Process Parameters Optimization of Drip Pipe Extrusion Process Using Taguchi Approach

Vrushali M. Shete and Ashok J. Keche

Abstract In the present analysis work, a plastic extrusion process that's used for production of drip irrigation pipes is optimized using Taugchi approach. It's vital to spot and optimize the process parameters, to assure quality extrusion pipe producing. Conjointly it's essential to find out the defects in it. For analysis work Akash Drip Industries, company was elite. Taguchi technique is employed to optimize the method parameters, temperature and take-off speed. The experiment was conducted for 3 totally different material providers as supplier changes properties of material aiming to modified due to parameter setting throughout producing of material. Taugchi L9 orthogonal array is chosen for experimental designing and experiment was analyzed exploitation business Minitab18 computer code. After interpretation of values, optimized factor settings were chosen to predict minimum defects. The result unconcealed that using optimized values of things proportion defects for uneven wall thickness decreased from average of 4.19, 4.103, 5.04 to 1.38, 1.66, and 1.18 severally for 3 material suppliers.

Keywords Plastic pipe extrusion · Design of experiment · Taguchi loss function · S/N ratio

1 Introduction

Plastic Extrusion could be a high-volume producing method wont to turn out product of continuous lengths of constant cross section like pipes and tubes. To optimize the manufacturing processes, several strategies are developed and used over the years. Amongst all processes Design of experiments is that the most generally used technique. This is often one in all the foremost thoroughgoing approaches in product and method development. The foremost perspective to DOE is Full Factorial Design and Taguchi technique. Orthogonal array could be a technique recommended by Taguchi

V. M. Shete (✉) · A. J. Keche
Department of Mechanical Engineering, MIT, Aurangabad, India
e-mail: shetevm@gmail.com

to review impact of many control factors over entire parameter space. Exploitation OA technique we tend to need lesser variety of experiments to be conducted, however Full Factorial style needs sizable amount of experiments to be conducted. To measure the performance characteristics which are deviating from the expected target value the concept of the loss function counseled by Taugchi. The value of this loss function is further regenerate into signal-to-noise(S/N) ratio. There are 3 S/N ratios of common interest that are: a. nominal-the-best, b. larger-the-better, and c. smaller-the-better. In present work smaller-the-better kind of control function, was employed in scheming the S/N magnitude relation. Akash Dip industry is a manufacturer of variety of best in class drip irrigation pipes, located close to Renapur, Dist. Latur-413527 (India).

2   Literature Review

Gadekar et al. [1] found that the inappropriate setting of operational parameters, recent machineries, compounding material with wrong proportion, poor testing and examination of material are the causes for the scrap within the company. Improper setting of operational parameters kept on an outsized share of the explanation for scrap and nonconformity of the merchandise. Taguchi's technique of design of experiment for setting of optimum operational parameters is employed for minimizing scrap rates. Rao et al. [2] executed the design and optimization of extrusion process using Taguchi method and finite element analysis of temperature and extrusion load during extrusion of aluminum 6061 alloy. Taguchi L9 design matrix used for experimental run. Analysis of variance (ANOVA) technique is used to check the importance of the input variables on the output responses. The optimal process parameters are obtained using Taguchi's approach. Kumar et al. [5] used Taguchi technique for optimization of process parameters in extrusion blown film machinery. To review the performance parameters on tensile strength orthogonal array and signal/noise ratio enforced. For higher quality characteristics bigger S/N ratio is chosen. Therefore, level with the greatest S/N ratio was elite. In these analysis four factors like melting temperature, winding speed, extrusion speed and pressure were elite for conducting experiments. By use of acceptable orthogonal array experiments were conducted. Afterward by measuring the tensile strength, Signal to Noise ratio was calculated. Exploitation MINITAB 17 computer code Main impact plots for S/N ratios were drawn and optimum parameter values were obtained. Narasimha et al. [7] targeted on to search out the basis causes for the prevalence of defects and wastes in plastic extrusion method. To spot the basis causes of those defects the cause and effect diagram was enforced. The important causes were the take off speed, temperature, vacuum pressure, screw speed and material properties as are often seen from cause and effect diagram. Exploitation Taguchi's principle of loss function the quality loss for the present performance variation was calculated and demand for improvement was verified.

Table 1 The categories of defects with frequency data for-1 month observation

Sr. no	Type of quality defects	Frequency of defect
1	Uneven wall thickness	70
2	Off-center	4
3	Diameter variation	52
4	Crack	14
5	Discontinuity in drilling	26
6	Rough surface finishing	12
	Total	178

Fig. 1 In-line drip pipe

3 Problem Statement

The present analysis work is administered at Akash Drip Industries, Renapur. The categories of defects determined with frequency are as shown in Table 1. The subsequent information is employed for investigation purpose.

Product: In-line Drip Pipe

Size: Diameter = 16 mm, Wall Thickness = 0.45 mm, Length = 300 m (Fig. 1).

4 Methodology

In present work design of Experiments (DOE) using Taguchi's design for optimization of the process parameters is employed. The fundamental steps related to design of experiments (DOE) using Taguchi approach:

  i. Recognition of objective function to be optimized
 ii. Recognition of noise factor
iii. Recognition of the control factors and their levels
 iv. Selection of appropriate orthogonal array
  v. S/N calculation and experimentation
 vi. Prediction of optimized setting from Taguchi analysis

vii. Prediction of optimum control factors levels and its performance.

4.1 Recognition of Objective Function

Our objective is to minimize the uneven wall thickness defect of drip pipe. Hence, objective Function: Smaller-the-Better is employed to reduce the response. S/N Ratio for this function:

$$S/N = -10 \log_{10}\left(1/n \sum_i^n y_i^2\right) \tag{1}$$

where, $n =$ Sample Size, and $y = \%$ defect in that run.

4.2 Recognition of Process Parameters

The factors that have an effect on the drip pipe dimensions and cause the defect of uneven wall thickness are as per Table 2.

The factors that considerably have an effect on the performance are taken into consideration in constructing matrix experiment. All alternative factors are considered as Noise Factors. The subsequent 3 parameters that are most affecting are designated for performing the matrix experiment:

  (i)   Take-off speed (m/min)
 (ii)   Temperature 1(°C) (Barrel zone 1)
(iii)   Temperature 2(°C) (Coating zone 1).

4.3 Recognition the Control Factors and Their Levels

The extrusion setup has various thermocouples connected to the extruder and coating machine. The most important temperatures are BZ1 and CZ1 that are to be set and alternative are to be accrued incrementally within the increments as in extruder BZ1 and BZ2 increments are by nearly 5 °C, in extruder SC, MZ1, DZ1 by 25 °C and in

Table 2 Factors that have an effect on production of drip pipe

Control factors	Noise factors
Take-off speed	Vacuum pressure
Temperature 1	Relative speed of auxiliary
Temperature 2	–

coating zone increments by 25 °C. For optimization purpose base temperature BZ1 (Temperature T1) and CZ1 (Temperature 2) is chosen as control factors. Because the material provider changes the defects incidence range and the parameter settings also changes. Hence there's need to optimize these control factors for every of the provider. So, experiments are designed differently for every material provider and process parameters are optimized consequently. The factors and their levels are shown Table 3.

4.4 Selection of Orthogonal Array

The Taguchi optimization technique starts with choice of associate accetable orthogonal array. The minimum number (min N) of runs within the array may be determined as follows:

$$N_{min} = (L - 1)F + 1 \tag{2}$$

where, L = number of levels, F = number of factors.
   where, $L = 3$ and $F = 3$.
   Now Taguchi's array is chosen for experimentation having minimum seven numbers of experiments. Total 9 experiments were administered as a result of the foremost appropriate orthogonal array for experimentation having three factors and three levels is L9 array.

4.5 Experimental Programme

With relation to the above OA, nine experiments were conducted with their factors and their levels as mentioned in Table 3. The defect uneven wall thickness for every experiment was measured and % defects for every supplier calculated. For every supplier want one separate experimental array of nine runs. Thickness variation of

Table 3 Control factor levels for three suppliers

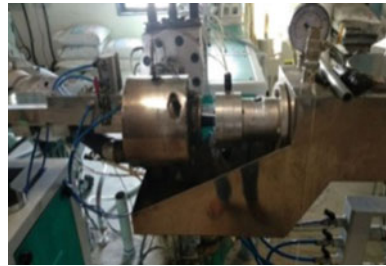| Control factors	Vardhaman Polymers, Ahemadnagar			Lata Industries, Latur			Bansal Polymers, Hyderabad		
	Level			Level			Level		
Unit	1	2	3	1	2	3	1	2	3
Take-off speed (m/min)	19	22	25	18	21	23	22	25	27
Temp. 1 (°C)	158	163	169	169	176	182	152	160	164
Temp. 2 (°C)	171	178	182	182	188	192	163	171	178

Fig. 2 Temperature control panel

Fig. 3 Machine control panel

Fig. 4 Die section

the pipe was measured using the screw gauge. Each of the above nine experiments were conducted three times (27 experiments for every supplier) to account for the variations which will occur because of the noise factors. The temperature instrument panel to manage temperatures, the machine control panels to manage takes off speed and different parameters and also the die section of machine are shown in Figs. 2, 3 and 4 severally.

5 Results and Discussion

Experimental work is administered at Akash Drip Industries, Renapur, Latur for 3 different material suppliers particularly Vardhaman Polymers Ahemadnagar, Lata Industries Latur, Bansal polymer Hyderabad. The experimental results are mentioned in Tables 4 and 5. Sample Calculation:

Table 4 OA with control factors for three suppliers

Exp. no.	Vardhaman Polymers, Ahemadnagar			Lata Industries, Latur			Bansal Polymers, Hyderabad		
	Take-off speed	Temp. 1	Temp. 2	Take-off speed	Temp. 1	Temp. 2	Take-off speed	Temp. 1	Temp. 2
1	19	158	171	18	169	182	22	152	163
2	19	163	178	18	176	188	22	160	171
3	19	169	182	18	182	192	22	164	178
4	22	158	178	21	169	188	25	152	171
5	22	163	182	21	176	192	25	160	178
6	22	169	171	21	182	182	25	164	163
7	25	158	182	23	169	192	27	152	178
8	25	163	171	23	176	182	27	160	163
9	25	169	178	23	182	188	27	164	171

Table 5 Percentage of defects for different suppliers

Exp. no.	1	2	3	4	5	6	7	8	9
Vardhaman Polymers, Ahemadnagar	4.688	3.333	4.412	4.762	8.065	7.273	3.226	3.279	5.172
Lata Industries, Latur	3.279	4.478	1.852	2.083	4.286	7.353	6.154	3.030	4.412
Bansal Polymers, Hydrabad	3.846	7.143	4.688	2.857	5.882	5.714	3.448	4.839	6.944

The percentage of defect per shift

$$= (\text{Number of defective products having uneven wall thickness})/$$

$$(\text{Total number of units produced per shift}) * 100 \qquad (3)$$

It was found that, total 65 units are produced per shift out of that 7 defective units having uneven wall thickness.

% defect = 7/65 * 100 = 10.769% … (Putting values in Eq. 3).

After conducting the experiment, the results were converted into S/N ratio values. For these experimentation and analysis using Taguchi results are adopted with the assistance of Minitab-18 software package. Smaller-the-better kind of control function was employed in calculating the S/N ratio. Main effects plot for the main effect terms viz. factors take-off speed, temperature 1 and, temperature 2 are shown in Figs. 5 and 6.

6 Confirmation Experiment

Confirmation experiments conducted using the factor levels obtained by S/N ratio plot, using Taguchi method, for each supplier the level of factors found different. Total three experiments were conducted and their % defects values were checked. It can be seen that the results are having minimum defects (Table 6).

7 Conclusion

The Following conclusions are drawn from the current study:

(1) The experimental results show that the temperature and take-off speed are the main parameters which will have an effect on uneven wall thickness defect.
(2) The optimum values for influential factors for lesser percentage defects in drip pipe extrusion are obtained from Taguchi's methodology for various material suppliers.
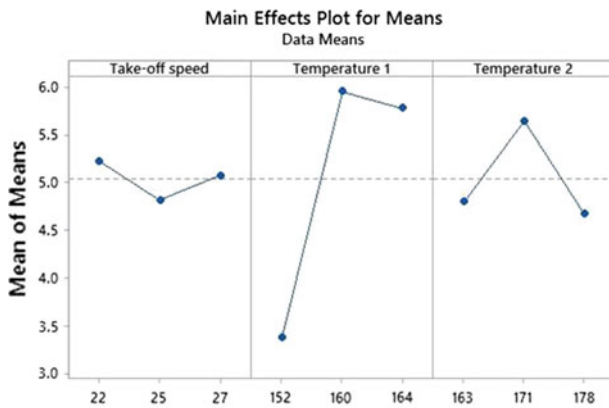
Table 6 Confirmation experiment

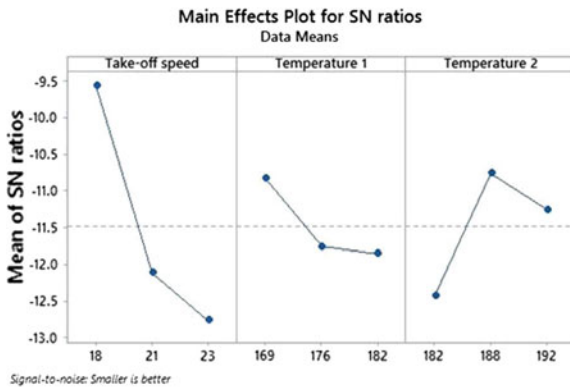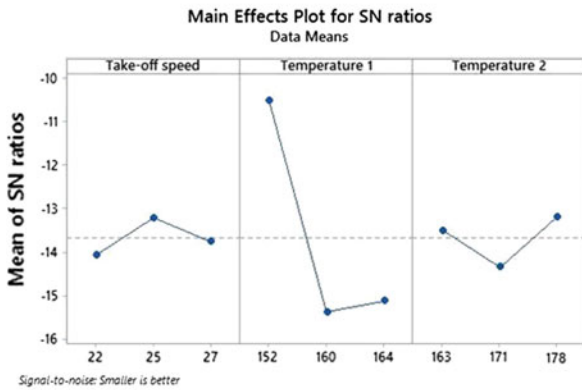| Supplier name	Optimized values of factors			% defects
	Take-off speed	Temp. 1	Temp. 2	
Vardhaman Polymers, Ahemadnagar	22	169	182	1.38
Lata Industries, Latur	23	182	182	1.66
Bansal Polymers, Hyderabad	22	160	171	1.18
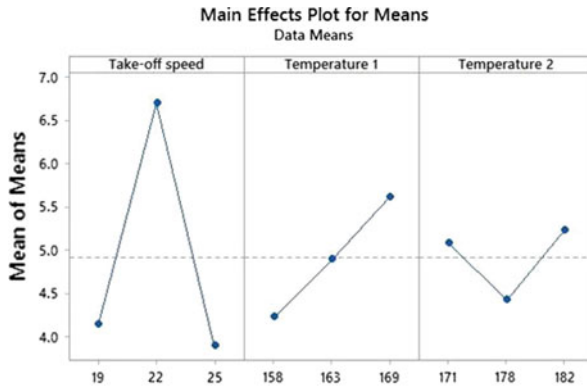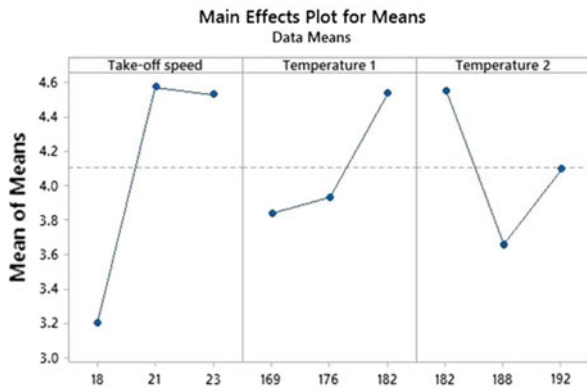
Fig. 5 Main effects plot for means
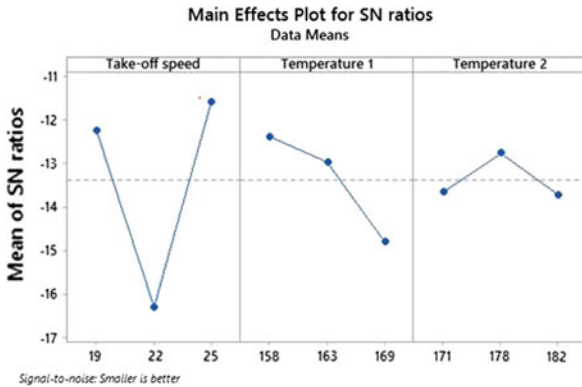
Vardhaman Polymers, Ahemadnagar

Lata Industries, Latur

Bansal Polymers, Hyderabad

Fig. 6 Main effects plot for S/N ratios

Using optimized values of factors percentage defects for uneven wall thickness reduced from average of 4.19, 4.103, 5.04 to 1.38, 1.66, and 1.18 severally for 3 material suppliers particularly Vardhaman Polymers Ahemadnagar, Lata Industries Latur and Bansal Polymers Hyderabad.

(4) The current work helps to boost the quality of product and to optimize drip pipe extrusion process.

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