Experimental Investigation to Optimize the Extrusion Process for PVC Pipe: A Case of Industry

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Abstract

In the present research work, the optimize extrusion process parameters for maximizing the PVC pipe wall thickness using Taguchi's method are investigated. The material of pipe manufacturing was PVC plastic. The experimental investigation was done in Jain Irrigation Systems Ltd., pipe manufacturing, company. The experiments are analyzed using commercial Minitab17 software, interpretation has made, and optimized factor settings were chosen. The present study concludes that the feed drum temperature: 130^0, the die temperature: 170^0, the extrusion pressure 100 Mpa, and extrusion speed: 50 rpm gives the maximum optimize the thickness of the PVC pipe for minimizing the pipe defects.

Index terms: *Taguchi method, PVC Plastic, Minitab 17, Extrusion*

1. INTRODUCTION

In the extrusion process, a material is a force through a formed orifice, with the material solidification to produce a continual length of the constant cross section. The squeezing of toothpaste from a tube is a familiar example. In the plastic extrusion process, the thermoplastic is softened by heating before extrusion and, for the form to be held; the thermoplastics should be quickly chilled and, usually, supported while cooling. In some large extruders in polymerization plants are fed hot melts, therefore their main duty is generating enough pressure to force the melt through spider die. In most extrusion operations, however, the plastics reach as powders or pellets at room temperature, and therefore the extrusion process should melt the plastic and make uniform it before it enters the die. Therefore, heating and melting the feedstock, changing it from a cold solid to a hot viscous liquid, accounts for regarding ninety-three of the energy needed. The work done in pumping the melt through the die is just five – ten percent of the entire [1].

The defect-free extrusion process needs the machine and tool operating in good conditions. This requires control over the process parameters such as temperature, pressure, machine speed, and the relative speeds of the auxiliary [1]. As the extrusion process involves steady state conditions, any action that can stabilize any parameter or condition is beneficial to the process [2].The mainly the plastic pipe extrusion process depends on the parameters such as take-off speed, temperatures, vacuum pressure and relative speed of auxiliary. The common defects which are normally occurring in plastic extrusion process are due to three main regions like the problem in mold design, improper material selection, and wrong processing. The failures occur during the processing the material and these failures cause some defects that can found in extruded part. The common defects found in the extrusion process are uneven wall thickness, centering problem (off-center), diameter variation crack, and discontinuity in drilling, rough surface finishing. In the extrusion process, the defects are arises during the production due to poor understanding of the processing method, use of improper machine setting, lack of trained staff machine breakdown, and inappropriate working environments.

2. LITERATURE REVIEW

Narasimha & Rejikumar [1] presented a systematic approach to find the root causes for the occurrence of defects and wastes in plastic extrusion process. The cause and effect diagram was implemented to identify the root

causes of these defects. The extrusion process parameters such as vacuum pressure, temperature, take-off speed, screw speed of the extrusion process and raw material properties were identified as the major root causes of the defects from the cause and-effect diagram. The quality loss for the current performance variation was calculated using Taguchi's principle of loss function and requirement for improvement was verified. In their paper design of experiment (DoE) was applied to optimize the process parameters for the extrusion of high-density polyethylene (HDPE) pipe Ø50mm and plain pipe Ø25mm. Four independent process parameters involving vacuum pressure, take-off speed, screw speed and temperature were investigated using Taguchi method. Minitab 15 software was used to analyze the result of the experiment. Based on the result of the analysis, optimum process parameters were selected.

Mr. Sandip S. Gadekar, Prof. Javed G. Khan et al. [2] studied the defects in the plastic pipe, to optimize the plastic pipe manufacturing process. The optimization taguchi techniques used in this paper. For the research work Shivraj HY-Tech Drip Irrigation pipe manufacturing, Company was selected. The experiment was analyzed using commercial Minitab16 software, interpretation has made, and optimized factor settings were chosen. After prediction of result the quality loss was calculated and it compared with before implementation of DOE. The research works has improves the production, quality and optimizes the process.

Dharmendra Kumar, Sunil Kumar [3] used the taguchi method to optimize the process parameters and improve the quality of components that manufactured. The objective of this study was to illustrate the procedure adopted in using taguchi method to a extrusion blown film machinery. The orthogonal array, signal-to-noise ratio 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 was 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.

Thella Babu Rao, A.Gopala Krishna [4] addressed design and optimization of extrusion process for aluminum 6061 alloy. They show that the extrusion temperature and load has significant on quality and cost of the extruded parts respectively. Hence, development of economical process conditions found as vital. Forward extrusion model developed to analyze the process responses temperature, extrusion load, extrusion ratio and blank velocity for deferent process designs. Some of the most significant design parameters ram velocity, coefficient of friction and die angle considered. Taguchi's L9 design employed to simulate the experiments for each set of chosen extrusion variables via Finite Element Analysis (FEA) solver. Analysis of variance (ANOVA) adopted to check the significance of the input variables on the output responses. Then, the optimal process parameters are determined using Taguchi's method.

Cunsheng Zhang & Guoqun Zhao et al. applied the Taguchi's design of experiment and numerical simulation to optimize the aluminum profile extrusion process. By means of Hyper Xtrude, the extrusion process was simulated and the effects of process parameters on the uniformity of metal flow and on the extrusion force were investigated with the signal to noise ratio and the analysis of variance. Through analysis, the optimum combination of process parameters for uniform flow velocity distribution was obtained, with the billet diameter of 170 mm, ram speed of 2.2 mm/s, die temperature of 465°C, billet preheated temperature of 480°C, and container temperature of 425°C.Compared with the initial process parameters, the velocity relative difference in the cross-section of extrudate was decreased from 2.81% to 1.39%. In the same way, the optimum process parameters for minimum required extrusion force were gained, with the billet diameter of 165 mm, ram speed of 0.4 mm/s, die temperature of 475°C, billet preheated temperature of 495°C, and container temperature of 445°C. A 24.7% decrease of required extrusion force with optimum process parameters was realized. Through the optimization analysis in this study, the extrusion performance has been greatly improved. Finally, the numerical results were validated by practical experiments, and the comparison showed that the optimization strategy developed in this work could provide the effective guidance for practical production.

3. PROBLEM DEFINATION

The extrusion pro***cess*** is the most widely used in pipe manufacturing industries. In the extrusion processes as discussed above the various defects are repeatedly arises and affect the productivity. If we need to enhance the production rate, it is very necessary to optimize the extrusion process parameters and improve the productivity. The following are the objectives of present research work:

- To minimize the variations in wall thickness in PVC pipe
- To design and develop the product for robustness in process

Fig.1 PVC pipe with uneven wall thickness

3. Process Parameters

The effective extrusion process needs the machine and tool operating in good conditions. This requires control over the process parameters such as feed drum temperature, mold heat, extruder pressure, and extruder speed. The machine cycle time is reduced due to the proper selection of process parameters. These parameters affect the microstructure, extrusion quality, and extrusion strength. The values of process parameters are fixed by the proper discussion with the industrial persons and referring data books. After confirming about the significance of all the process parameters, the values of the process parameters are listed in a table.

Table1. Extrusion process parameters and their levels

Levels	Feed Drum Temp.	Die Temp.	Extruder Pressure	Extruder Speed
1	125	170	100	50
2	130	180	150	70
3	135	190	200	90

4. Experimentation

The parameters selected for experimentation are shown in table 1.The experimentation is conducted in the industry as per L9 orthogonal array. The experiments are designed by Taguchi's method. The design of experiment is as shown in fig.2

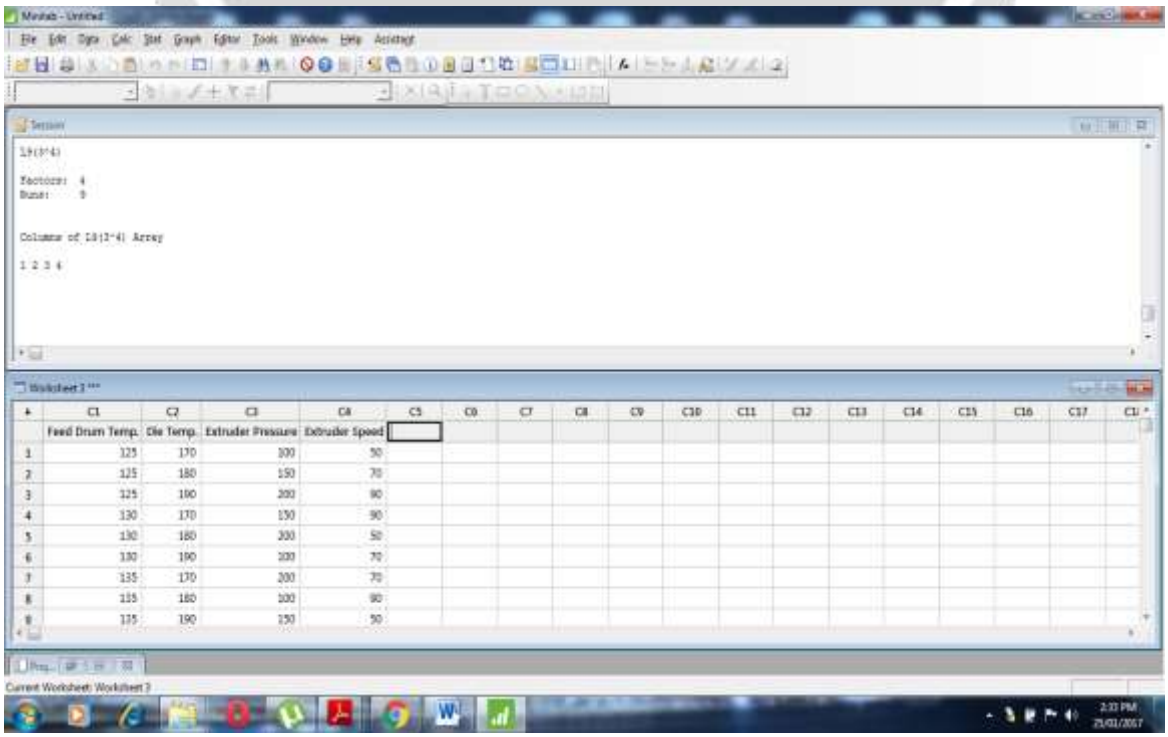

Fig.2 Design of experiment by Minitab 17Software (L9 OA)

The experimental unit is shown in fig.3. The different parts of experimental unit are shown as well.

(a) Main section

(b) Extrusion die

(c) Cooling chambers

Fig.3 Experimental unit

The extrusion machine manufactures the approximately 3000 pieces of PVC pipe per shift. The criteria selected for S/N ratio calculation is "Larger is better". Due to this we get the possible set process parameters which manufacture product with minimize the pipe defects. The diameter of pipe is measured using digital micrometer at eight points. The measured average values of PVC pipe wall thickness is given with S/N ratio calculation, see fig.6 .The response table shows that die temperature is most significant process parameter in PVC pipe extrusion process and second most significant factor is extrusion pressure.

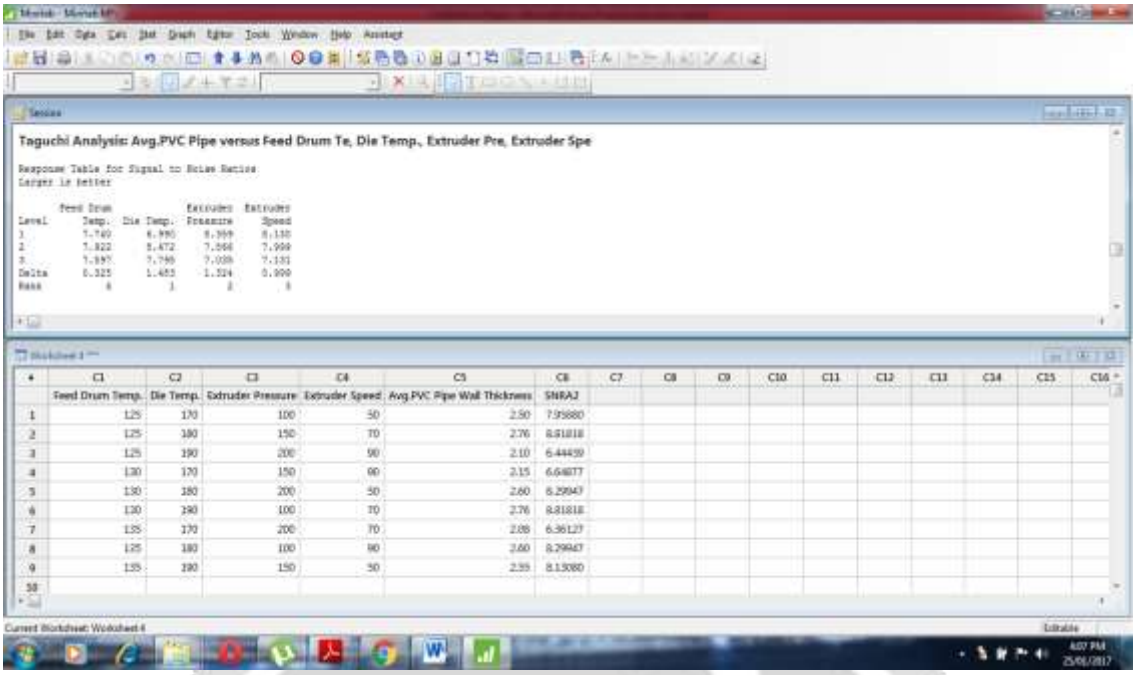

Fig.4 shows the response table and S/N ratio calculation

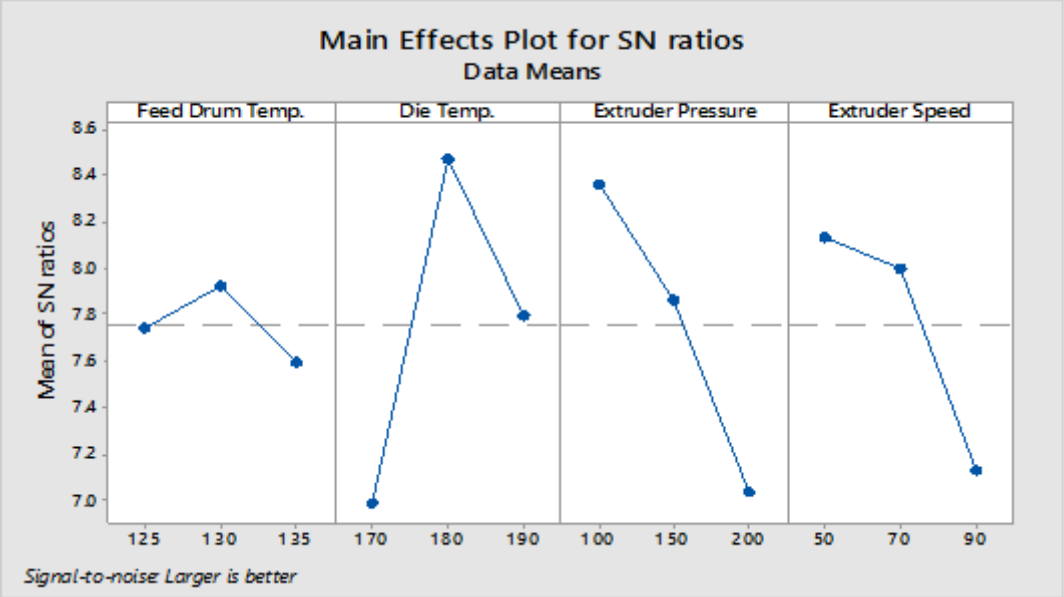

Fig.5 Main effect plot for PVC pipe wall thickness

After analysis we get the optimum set of process parameters which are shown in graphs. The graphs (fig.5) shows that the feed drum temperature:130^0, the die temperature: 170^0,the extrusion pressure 100Mpa, and extrusion speed :50Rpm gives the maximum optimize thickness of the PVC pipe to avoid the defects in PVC pipe.

4. Conclusion

The present research work concludes that

1. The feed drum temperature:130^0, the die temperature: 170^0, the extrusion pressure 100 Mpa, and extrusion speed:50 rpm gives the maximum optimize the thickness of the PVC pipe for minimizing the pipe defects.

2. The die temperature is most significant process parameter in PVC pipe extrusion process and the second most significant factor is extrusion pressure which affects the PVC pipe wall thickness.

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