International Journal of Advanced Mechanical Engineering.
ISSN 2250-3234 Volume 4, Number 6 (2014), pp. 583-588

http://www.ripublication.com

Recent Methods for Optimization of Plastic Extrusion Process: A Literature Review

Geo Raju[1], Mohan Lal Sharma[2], Makkhan Lal Meena[3]

*[1,3]Department of mechanical engineering,
Malaviya National Institute of Technology, Jaipur-302017, Rajasthan.
[2]Government polytechnic college, Churu-331001, Rajasthan*

Abstract

Plastic extrusion has been a challenging process for many manufacturers and researchers to produce products meeting requirements at the lowest cost. Faced with global competition in plastic-products industry, using the trial-and-error approach to determine the process parameters for plastic extrusion is no longer good enough. During production, quality characteristics may deviate due to drifting or shifting of processing conditions caused by machine wear, environmental change or operator fatigue. Determining optimal process parameter settings critically influences productivity, quality, and cost of production in the plastic related industries. The aim of this article is to review the research of the determination of process parameters and die design for plastic extrusion. Research based on various approaches, including Taguchi technique, artificial neural networks (ANN), fuzzy logic, genetic algorithms (GA), non-linear modeling, and response surface methodology are discussed.

Keywords: Genetic algorithms (GA), Artificial neural networks (ANN), Response surface methodology, Fuzzy logic, Taguchi technique.

Introduction

Plastic extrusion has been a challenging process for many manufacturers and researchers to produce products meeting requirements at the lowest cost. The complexity of extrusion process and the enormous amount of process parameters involved make it difficult to keep the process under control. The complexity and parameter manipulation may cause serious quality problems and high manufacturing costs. One of the main goals of extrusion is the improvement of quality of extruded parts besides the reduction of cycle time, and lower production cost. Solving problems related to quality has a direct effect on the expected profit for companies manufacturing plastic products. Quality characteristics in extrusion process are mechanical properties, dimensions or measurable characteristics, and attributes. In general, some of the main causes of quality problems are material related defects, process related problems, packing and cooling related defects, and post extrusion related defects. Factors that affect the quality of an extruded part can be classified into four categories: part design, die design, machine performance and processing conditions. The part and die design are assumed as established and fixed. During production, quality characteristics may deviate due to drifting or shifting of processing conditions caused by machine wear, environmental change or operator fatigue.

Determining optimal process parameter settings critically influences productivity, quality, and cost of production in the plastic related industries. Previously, production engineers used either trial-and-error method or Taguchi's parameter design method to determine optimal process parameter setting for plastic extrusion. However, these methods are unsuitable in the present scenario because of the increasing complexity of product design and the requirement of multi-response quality characteristics. Optimizing process parameter problems is routinely performed in the manufacturing industry, particularly in setting final optimal process parameters. Final optimal process parameter setting is recognized as one of the most important step in plastic extrusion for improving the quality of extruded products. Faced with global competition in plastic-products industry, using the trial-and-error approach to determine the process parameters for plastic extrusion is no longer good enough. Quite a few researchers have attempted various approaches in the determination of process parameters for plastic extrusion in order to reduce the time to market and obtain consistent quality of extruded parts.

The aim of this article is to review the research of the determination of process parameters and die design for plastic extrusion. Research based on various approaches, including Taguchi technique, artificial neural networks (ANN), fuzzy logic, genetic algorithms (GA), non-linear modeling, and response surface methodology are discussed.

Optimization methods

Taguchi method

Narasimha and Rejikumar presented a systematic approach to find the root causes for the occurrence of defects and wastes in plastic extrusion process [1]. 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 this paper design of experiment (DOE) was applied to optimize the process parameters for the extrusion of *high-density polyethylene* (HDPE) pipe Ø 50mm and plain pipe Ø 25mm. Four independent process parameters viz. 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.

Artificial neural networks (ANN)

Huang and Liao investigated the diameter and thickness swells of the parison in the continuous extrusion blow molding of high-density polyethylene (HDPE) as a function of the processing parameters including the die temperature and flow rate [2]. A back-propagation neural network model was used to predict the parison swells under the effect of sag. A 2-20-20 neural network architecture with two input nodes, one hidden layer with 20 nodes, and 20 out-put nodes was utilized. Twenty-eight data sets obtained from experiments were provided to the neural network as samples, which were divided into 20 sets of training data and eight sets of testing data. The comparison of the experimentally determined parison swells with the predicted ones using the trained neural network model showed very good agreement between the two.

Cirak and Kozan presented knowledge based and neural network approaches to wire coating for polymer extrusıon [3]. The dependency of extrusion process parameters viz. barrel heating zones' temperatures and screw speed on coating thickness of wire coating extrusion processes was investigated using ANN. A back-propagation neural network model was used to predict the coating thickness.

Al Rozuq and Al Robaidi presented an experimental study to investigate the dependency of extrusion parameter on the coating thickness and degree of crosslinking of crosslinked polyethylene (XLPE) cable [4]. A three layer back propagation artificial neutral network (ANN) model was used for the description of wire coating thickness.

Fuzzy logic

Oke et al. optimized the flow rate of the plastic extrusion process in a plastic recycling plant with the application of a neuro-fuzzy model [5]. The input parameters viz. effective frictional force between the surfaces of the material and the walls of the extrusion chamber and diameter of the extrusion chamber determine the rate of flow of the solid waste material to be recycled through the extrusion chamber. The model is designed such that the most favorable condition where maximum quantity of solid waste material is recycled is attained. The linguistic variable serves as the engine of the model in bringing about relationship between the input and the output parameters to evaluate the outcome of such relationship. The result obtained indicates the feasibility of applying the neuro-fuzzy model in plastic recycling extruder process.

Response surface methodology

Lebaal et al. developed a new approach to the optimal design of the die wall temperature profile in polymer extrusion processes [6]. The optimization method was based on response surface method. It has a very fast convergence, which is an advantage when time-consuming flow analysis calculations are involved. Design of experiment (DOE) needed for the construction of the response surface was used to evaluate the objective and the constraint functions on the basis of a finite element method (FEM). Two designs of experiments were used and the performances of the optimization results were compared with respect to efficiency and ability to obtain a global optimum. The effect of the design variables in the objective and constraint functions was investigated using Taguchi method. The flow analysis results were then combined.

Genetic algorithm

Yu et al. determined the optimal die gap programming of extrusion blow molding processes using soft-computing techniques [7]. The design objective was to obtain a uniform part thickness after parison inflation by manipulating the prison die gap openings over time. Commercial finite element software (BlowSim) from the National Research Council (NRC) of Canada was used to model the whole process, i.e., the parison extrusion, the mould clamping, and the parison inflation. A new approach called fuzzy neural-Taguchi network with genetic algorithm (FUNTGA) was implemented to establish a back propagation network using a Taguchi's experimental array to predict the relationship between design variables and responses. Taguchi's experimental designs were employed for the training of a neural network model and the trained network was used as the function generator of the design fitness in the genetic algorithm (GA). The GA searching efficiency was enhanced using the introduction of a fuzzy inference of the engineering knowledge.

Mu et al. proposed an optimization approach for the processing design in the extrusion process of plastic profile with metal insert based on finite element simulation, back propagation neural network and genetic algorithm [8]. The polymer melts flow in the extrusion process was predicted using finite element simulation. The simulated results were extracted for the establishment of neural network. The search for globally optimal design variable for the extrusion was done using GA with its objective function evaluated using the established neural network model. The uniformity of outlet flow distribution was taken as the optimization objective with a constraint condition on the maximum shear stress. The objective of flow balance was achieved by the optimal design of two processing parameters including the volume flow rate and the metal insert moving velocity.

Non-linear modeling

Mamalis et al. applied multi-parametric optimization to the processing conditions in a spider die used for the extrusion of high density polyethylene (HDPE) tubes [9]. The parameters investigated were inlet pressure, inlet temperature of the melt, temperature of the die walls, and temperature of the spider legs. A computational fluid dynamics (CFD) based model using the generalized Newtonian approach was employed, to investigate pressure drop, along with flow and temperature uniformity in the die. The numerical calculations for the three-dimensional flow and temperature fields were performed with a finite element based CFD code, Comsol 3.5. The Nelder-Mead nonlinear optimization technique was applied to the numerical model, in order to pinpoint the processing conditions that result into maximizing flow homogeneity at the die outlet. The objective function utilized was a weighted average of the Signal-to-Noise Ratios (SNRs) of flow temperature and velocity at the die outlet.

Conclusion

This article presents a review of research in the determination of the process parameters for plastic extrusion. A number of research works based on various approaches including mathematical model, Taguchi technique, artificial neural networks (ANN), fuzzy logic, genetic algorithms (GA), non-linear modeling, and response surface methodology have been described.

A review of literature on optimization techniques has shown a successful industrial application of DOE-based approaches for optimal settings of process variables. Taguchi method is a robust design technique widely used in industries for making the product/process insensitive to any uncontrollable factors such as environmental variables. Taguchi approach has helped in reducing the experimental time and cost of product or process development and quality improvement.

ANN and GA are emerging as the new approaches in the determination of the process parameters for plastic extrusion. A trained neural network system can quickly provide a set of extrusion parameters according to the results of the predicted quality of extruded parts. However, the time required in the training and retraining for a neural network could be very long. By using GA approach, the system can locally optimize the extrusion parameters even without the knowledge about the process.

References

[1] Narasimha M, Rejikumar R. *Plastic pipe defects minimization*. International Journal of Innovative Research & Development 2013; 2(5):1337-1351.

[2] Huang H-X, Liao C-M. *Prediction of parison swell in plastics extrusion blow molding using a neural network method*. Polymer Testing 2002; 21(7):745-749.

[3] Cirak B, Kozan R. *Prediction of the coating thickness of wire coating extrusion processes using artificial neural network (ANN)*. Modern Applied Science 2009; 3(7):52-66.

[4] Al Rozuq R, Al Robaidi A. *Application of neural network (ANN) to predict XLPE cable in extrusion processes*. Journal of Materials Sciences and Applications 2013; 2013.

[5] Oke S.A, Johnson A.O, Charles-Owaba O.E, Oyawale F.A, Popoola I.O. *A neuro-fuzzy linguistic approach in optimizing the flow rate of a plastic extruder process.* International Journal of Science & Technology 2006; 1(2):115-123.

[6] Lebaal N, Puissant S, Schmidt F. *Application of a response surface method to the optimal design of the wall temperature profiles in extrusion die*. International Journal of Material Forming 2010; 3(1):47-58.

[7] Yu J-C, Chen X-X, Hung T-R, Thibault F. *Optimization of extrusion blow molding processes using soft-computing and Taguchi's method*. Journal of Intelligent Manufacturing 2004; 15(5):625-634.

[8] Mu Y, Zhao G, Wu X. *Optimization approach for processing design in the extrusion process of plastic profile with metal insert*. e-Polymers 2013; 12(1):353-366.

[9] Mamalis A.G, Vortselas A.K, Kouzilos G. *Tube-extrusion of polymeric materials: optimization of processing parameters*. Journal of Applied Polymer Science 2012; 126(1):186-193.