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Experimental Investigation and Optimization of Blow Molding Process Parameters of HDPE Material

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Abstract: Optimization of machining processes is essential for achieving higher productivity and high-quality products in order to remain competitive. The objective of this study is to optimize the process parameter of extrusion blow molding process of high density polyethylene (HDPE). In this paper three process parameters namely barrel temperature, Mandrel Position, Screw Rotation. Taguchi Method is a statistical method to improve the process parameters and improve the quality of components that are manufactured. ANOVA has been carried out to identify importance of the operating parameters on the performance characteristics considered. Further the verification experiment has been carried out to confirm the performance of optimum parameters. The results from this study will be useful for selecting appropriate set of process parameters to epoxy coating has been selected. The analysis of variance (ANOVA) has been used to determine effect of each parameter on wear rate so Finally, the confirmation test has been carried out to compare the predicted value of wear rate with the experimental value.
Keywords: Taguchi Method, HDPE, Blow molding, ANOVA.

I. INTRODUCTION

The modern manufacturing industry makes significant use of plastic in a variety of applications. Plastic products may be manufactured using a wide variety of techniques, some of which include blow molding, casting, compression molding, extrusion, fabrication, foaming, injection molding, rotational molding, and thermoforming. Injection molding is a manufacturing method that may be used to make plastic injection molds from both thermoplastic and thermosetting plastic materials. The molds are then injected into the plastic. The injection molding manufacturing technique allows for excellent dimensional units and has a high rate of production. As a result, the method of injection molding is the one that is utilized the most frequently in the plastics sector. In addition to that, injection molding machines have the capability of producing intricate components and forms. Design of experiments, often known as DOE, is a strategy that is both practical and methodical, and it is used to limit the mistake that is associated with finding the link between the factors of the process and the quality of the result. The optimization of the process setup is something that may be done with the assistance of DOE.
The objective of today's industry is to produce goods that are of excellent quality at a cheap cost and in a relatively short amount of time.In order to achieve this goal, automated production systems, in conjunction with PLC control, are utilized.Extrusion blow molding machines that are capable of obtaining high precision while simultaneously reducing the amount of time required for processing. The production of high density polyethylene (HDPE) containers is most frequently accomplished through the process of blowing. In addition, in order to manufacture any product with the shape and dimensions that are desired.

II. MATERIAL AND METHODS

A. Methodology of Experiment

Based on the present molding process followed, some of the problems were identified such as Parameters like as barrel temperature, mandrel position and screw rotation etc. play an important role in maximum ultimate load so as to overcome the existing problem, few optimization technique has to be incorporated.
To get the perfect result of the molding process by using the blow molding we need to find the correct parameter setting. Until now, so, it is important to find the best parameter setting before start the machining process in order to achieve the maximum result in its ultimate load. In this work, HDPE material is to be used as the specimen material. There are many processes which are studied to optimize the molding of HDPE material by using injection molding machine. The main focus in this work is to optimize the ultimate load while molding HDPE material.

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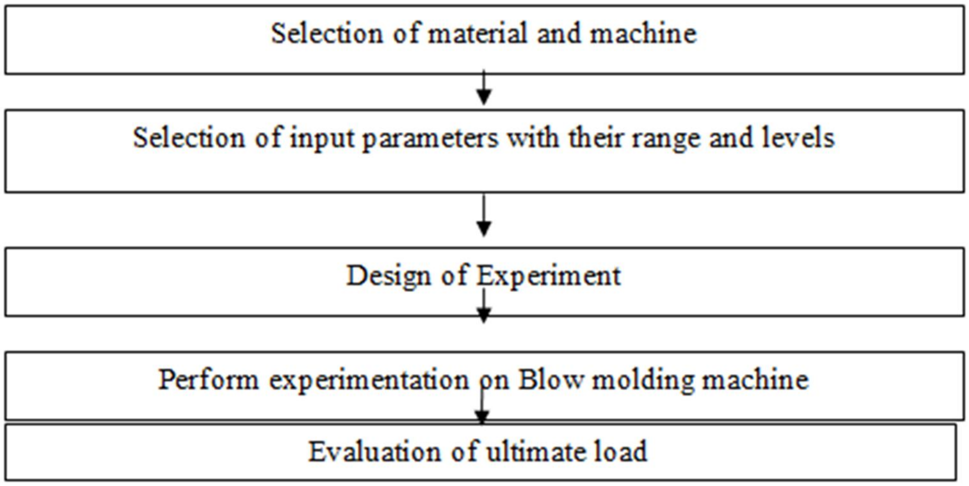

Figure1: Flow chart for Experimentation Design

B. Experimental Machine Selection

All the experiments were conducted at Nitin Industries, MIDC Chikalthana, Aurangabad, M.S, India

Figure 1. Blow molding Machine

Table 1. Blow Molding machine Specification

Capacity (Kg/hr)	1100-4200 BPH
Production Capacity	1100 1200 BPH
Mould Thickness Min	150mm
Lamp Power	2000W.
Compressor Power	20HP
(W×H) Mold Platen	1200×1720mm

C. Selection Of Material

HDPE molding is the injection molding of parts using the material high-density polyethylene (HDPE). It is a commonly used plastic because it is lower in cost and has good chemical and impact resistance

Fig.2 HDPE Material

The material used for this work is. HDPE material is a general purpose plastic industry that is typically used in applications where better strength, stress corrosion resistant and corrosion protection required.

Table: 2 Properties of HDPE material

Property	Value
Density (g/cc)	0.96
Melt Flow Index (g/10 min)	8.0
Tensile strength at yield (Mpa)	25
Elongation at yield (%)	11
Elongation at break (%)	800
Flexural strength (Mpa)	30

III. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters Barrel Temperature, Mandrel Position and Screw Rotation on output Ultimate Load, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 19 statistical software has been used. It has been done. ANOVA has been conducted to find out effect of each parameter on the Ultimate Load and linear regression model has been established to predict the values Ultimate Load.

A. Evaluation of S/N Ratio

Table 4 shows the L9 orthogonal array with measurement of Ultimate Load for runs one to nine. It also shows S/N ratio for all nine experiments.

Table 3 L9 orthogonal array with response characteristic

Experiments	Inputs Factors			Output Responses	
Trial No.	Barrel Temperature	Mandrel Position	Screw Rotation	Ultimate Load	S/N ratio
1	175	Above	10	1139.13	61.1314
2	175	Intermediate	15	1053.17	60.4500
3	175	below	20	1254.14	61.9669
4	185	Above	15	1103.92	60.8587
5	185	Intermediate	20	1114.52	60.9418
6	185	below	10	956.67	59.6152
7	195	Above	20	1161.50	61.3004
8	195	Intermediate	10	954.57	59.5962
9	195	below	15	995.50	59.9609

The S/N ratio values are calculated with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

B. Main Effects of UTS

The influence of each control factor (Barrel Temperature, Mandrel Position and Screw Rotation) Ultimate load was analyzed from the S/N ratio response table, which expresses the S/N ratio at each level of control factor. The control factor influence is determined by its level difference values. A bigger control factor level difference means a greater influence on the Ultimate load. Measured of SN ratio:

Figure 3 shows the main effects plot from S/N ratios.

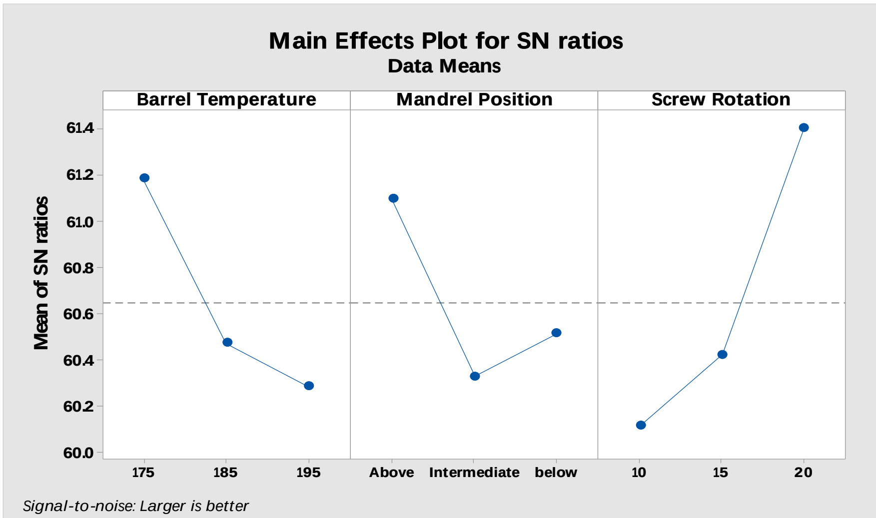

Figure: 3 Main Effects Plot for S/N Ratio

The optimal input parameters were Barrel temp 175oC (level 1), Mandrel position above (level 1) and Screw rotation 20Hz (level 3). The graph graphically shows the effect of the control factors on HDPE material. The configuration of the process parameters with the highest ratio always provides the optimum quality with a minimum variation. The graph shows the relationship change when the control factor configuration was changed from one level to another.

C. ANOVA Result

The analysis of variance was carried out at 95% confidence level. The main purpose of ANOVA is to investigate the influence of the designed process parameters on Tensile strength by indicating that, which parameter is significantly affected the response. This is accomplished by separating the total variability of the S/N Ratios, which is measured by the sum of squared deviations from the total mean of the S/N ratio, into contributions by each welding process parameter and the error. The percentage contribution by each of the welding process parameters in the total sum of the squared deviations can be used to evaluate the importance of the process parameter change on the quality characteristic. Degrees of freedom (DOF) for OA should be greater than or at least equal to those for the parameters. In this study, Table 5 shows results obtained from analysis of variance

Table 4 ANOVA Result.

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Barrel Temperature	2	1.3445	0.67227	7.06	0.031	25.78
Mandrel Position	2	0.9627	0.48135	5.06	0.045	18.46
Screw Rotation	2	2.7164	1.35822	14.27	0.015	52.09
Residual Error	2	0.1903	0.09516			
Total	8	5.2140				

It shows that the table shows that the barrel temperature (25.78%), the Mandrel Position (18.46%) and the Screw Rotation (52.09%) have a major influence on the ultimate load.

D. Development of Regression Model for Ultimate load

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for ultimate load have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of ultimate load correlates with each other.

Regression Equation:

$$\text{Ultimate Load} = 1874 - 5.58 \text{ Barrel Temperature} + 15.99 \text{ Screw Rotation}$$

Table number 5 gives comparison between experimentally measured and predicted ultimate load by developed mathematical equation

Table 5 Experimental and Predicted Values of ultimate load

Sr. No.	Experimental value	Predicted value	Error %
1	660	663	0.54
2	639	631	1.26
3	618	600	3.01
4	650	664	2.10
5	625	632	1.10
6	588	610	3.60
7	665	669	0.59
8	678	642	5.60
9	598	611	2.12

Difference between ultimate load values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid.

E. Confirmation Experiment Result

Table 5 shows the difference between value of ultimate load of confirmation experiment and value predicted from regression model developed.

An experiment was conducted barrel temperature at level 1, Mandrel Position at level 1 and Screw Rotation 20Hz at level 3.

Table 6 Confirmation Experiment Result

Parameter	Predicted value	Experimental value	Error %
Ultimate load	1217.3	1272.47	4.53

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the ultimate load value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 4.53%. This indicates that the experimental value correlates to the estimated value.

IV. CONCLUSIONS

This paper investigates the implementation of Taguchi design in the estimation of optimum ultimate load of HDPE material and different working parameters. It had been concluded that Taguchi design prepare a useful methodology for the setup and optimization of ultimate load with minimum numbers of trials in comparison to other experimental design

This study covers the observations about the ultimate load over HDPE material by the process of blow molding for the different input parameters to thoroughly study over the effect of molding process on the HDPE material. Throughout the experimentation I got some results as under.

1) The optimal solution obtained for ultimate load based on the molding parameters and their levels is (i.e. barrel temperature 175oC at level 1, Mandrel position above 3mm at level 1 and screw rotation 20Hz at level 3. The time more significant Parameters than screw rotation and barrel temperature

2) Barrel temperature 175oC (level 1), Mandrel position above (level 1) and screw rotation 20Hz (level 3).
3) ANOVA results indicate that screw rotation plays prominent role in determining the ultimate load the contribution of barrel temperature, Mandrel position, screw rotation to the quality characteristics ultimate load is 25.78%, 18.46% and 52.09 % respectively.
4) The optimal process parameters are determined using Taguchi methods match with the experimental values by minimum errors i.e 4.53 % .
5) Through the developed mathematical models, any experimental results of ultimate load with any combination of blow molding parameters can be estimated.

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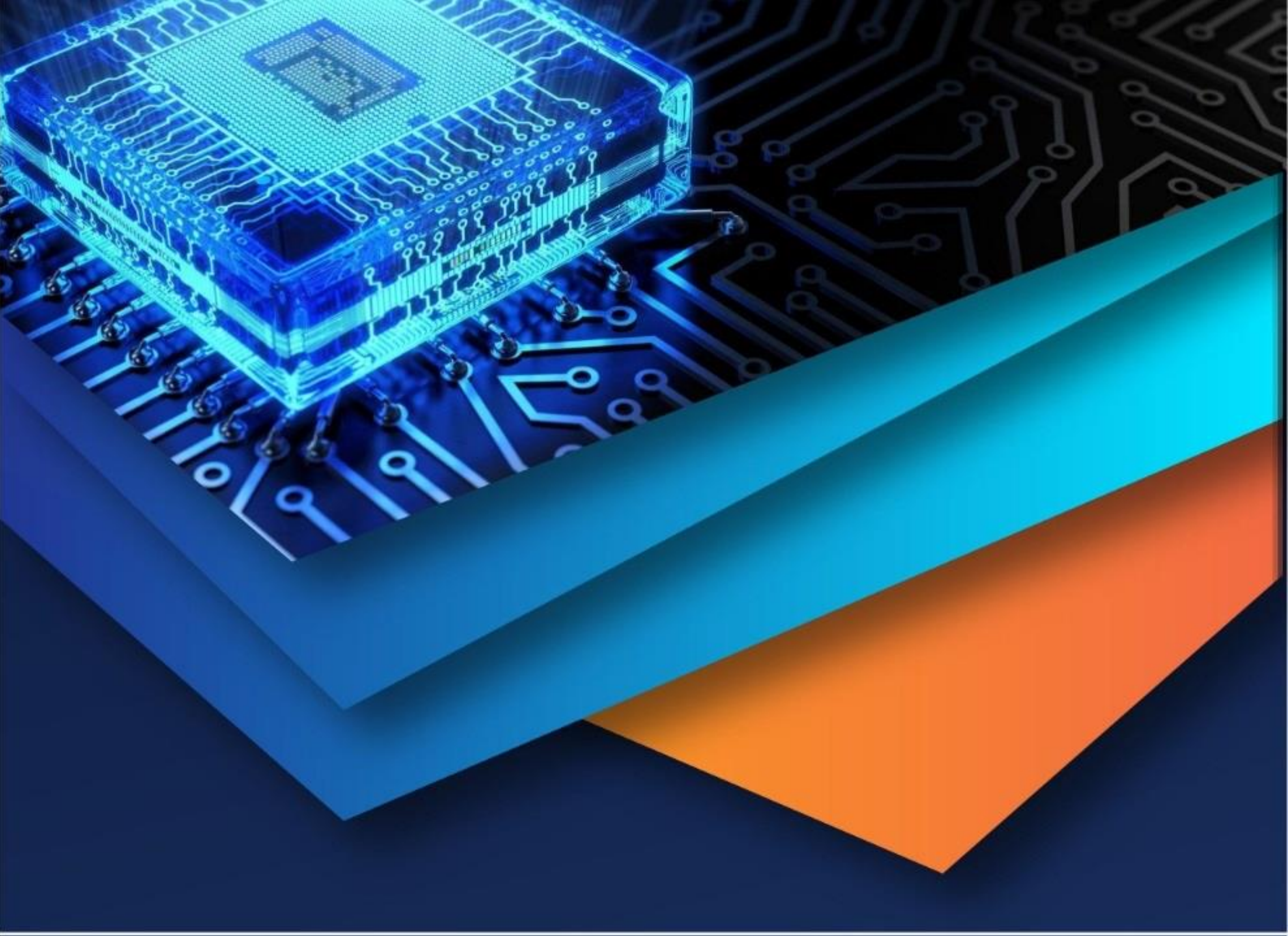

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