Experimental Analysis and Optimization of Process Parameters of Plastic Injection Moulding for the Material HDPE

S.S.Bajaj1, Dr.D.B.Magar2, K.R.Dachawar3

1. Asst. Prof. DIEMS A'bad, swati.bajaj64@gmail.com

2. Asst. Prof. DIEMS A'bad, deepakbmagar@gmail.com

3. Asst. Prof. DIEMS A'bad, dachawarkr@gmail.com

ABSTRACT

Abstract In present work, experimental analysis and optimization of process parameters of plastic injection moulding has been reported. Response surface methodology (RSM) has been utilized to investigate the influence of three important input parameters – plasticizing temperature, injection pressure and cooling time on two performance characteristics- Tensile Strength and Flexural Strength of material High Density Polyethylene (HDPE). Centered central composite design was employed to conduct the experiments and to develop a correlation between the process parameters and performance characteristics. The analysis of experimental work is performed using MINITAB 16 statistical software. Response surface methodology (RSM) was applied for developing the mathematical models in the form of regression equation and to find optimized values of process parameters. The optimum set of process parameters obtained are cross validated by using ANOVA method. The influence of all factors has been identified which can play a key role in increasing Tensile and Flexural Strength HDPE. Surface plots and Contour plots have been plotted for studying combined effect of two factors while keeping other factor at their mid-values. From ANOVA it is clear that for High Density Polyethylene to achieve maximum Tensile Strength plasticizing temperature is the most significant factor followed by cooling time and injection pressure.

***Keywords:** ANOVA, HDPE, MINITAB 16, RSM.*

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1. INTRODUCTION

Injection Moulding is one of the most important shape forming process for thermoplastic polymer. Injection Moulding converts wax, thermoplastics, thermo sets as well as powdered metals and magnesium into thousands of products. Injection Moulding is the most commonly used manufacturing process for the fabrication of plastic parts. In this process, hot melted plastic is forced into a mould. Then, the hot melt is solidified and the product is ejected out by opening the mould. A wide variety of products are manufactured using injection moulding, which vary greatly in their size, complexity, and application. Injection Moulding is a manufacturing process which is producing parts from both thermoplastic and thermosetting plastic materials transformation of plastic pellets into a moulded part. Identical parts are produced through a cyclic process.

2. SYSTEM MODEL

An injection moulding machine produces components by injection moulding process. Most commonly used machines are hydraulically powered in-line screw machines, although electric machines are appearing and will be more dominant in the market in near future. The main units of a typical injection moulding machine are the clamping unit, the plasticizing unit, and the drive unit; they are shown in Figure 1. The clamping unit holds the mould. It is capable of closing, clamping, and opening the mould. Its main components are the fixed and moving plates, the tie bars and the mechanism for opening, closing and clamping. The injection unit or plasticizing unit melts the plastic and injects it into the mould. The drive unit provides power to the plasticizing unit and clamping unit. The clamping force of typical injection moulding machines range from 200 to 100,000 kN.

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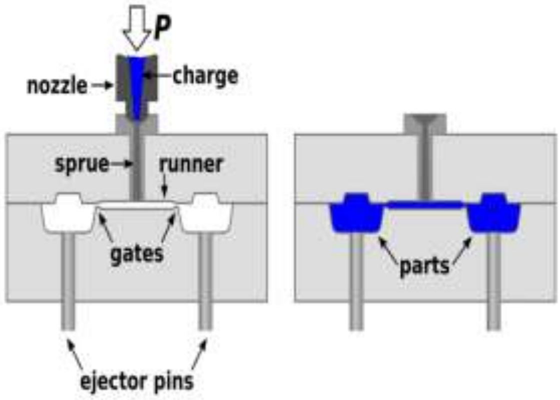


Figure no: 1 Injection Moulding Mould

There are three main stages in the injection moulding cycle: stage 1-injection, followed by stage 2- holding pressure and plasticizing and finally stage 3- ejection of the moulded part. When stage 3 is completed, the mould closes again and the cycle starts over again.

3. PREVIOUS WORK

S.Kamaruddin, Zahid A.Khan & S.H. Foong , Application of Taguchi Method in the Optimization of Injection Moulding Parameters for Manufacturing products from Plastic Bend, International Journal of Engg and Technology, 2010.

This paper presents a study in which an attempt has been made to improve the quality characteristic (shrinkage) of an injection molding product (plastic tray) made from blends plastic (75% polypropylene (PP) and 25% low density polyethylene (LDPE)) by optimizing the injection molding parameters using the Taguchi method. The performance of the plastic trays is evaluated in terms of its shrinkage behaviour. An orthogonal array (OA), main effect, signal-to-noise (S/N) ratio and analysis of variance (ANOVA) are employed to analyze the effect of injection molding parameters on the shrinkage behaviour of the product. The analysis of the results shows that the optimal combination for low shrinkage are low melting temperature, high injection pressure, low holding pressure, long holding time and long cooling time. Using Taguchi method for design of experiment (DOE), other significant effects such as interaction among injection molding parameters are also investigated. From the analysis of the results in injection moulding of plastic tray produced from the blend of 75% polypropylene (PP) and 25% low density polyethylene (LDPE) using the Taguchi approach, the following can be concluded from the present study.

Sanjay Lahoti, et.al, Optimization of Critical Processing Parameters for Plastic Injection Molding for Enchance Productivity and reduced time for development, International Journal of Advanced Engg Research and studies, 2014.

The main objectives of the process are to reduce cycle time by process parameters optimization to ensure high quality parts. The aim of this project work is to identify the factors affecting cycle time and to reduce cycle time to optimize process. The approach of design of experiment was successfully applied for the study which explained the linear model of injection molding process parameter for selected range of parameters of melt temperature, mold temperature, injection pressure, hold pressure and cool time for ABS and PP. The experimental work resulted into finding of the influence of molding process parameters. According to ANOVA analysis, the most effective parameters with respect to cycle time are melt temperature and injection pressure. The confirmation experiment was conducted and finds that there is no much difference in optimum condition.

Michael Packianather, et.al, Micro injection moulding process parameter tuning, ScienceDirect, 2015

This paper focuses on tuning the micro injection moulding process parameters. In this study four process parameters namely, barrel temperature, mould temperature, holding pressure and injection speed were considered. In order to capture their behaviour a L16 Orthogonal Array with two levels for each parameter was employed to produce the design of a 15 mm x 20 mm x 1 mm microfluidic platform using Cyclic Olefin Copolymer (COC), a common polymer. The demoulding force was measured during the micro injection moulding process. The sixteen trials were repeated ten times to incorporate process variation, systematic and random noise in the experimental procedure. The results were analysed using Taguchi method to identify the influence of the process parameters upon the demoulding force and their sensitivity to noise. In addition, the results also indicated either the presence or absence of the two level interactions between these process parameters. This study has contributed to understanding the characteristics of these process parameters in terms of their main effects, interactions and sensitivity to noise and to tune them for their optimal performance. Design of experiment using Taguchi L16 Orthogonal Array has been conducted with four process parameters namely, mould temperature, barrel temperature, holding pressure, and injection speed in order to understand the effect of these parameters during the micro injection moulding process. The analysis was carried out using Minitab16. Two criteria for S/N were used. This study has shown that the most significant parameters are mould temperature and holding pressure. Different polymers will be used in the future to study the effects of these process parameters upon different materials.

D.Bhattacharya & B.Bepari, Feasibility study of recycled polypropylene through multi response optimization of injection moulding parameters using grey relational analysis, ScienceDirect , 2014, aimed the feasibility of recyclability of polypropylene (PP) in injection molding based on grey relational analysis. Virgin to recycled material ratio (V: R), injection pressure (IP), injection temperature (IT) and injection speed (IS) were the parameters dictating the product's quality and they were all taken at three levels. The conclusion is obtained by results of various tests done on PP. The tests held are Tensile strength at the yield, Elongation at break, Density test and Vicat Softening Point test. The conclusion by test is the lower level of injection temperature, lower level injection pressure, higher level of injection speed must be chosen for virgin to recycled ratio of 95:05. Through investigation reveals that injection speed is the most dictating factor and other factors are injection pressure, virgin to recycled ratio and injection temperature.

4. PROPOSED METHODOLOGY

The Experimental Set-up (Injection moulding machine), work piece material, tensile and flexural sample specifications, process parameters (input and output) and measuring instruments.

4.1 Material used in the process

The tensile specimens are made by using High Density Polyethylene (HDPE).

High Density Polyethylene Injection Molding

Product Description:

180M50 is a High Density Polyethylene manufactured using Nova Chemical's Sclairtech Solution Polymerization Technology. 180M50 is a natural colored polymer with excellent flow properties, very good processability and excellent gloss.

4.2 Input Parameters

Plasticizing Temperature

Injection pressure

Cooling time

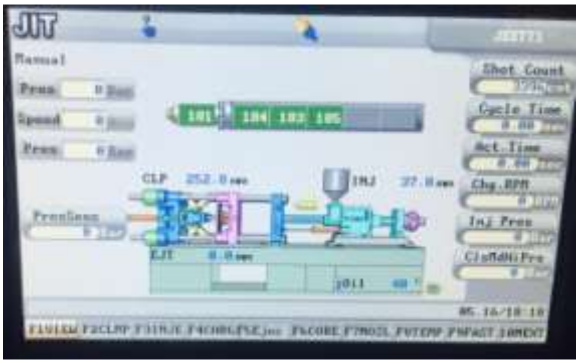


Figure no: 2 Injection Moulding Machine Settings

4.3 Response Parameters

Tensile Strength

Tensile Strength determines the behaviour of materials under axial stretch loading. Data from test are used to determine elastic limit, elongation, modulus of elasticity, proportional limit, reduction in area, tensile strength, yield point, yield strength and other tensile properties. Methods for tensile tests of plastics are outlined in ASTM D-638.

Tensile Specimen

The tensile specimens are manufactured on the injection moulding machine. The dimensions of the tensile samples are

ASTM D 638-2010 Dumbbell 127×12.7×3.2mm

5. SIMULATION/EXPERIMENTAL RESULTS

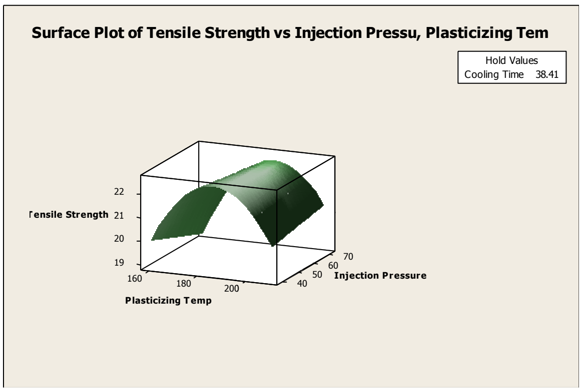
In this paper, the experimental results were obtained by conducting experiments based on DOE by Response surface methodology's (RSM) Central composite design using Minitab 16 software.

Plasticizing Temp	Injection Pressure	Cooling Time	Tensile Strength N/mm^2	Flexural Strength N/mm^2
185	38	30	22.2932	11.0336
200	65	25	20.2895	11.4234
185	55	30	22.2748	11.1689
185	55	30	22.2748	11.1689
170	65	25	22.3314	11.5889
185	55	30	22.2748	11.1689
160	55	30	19.2564	10.1265
185	72	30	22.5079	11.2899
200	45	25	19.8272	11.4554
210	55	30	20.6036	12.5946
185	55	22	22.1235	11.3664
185	55	30	22.2748	11.1689
170	45	35	22.0715	11.5836
185	55	30	22.2748	11.1689
200	65	35	21.2722	11.3575
185	55	38	22.534	11.3985
170	45	25	22.0876	12.0357
185	55	30	22.2748	11.1689
170	65	35	21.6184	11.7723
200	45	35	20.8451	12.6355

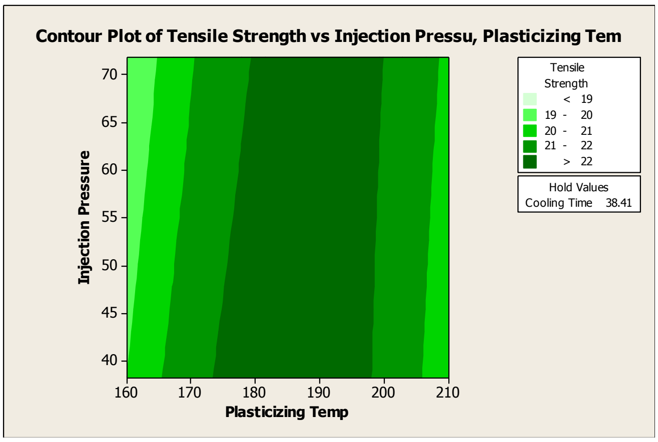
Table no: 1 High Density Polyethylene input and output parameters values in RSM

5.1 Central Composite Design for Tensile Strength of High Density Polyethylene

Response surface design selected according to D-optimality



Graph: 1 Surface Plot of Tensile Strength vs Injection Pressure, Plasticizing Temperature, Cooling Time (HDPE)



Graph: 2 Contour Plot of Tensile Strength vs Injection Pressure, Plasticizing Temperature, Cooling Time. (HDPE)

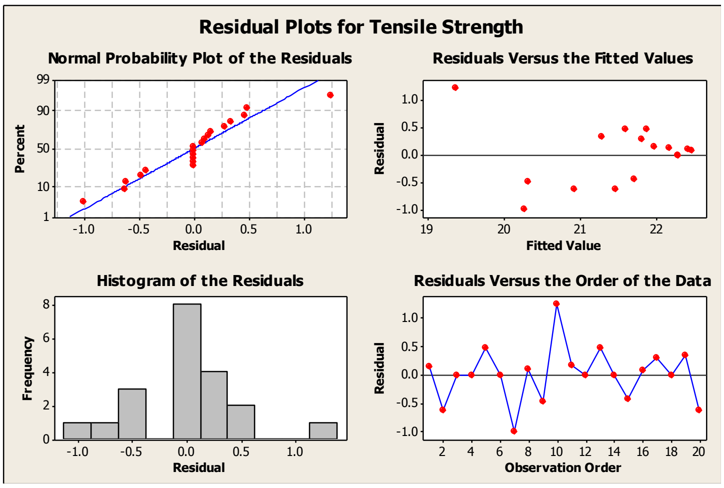
Term	Coef	SE Coef	T	P
Constant	-37.5723	16.8693	-2.227	0.050
Plasticizing Temp(A)	0.7351	0.14	5.253	0.0001
Injection Pressure(B)	0.107	0.1643	0.651	0.530
Cooling Time(C)	-0.6039	0.3432	-1.76	0.109
A*A	-0.0023	0.0003	-6.558	0.0001
B*B	-0.0001	0.0008	-0.196	0.848
C*C	-0.0021	0.0033	-0.633	0.541
A*B	-0.0006	0.0007	-0.918	0.38
A*C	0.0039	0.0014	2.811	0.018
B*C	0.0007	0.0021	0.327	0.75

S = 0.2921   R-Sq = 88.2%   R-Sq(adj) = 77.7%

Table no: 2 Analysis of Variance for Tensile Strength (HDPE)

5.2 Validation of the Models: Graphical Tools

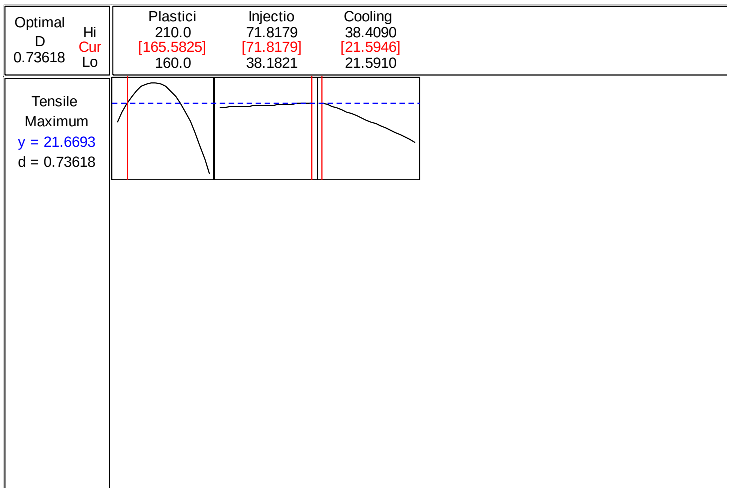
It is usually necessary to check the fitted model to ensure it provides an adequate approximation to the real system. Unless, the model shows an adequate fit, proceeding with investigation and optimization of the fitted response is likely to give poor and misleading results. Graphical tools can be used for validation of the models. The graphical method characterizes the nature of residuals of the models. A residual is defined as the difference between an observed value and its fitted value. Graphs below show the residual plots Tensile for the material HDPE.



Graph: 3 Residual Plots for Tensile Strength for High Density Polyethylene

5.5 RSM Optimization

Tensile strength within the experimental constraints. In this context, a response surface optimization is attempted using Minitab software. The objective function for optimization was set to achieve the maximum value of Tensile strength for the material HDPE.



Graph: 4 Response Optimizer for Tensile Strength (HDPE)

From the response optimizer graph, to achieve maximum value for tensile strength i.e. 21.6693N/mm^2 the global solution for the input parameters is:- Plasticizing Temperature = 165.582 ^{0}C Injection Pressure = 71.818bar

Cooling Time = 21.595sec

6. CONCLUSIONS

In experimental analysis and optimization of process parameters of plastic injection moulding for the material HDPE . Response surface methodology (RSM) has been utilized to investigate the influence of three important input parameters – plasticizing temperature, injection pressure and cooling time on Tensile strength of material HDPE. Centered central composite design was employed to conduct the experiments and to develop a correlation between the process parameters and performance characteristics. The analysis of experimental work is performed using MINITAB 16 statistical software.RSM was applied for developing the mathematical models in the form of regression equation.Surface plots and Contour plots have been plotted for studying combined effect of two factors while keeping other factor at their least-values. From ANOVA it is clear that for HDPE to achieve maximum Tensile Strength plasticizing temperature is the most significant factor followed by cooling time and injection pressure.

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