I J M S E
© Serials Publications
8(1) 2017 : January-June • pp. 95-99

EXPERIMENTAL INVESTIGATION FOR MECHANICAL PROPERTIES OF POLYVINYL CHLORIDE FEED STOCK FILAMENT PREPARED WITH TWIN-SCREW EXTRUDER

RUPINDER SINGH[1] AND NISHANT RANJAN[1]

[1]*Department of Production Engineering, Guru Nanak Dev Engineering College, Ludhiana 141006, Punjab, India, Emails: rupindersingh78@yahoo.com, ranjan_nishant92@hotmail.com*

Abstract: Twin-screw extruder is commercially available for the improved mixing of polymer with fillers. In last decades, many studies were reported on preparation of hybrid feedstock filament of different polymer and fillers. Hitherto very less has been reported on investigations for mechanical properties of feedstock filament prepared from twin-screw extruder. In the present work, an effort has been made to prepare the feedstock filament of polyvinyl chloride by considering three input parameters (namely; nozzle diameter, rotational speed and temperature). Investigations were made to check the influences of process variables on the tensile properties (like; tensile strength at peak and percentage elongation at peak) of feed stock filament. The process parameters were optimized using Minitab software based Taguchi L9 orthogonal array. This study suggested that, variation in screw speed has minimum effect on the tensile properties.

Keywords: Twin screw extruder, PVC feedstock, mechanical properties, Taguchi L9 orthogonal array.

1. INTRODUCTION

Polymeric materials are widely used all over the world primarily due to their superior properties such as high strength to weight ratio; high temperature/chemical/corrosive resistance; non-conductivity; high clarity; re-processability; low cost and so forth. Although the processing of polymers demands a less amount of energy compared to other materials [1-2]. Polymer extrusion is an unpredictable process and hence it is highly prone to fluctuations in nature. Moreover, the process parameters are complexly coupled each to other and hence difficult to set-up and control [3].

There are many twin-screw extruders commercially available. The choice should depend on the end-use application. Different models have two parallel screw shafts that either rotate in the same direction (called corotating) or rotate in opposite directions (called counterrotating), with varying distances between the screw shafts. If the centreline distance between the shafts is less than the screw diameter, the screws are called intermeshing unless are called non-inter-meshing [4-5]. Twin-screw extruders used in profile extrusion have a closely fitting flight, channel profile, and operate at relatively low screw speeds, in the range of about 20 rpm. These machines offer several advantages over single screw extruders. Better feeding and more positive conveying characteristics allow the machine to process hard-tofeed materials (powders, slippery materials, etc.) [6].

Tensile testing indicates the resistance of the wire material to necking and fracture, although such phenomena may not occur in normal wire drawing. The micro-mechanisms of plastic flow involve crystallographic slip by way of dislocation motion [7].

Genichi Taguchi has made valuable contribution to statistics and engineering. His emphasis on loss to society, techniques for investigating variation in experiments, and his overall strategy of system, parameter and tolerance design have been influential in improving manufactured quality worldwide [8].

The literature review reveals that there are three important parameters of twin-screw extruder namely: nozzle diameter, temperature and r.p.m. of the screw. With proper selection of process parametric range, the PVC plastic/polymers wire can be prepared with accurate size in terms of diameter and with better tensile strength.

2. EXPERIMENTATION

In the pilot experimentation, an effort has been made to prepare the feed stock filament of biocompatible PVC. The first step was to check the possibility of preparation of PVC filament with varying input parameters. In this experimentation for feedstock preparation of plastic/polymers were selected (namely; PVC). PVC wire was prepared on the twin screw extruder by taking random selections of specific parameter and wire were drawn with 210! at 40 r.p.m. speed with 1.5mm diameter but obtained feedstock filament's diameter was not accurate in size. In this experimentation, it Taguchi L9 orthogonal array was selected for design of experimentation. The process variables were chosen as availability on twin-screw extruder, as nozzle diameter, temperature of melting zone and r.p.m. of the extruder screw. The nozzle diameter was taken at 3 different level of 2, 1.5 and 1mm size and the rotational speed of the extruder screw was at 40, 30 and 20rpm and the temperature is taken as 220, 200 and 180! and after that feedstock filament were made according to the Taguchi L9 orthogonal array.

Table 1
Parameter selected for experimentation

Levels	*A Nozzle Diameter (in mm)*	*B Rotational Speed (in rpm)*	*C Temperature (in °C)*
1	2	40	220
2	1.5	30	200
3	1	20	180

Table 1 shows the selected process parameters and their level for the final experimentation. Table 2 shows the control log of experimentation based upon Taguchi L9 orthogonal array.

The investigations for tensile properties were performed on universal tensile tester. In this experimentation, the mechanical properties of tensile nature.(like; tensile strength at peak and percentage elongation at peak) were optimized.

Table 2
Control log of experimentation.

Parametric condition	*A Nozzle Diameter (in mm)*	*B Rotational Speed (in r.p.m.)*	*C Temperature (in °C)*
1	2	40	220
2	2	30	200
3	2	20	180
4	1.5	40	200
5	1.5	30	180
6	1.5	20	220
7	1	40	180
8	1	30	220
9	1	20	200

3. RESULT AND DISCUSSION

After successful pilot experimentation at defined level of process variables, PVC plastic/polymers were prepared as per Taguchi L9 orthogonal array, the results for the different output parameters (namely: Percentage elongation at peak and Strength at peak) discussed as below:-

3.1. Percentage Elongation at Peak

Table 3
Output of percentage elongation at peak for different parametric conditions

Parametric condition	*A Nozzle Diameter (in mm)*	*B Rotational Speed (in r.p.m.)*	*C Temp-erature (in °C)*	*Percentage elongation at Peak*
1	2	40	220	224
2	2	30	200	263
3	2	20	180	337
4	1.5	40	200	296
5	1.5	30	180	351
6	1.5	20	220	392
7	1	40	180	256
8	1	30	220	238
9	1	20	200	234

Table 3 shows the output of percentage elongation at peak for different parametric conditions based upon Taguchi L9 orthogonal array. The maximum value of percentage elongation for peak occurred for sample no. 6, which is the combinations of parameters nozzle

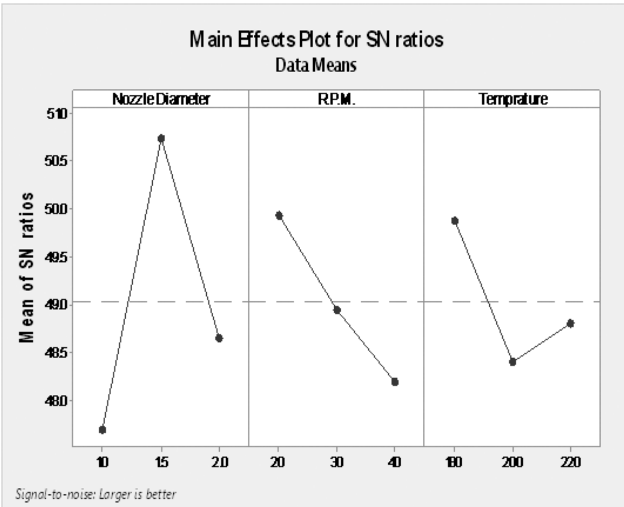

Figure 1: Main Effect Plots for SN Ratios

diameter 1.5mm, rotational speed 20rpm and temperature of 220 degree centigrade. The minimum value obtained for sample no. 1, which is the parametric conditions of nozzle diameter 2mm, rotational speed of 40rpm and temperature at 220 degree centigrade.

As shown in Fig. 1, the SN ratios first increases as nozzle diameter increased, but further increase in nozzle diameter resulted into decreased SN ratios. The SN ratios for rotational speed was continuously decreased as rotational speed increased.SN ratios for temperature variations is as reverse as nozzle diameter where SN ratios decreased as increased in temperature but after then it was started to increase.

Table 4
Response Table for Signal to Noise Ratios Larger is better

Level	*Nozzle Diameter*	*R.P.M.*	*Temperature*
1	47.69	49.93	49.87
2	50.73	48.95	48.40
3	48.65	48.20	48.80
Delta	3.04	1.74	1.47
Rank	1	2	3

Table 4 shows that, nozzle diameter has maximum impact for contributions in SN ratios whereas temperature has minimum contributions.

As shown in Table 5, percentage error was found to be 7.137%. It shows that model has higher degree of accuracy. For optimization

Table 5
Analysis of Variance for SN ratios

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*	*% age contri-bution*
Nozzle Diameter	2	14.48	14.48	7.24	8.37	0.10	59.75
R.P.M.	2	4.548	4.548	2.27	2.63	0.28	18.76
Tempe-rature	2	3.476	3.476	1.73	2.01	0.33	14.34
Residual Error	2	1.730	1.730	0.86			7.13
Total	8	24.23					

following formula based upon Taguchi design has been used:

$$\eta_{opt} = m+(m_{A2}-m) +(m_{B1}-m) +(m_{C1}-m)$$

Where 'm' is the overall mean of S/N data, m_{A2} is the mean of S/N data for nozzle diameter at level 2 and m_{B1} is the mean of S/N data for rotational speed at level 1 and m_{C1} is the mean of S/N data for temperature at level 1.

$y_{opt}^2 = (1/10)^{\text{çopt}/10}$ for properties, lesser is better

$y_{opt}^2 = (10)^{\text{çopt}/10}$ for properties, greater is better

Calculation, overall mean of SN ratio (m) was taken from Minitab software.

$$m = 49.0261$$

Now from response table of signal to noise ratio, $m_{A2} =$ 50.73, m_{B1}=49.93 and m_{C1}=49.87

From here,

$$\eta_{opt} = 49.0261+(50.73-49.0261) +(49.93-49.0261) +(49.87-49.0261)$$

$$\eta_{opt} = 52.4778 \text{ db}$$

Now, $y_{opt}^2 = (10)^{\text{çopt}/10}$

$$y_{opt}^2 = (10)^{52.478/10}$$

$$y_{opt} = 420.5813$$

So, Optimum Percentage Elongation at Peak = 420.5813%

3.2. Tensile Strength at Peak

As Table 6 shows the output of strength at peak for different parametric conditions based upon

Table 6
Output of strength at peak for different parametric conditions

S.No	*A Nozzle Diameter (in mm)*	*B Rotational Speed (in r.p.m.)*	*C Temperature (in°C)*	*Strength at peak*
1	2	40	220	14.95
2	2	30	200	14.29
3	2	20	180	16.94
4	1.5	40	200	18.30
5	1.5	30	180	19.31
6	1.5	20	220	26.37
7	1	40	180	18.52
8	1	30	220	25.47
9	1	20	200	18.88

Taguchi L9 orthogonal array. The maximum value of strength at peak occurred for sample no. 6, which is the combinations of parameters nozzle diameter 1.5mm, rotational speed 20rpm and temperature of 220 degree centigrade. The minimum value obtained for sample no. 2, which is the parametric conditions of nozzle diameter 2mm, rotational speed of 30rpm and temperature at 200 degree centigrade.

As shown in Fig. 2, the SN ratios is first increases as nozzle diameter increased, but further increase in nozzle diameter resulted into decreased SN ratios. The SN ratios for rotational speed was continuously decreased as rotational speed increased.SN ratios for temperature variations is as reverse as nozzle diameter where SN ratios decreased as increased in temperature but after then it was started to increase.

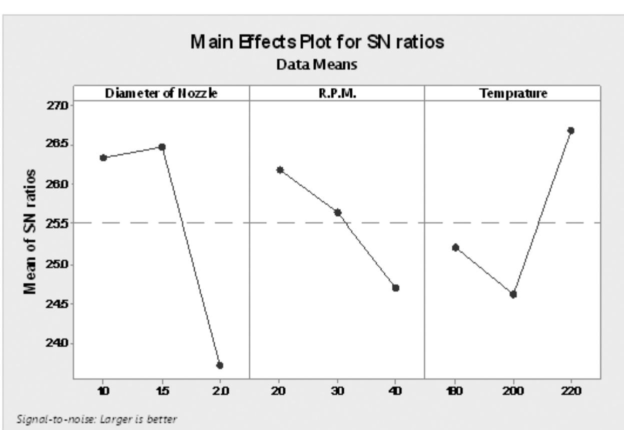

Figure 2: Main Effect Plots for SN Ratios

Table 7
Analysis of Variance for SN ratios

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*	*% age contri-bution*
Nozzle Diameter	2	14.31	14.31	7.156	7.99	0.11	54.68
R.P.M.	2	3.353	3.353	1.676	1.87	0.34	12.81
Temp-erature	2	6.715	6.715	3.357	3.75	0.21	25.66
Residual Error	2	1.792	1.792	0.895			6.85
Total	8	26.17					

As shown in Table 7, percentage error found to be 6.85%. It shows that model has higher degree of accuracy of 93.15%.

Table 8
Response Table for Signal to Noise Ratios Larger is better

Level	*Diameter of Nozzle*	*R.P.M.*	*Temperature*
1	26.33	26.17	25.22
2	26.46	25.65	24.62
3	23.72	24.70	26.68
Delta	2.74	1.48	2.06
Rank	1	3	2

Table 8 shows that, nozzle diameter has maximum impact for contributions in SN ratios whereas rpm has minimum contributions.

The optimization performed for the tensile strength at peak was similar to the percentage elongation at peak of "larger is better" type, and calculated as; Optimum Strength at peak 25.9956KN/mm^2

4. CONCLUSIONS

This study highlights the best settings of input parameters of PVC feed stock filament for mechanical properties. Following conclusions made for the present study.

a. The maximum percentage elongation at peak was observed as 420.5813%. The maximum value of percentage at elongation for peak occurred for sample no. 6, which is the combinations of parameters nozzle diameter 1.5mm, rotational speed 20rpm and temperature of 220 degree centigrade.

b. The maximum strength at peak 25.9956KN/mm^2. The maximum value of strength for peak occurred for sample no. 6, which is the combinations of parameters nozzle diameter 1.5mm, rotational speed 20rpm and temperature of 220 degree centigrade.

ACKNOWLEDGEMENT

The authors is highly thankful to Manufacturing Research Lab (Production Engineering, GNDEC Ludhiana), to carry out the research work.

REFERENCES

[1] D.V. Rosato, N.R. Rosato & M.G. Rosato, "Manufacturing & data handbook: fundamental and processes", Plastics engineering, Kluwer Academic Publishers, Vol. 2, 2001, pp. 54-65.

[2] C. Abeykoon, A.L. Kelly, J.V. Sorroche, E.C. Brown, P.D. Coates, J. Deng, K. Ling, E.H. Jones & M. Price, "Process efficiency in polymer extrusion: Correlation between the energy demand and melt thermal stability", Applied Energy, Vol.135, 2014, pp. 560-571.

[3] C. Abeykoon, "Modelling and control of melt temperature in polymer extrusion", Ph.D. thesis, United Kingdom, Queen's University Belfast, 2011.

[4] H. Herrman, U. Burkhardt & S. Jakopin, "A Comprehensive Analysis of Multi-Screw Extruder Mechanisms", ANTEC, Montreal, 1977.

[5] R. Erdmenger, "Chem. Ing. Tech.", Vol. 36, Jan.1964, pp. 175-185.

[6] R. wendaal, "Twin Screw Extruder", ch. 10, 2014, pp. 697-698.

[7] R. N. Wright, "Mechanical properties of Wire and Related Testing", Wire Technology (Second Edition), feb.2016, pp. 129-157.

[8] I. Ben-Gal, "On the use of data compression measures to assess robust designs", IEEE Trans. On Reliability, Vol. 54, 2005, pp. 381-388.