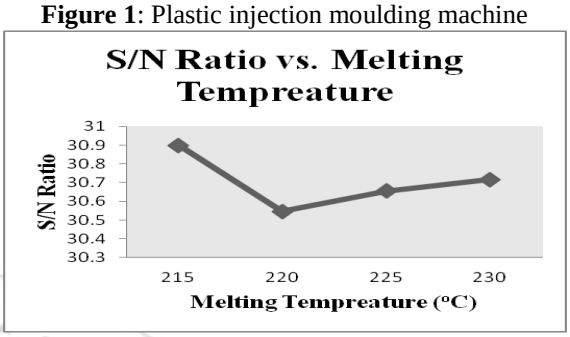

Figure 2: plot between melting temperature and s/n ratio

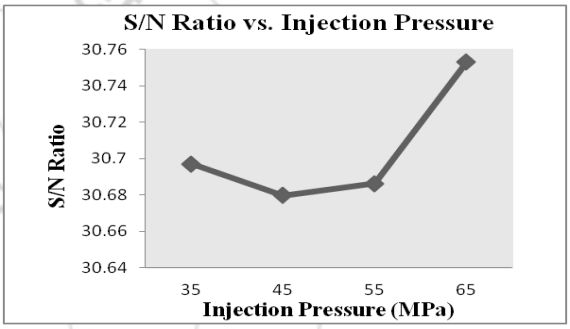

Figure 3: plot between injection pressure and S/N ratio

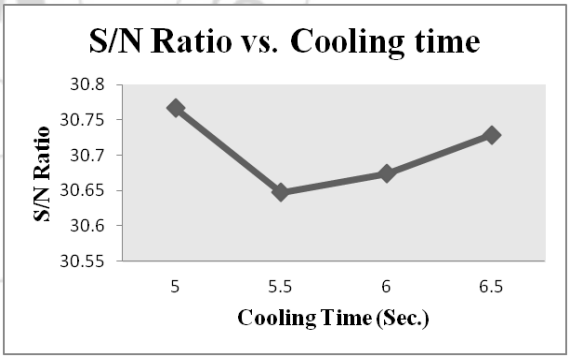

Figure 4: plot between cooling time and S/N ratio

Table 1: Parameters And Their Levels

S. No	Symbol	Parameters	Levels			
			1	2	3	4
	A	Melting temperature (^{o}C)	215	220	225	230
	B	Injection pressure (MPa)	35	45	55	65
	C	Cooling time (sec.)	5	5.5	6	6.5

Table 2: L_{16} (4^3) orthogonal array used for different parameters and their values

Experiment No.	Columns		
	A	B	C
1	215	35	5
2	215	45	5.5
3	215	55	6

4	215	65	6.5
5	220	35	5.5
6	220	45	5
7	220	55	6.5
8	220	65	6
9	225	35	6
10	225	45	6.5
11	225	55	5
12	225	65	5.5
13	230	35	6.5
14	230	45	6
15	230	55	5.5
16	230	65	5

Table 3: tensile strength test and S/N ratio value

Experiment No.	Columns			Tensile strength	S/N ratio
	A	B	C		
1	215	35	5	35.4	30.979
2	215	45	5.5	34.9	30.856
3	215	55	6	34.3	30.705
4	215	65	6.5	35.7	31.051
5	220	35	5.5	33.2	30.423
6	220	45	5	33.8	30.579
7	220	55	6.5	33.9	30.604
8	220	65	6	33.8	30.579
9	225	35	6	34.4	30.731
10	225	45	6.5	33.9	30.604
11	225	55	5	34.3	30.705
12	225	65	5.5	33.8	30.579
13	230	35	6.5	34.1	30.655
14	230	45	6	34.2	30.68
15	230	55	5.5	34.4	30.731
16	230	65	5	34.7	30.803

Table 4: S/N ratio for each factor

Parameters	Levels			
	1	2	3	4
A	30.89775	30.54625	30.65475	30.71725
B	30.697	30.67975	30.68625	30.753
C	30.7665	30.64725	30.67375	30.7285

Table 5: percentage distribution by ANOVA method

Parameters	*Sum of squares*	*Degree of freedom*	*Variance*	*F_0 value*	*Percentage contribution*
A	4.135	3	1.378333	7.351111	68.46
B	0.225	3	0.075	0.4	3.73
C	0.555	3	0.185	0.986667	9.19
Error	1.125	6	0.1875		18.62
Total	6.04	15	1.825833		100

6. Conclusion

Form this research it has been concluded that in the manufacturing of the bottle cover by injection moulding process the melting temperature having contribution of 68.46% are considered as the most significant parameter followed by the cooling time and injection pressure. So the best set of parameters for the tensile strength of the bottle cover is 215 ^{0}C melting temperature, 65MPa injection pressure and 5 sec. cooling time. The influence of all factors has been identified and believed can be a key factor in helping mould designers in determining optimum process conditions injection moulding parameters.

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