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Process parameters optimization for HDPE material in Extrusion Blown Film Machinery using Taguchi method

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Abstract: *Taguchi Method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. The objective of this study is to illustrate the procedure adopted in using Taguchi Method to a Extrusion blown film machinery. The orthogonal array, signal-to-noise ratio is employed to study the performance characteristics on tensile strength; a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimum level of the process parameters is the level with the greatest S/N ratio. In this analysis; four factors namely melting temperature, extrusion speed, extrusion pressure and winding speed were considered. Accordingly, a suitable orthogonal array was selected and experiments were conducted. After conducting the experiments the tensile strength was measured and Signal to Noise ratio was calculated. With the help of graph and table, optimum parameter values were obtained.*

Keywords: *orthogonal array, optimize, process parameter signal-to-noise ratio, tensile strength.*

I. Introduction

Blown film extrusion is one of the most widely used thin-gauge fabrication processes. The majority of the plastic films such as grocery bags, agricultural films and other flexible packaging films are produced by this technique. The method of producing film by extruding molten plastic is a simple process. The blown film line consists of an extruder, die, iris or bubble cage, air ring, collapsing frame, and a winder. It is one of the most important polymer processing technologies. Several billion pounds of polymer, mostly polyethylene, are processed annually by this technique. While some applications for blown film are quite complex, such as scientific balloons, the maximum products manufactured on blown film equipments are used in commodity applications with lower profit margins: grocery sacks, garbage bags, and flexible packaging. For optimization, we used the Taguchi technique, which is optimization power tool for the design of quality system. It introduced an integrated that is simple and efficient to find the optimum range of design for quality performance and computational cost[1] 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[2].The signal to noise ratio is simple quality indicator that researchers and designers can use to evaluate the effects of changing a particular design parameter on performance of the products.[3] Taguchi methods use a special design orthogonal array to study the entire factor with only a small number of experiments[4]. It introduces an integrated approach that is simple and efficient to find the designs for quality, performance and computational cost[5]. 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 [6].

Taguchi method uses the signal-to-noise (S/N) ratio instead of average value of the experimental data. The S/N ratio reflects both the average and the variation of the quality characteristics [7]. 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) [8]. In this study higher value of tensile strength is expected. Thus S/N ratio characteristics the higher – the- better is applied. This technique is helpful to study effect of various process parameters (variables) on the desired quality and productivity in a most economical manner. By analyzing the effect of various process parameters on the results, the best factor combination taken [9]. Taguchi designs of experiments using specially designed tables known as "orthogonal array". With the help of these experiments table the design of experiments become the use of these tables makes the design of experiments very easy and consistent [10].

II. Process Parameters

Effective extrusion process requires that the machine and tool operating in well conditions. This requires control over the process parameters such as temperature, pressure, machine speed, and the relative speeds of the auxiliary [11]. As these manufacturing processes involve steady state conditions, any action that can stabilize any parameter or condition is beneficial to the process [12]. Cycle time reduction has been also done successfully by considering proper selection of process parameters[13].These parameters have significant effects on microstructure, extrude quality, material flow behavior and strength of the extrude. So these parameters need to be analyzed and according to this modeled the extrude product [14]. Proper selections of all the process parameter put direct impact on the quality and productivity of the plastic product so by considering all these factors some important process parameters like Melting temperature, Extrusion pressure, Winding speed and Extruder speed are selected and for conducting the experiments some set of definite values of all the process parameters are taken in the Table-1. The values of process parameters are taken by the proper discussion with the industry and CIPET (Central Institute of Plastic Engineering & Technology) personals. After confirming about the significance of all the process parameters the values of the process parameters are listed as a table.

S.NO.	Process Parameters	Units	Level 1	Level 2	Level 3
1	Extrusion pressure (A)	MPa	100	140	180
2	Melting Temperature (B)	°C	160	180	200
3	Winder speed(C)	Rpm	20	30	40
4	Extruder speed(D)	Rpm	50	75	100

Table-1: Selected values of process parameters

III. Experimentation

After selection of definite values of the process parameter L9 orthogonal array has been selected depending upon the total degrees of freedom for the parameters. Experiments were carried out on KONARK Extrusion blown film machine.

Fig: 1 KONARK Extrusion blown film machine

For conducting the experiments the setting of the process parameters has been done as per the given values in Table-1

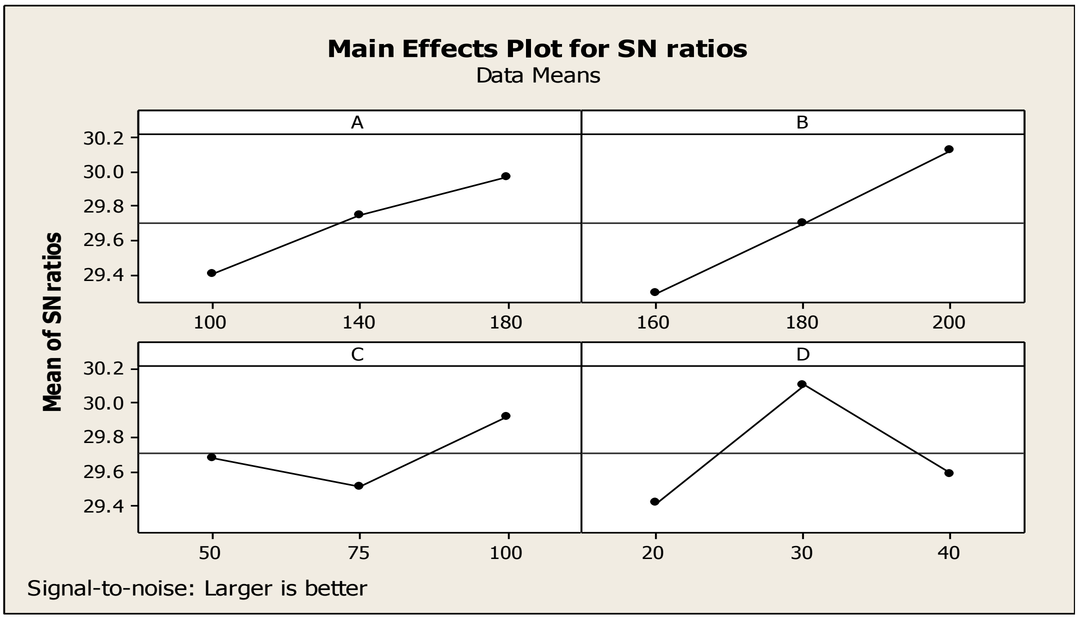
S.N.	Extrusion pressure(A) (Mpa)	Melting Temperature(B) (°C)	Winder speed(C) (rpm)	Extruder Speed(D) (rpm)	T.S. Trial1 (Mpa)	T.S. Trial2 (Mpa)	T.S Trial3 (Mpa)	Tensile Strength (E) (Mean) (Mpa)	S/N Ratio
1	100	160	20	50	25	28	29	27.33	28.6811
2	100	180	30	75	32	31	28	30.33	29.5957
3	100	200	40	100	31	32	31	31.33	29.9172
4	140	160	30	100	28	30	27	28.33	29.0212
5	140	180	40	50	28	32	32	30.67	29.6810
6	140	200	20	75	34	34	33	33.67	30.5414
7	180	160	40	75	34	32	31	32.33	30.1740
8	180	180	20	100	32	31	30	31.00	29.8182
9	180	200	30	50	32	30	32	31.33	29.9080

TABLE-2: Experimental result for Tensile strength and S/N Ratio

Level	Extrusion pressure(A) (Mpa)	Melting Temperature (B) (°C)	Winder speed(C) (rpm)	Extruder speed(D) (rpm)
1	29.40	29.29	29.68	29.42
2	29.75	29.70	29.51	30.10
3	29.97	30.12	29.92	29.59
Delta	0.57	0.83	0.42	0.68
Rank	3	1	4	2

TABLE-3: Response Table for S/N Ratio

Here in the Table -1 nine set of experiment has been designed for selected process parameters like Extrusion pressure (A), Melting temperature (B), Winder speed (C) and Extruder speed (D) as per the Taguchi L9 orthogonal array design system, for optimization of process parameters Tensile Strength (T.S.) is considered as a result parameter and hence it is measured and signal to noise ratio has been calculated for all the nine experiments and Main effects plot for S/N Ratios are drawn with the help of MINITAB 17 software.



Graph 1: Main effects plot for S/N Ratios

IV. Conclusion

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 HDPE is A3, B3, C3, D2.The difference value given in table 3 denotes which factor is the most significant for Tensile strength of HDPE, Melting Temperature (B) is found most effective factor for HDPE followed by Extrusion speed (D) Extrusion pressure (A) and Winding speed (C).

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