Application of Artificial Neural Network Technique for prediction of Injection Molding Process

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Abstract

This Present study has been made to predict the process parameter during forming of PVC (L-bow) fitting by injection molding machine using Artificial Neural Network (ANN). Four input process parameters of injection molding machine namely filling time, refill time (RFT), tonnage time (TT) and Ejector retraction time (ERT)) is chosen as variables to determine the process performance in terms of cycle time (CT). The ANN models presented excellent predictions, and the comparison between the predicted values and the experimental values was carried out based on the mean absolute percentage error. The ANN model gave a Mean Absolute Percentage Error (MAPE) of 1.4 % which confirms the accuracy of the model.

Keywords: Injection molding, Artificial Neural Network (ANN), Mean Absolute Percentage Error (MAPE)

الملخص:

تم إجراء هذه الدراسة الحالية للتنبؤ بمعامل العملية أثناء تشكيل تركيب) PVC القوس (L عن طريق آلة التشكيل بالحقن باستخدام الشبكة العصبية الاصطناعية .(ANN) يتم اختيار أربع معلمات لعملية الإدخال لآلة التشكيل بالحقن وهي وقت الملء ، ووقت إعادة الملء (RFT) ، ووقت الحمولة (TT) ، ووقت سحب القاذف ((ERT) كمتغيرات لتحديد أداء العملية من حيث وقت الدورة .(CT) قدمت نماذج ANN تنبؤات ممتازة ، وأجريت المقارنة بين القيم المتوقعة والقيم التجريبية بناءً على متوسط نسبة الخطأ المطلق. أعطى نموذج ANN متوسط نسبة الخطأ المطلق1.4 (MAPE) ٪ مما يؤكد دقة النموذج.

1- Introduction

Injection molding is a difficult process for many manufacturers and researchers to produce products that meet their requirements and maintain the desired quality at the lowest cost. More complex and parameter manipulations can affect product quality and high manufacturing costs. The main goals of injection molding are to improve product quality, reduce cycle times and reduce manufacturing costs. Injection molding (IM) technology enables the production of parts with complex shapes in large quantities in short cycle times with excellent dimensional accuracy. Quality and production issues directly affect the expected profits of the injection molding industry. Injection molding quality properties are categorized into mechanical properties, dimensions, or measurable properties and attributes. All manufacturing activities want optimized productivity and quality. In plastic injection molding, quality is determined by considering part design, mold design, and mold accuracy, and scrap-free, defect-free hills also ensure productivity and optimize cycle time. Response surface methodology (RSM) is a collection of statistical and mathematical methods that are useful for modeling and analyzing technical problems. From a manufacturing perspective, cycle time can be seen as the most important factor in improving production rates. It is important to achieve better quality and lowest product cost based on customer demand. It is a characteristic that improves the manufacturing cost of the product (Amit, et al, 2014). Cycle time has been identified as a quality aspect and is assumed to be directly related to mechanical section performance and production rate. Aside from quality, there is another criterion known as productivity, which is directly proportional to an organization's profitability and goodwill. As a result of these factors, and divide time in molding process

Injection molding is one of the most important and common plastic molding processes. A set of modeling tools and optimization algorithms can be used to determine the optimal process conditions for injection molding of a specific part. Analytical modeling of the process is impossible or difficult due to the complexity of the injection molding process and the large number of parameters and their interactions. Therefore, use an artificial neural network (ANN) to model the process. To model a process through a neural network, we need process condition data. After the modeling step, the model is combined with the genetic algorithm (GA). Optimized conditions are achieved based on the injection target transformed into a fitness function.(Mohammed. et al, 2013). Rishi et al. determined the appropriate parameters in the production of plastic products in. The term force. The paper described the effect of temperature, pressure and cooling time. Plastic polycarbonate is studied in this paper which is commonly used in industries. The operating parameters must be correct and can produce a better product. There are changes that occur in the product with a change in parameters. The optimum parameter is related to quality to produce a product without defects such as short casting, flashing, etc. The plastic product (tea dish) is produced from polycarbonate plastic using De-Tech85 LNC5 injection molding machine with different melting temperature, injection pressure and cooling time. The tensile strength test of each workpiece was carried out with a Tinius Olsen H10K-T UTM. Each panel has showed different strength, surface finish and some other characteristics differences. Using Taguchi and ANOVA optimal value or best value Melting temperature, injection pressure and cooling time are obtained (Pareek R. and Bhamniya J., 2013). An optimized algorithmic artificial neural network and particle swarm (PSO) algorithm method for optimizing the injection molding process was proposed by Yingjie et al. He first proposed an integrated finite element analysis of the injection molding process, the residual stresses caused by cuffing during assembly, and the mechanical performance of the serviced product. Then an inverse neural network model was developed to map the complex nonlinear relationship between process parameters and product mechanical performance. The PSO algorithm has been linked to this predictive model to improve process parameters and thus significantly improve mechanical performance. A case study of polycarbonate (PC) car windows is presented. They determined the optimal values of process parameters to reduce the maximum stress of von Mises within the window of a PC vehicle under shock loading (Yingjie et al, 2015).

1. Artificial Neural Networks

Artificial Neural Network (ANN) is a computational technique when formulating an algorithmic solution for a problem becomes impossible or modeling tools for statistical data is not linear in a case with a lot of samples and the purpose of predicting the future [Farideh, el at, 2018]. An artificial neural network (ANN) is a collection of artificial neurons that collaborate to solve nonlinear approximations, determine target functions, and other tasks. ANNs learn from samples in the same way that people do. The three major layers of ANNs are input, hidden, and output. They are made up of a sequence of nodes connected by weights. The input data is multiplied by the associated weight of the neuron, then a bias is applied to the outcome. Finally, as shown in Figure 1, the output is sent through a non-linear filter called the activation function (transfer function) to produce the final output.

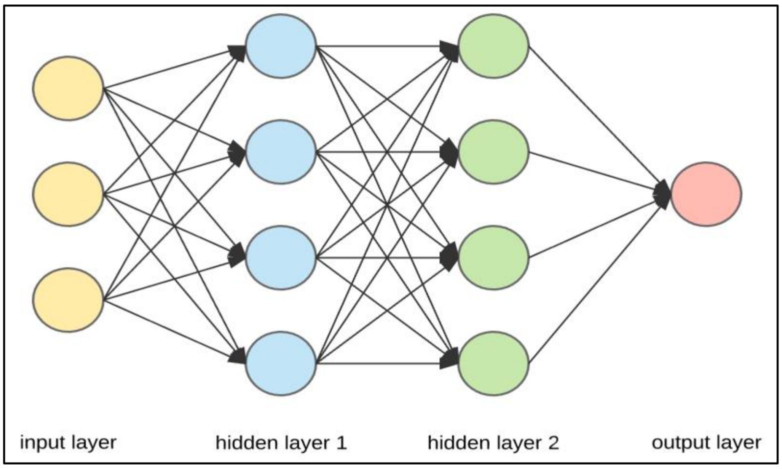

Fig 1. Fundamental Elements of Artificial Neural Network.

Each problem's number of neurons and layers can be determined by trial and error. The multi-layer feed-forward network is an acyclic network in which signals pass through the network solely in a forward manner, starting with the input neurons and ending at the output neurons shown figure 1 Problem-solving procedures are a set of properties that ANNs have. Learning ability, generalization ability, parallel processing, resilience, application, and fault-recognition are all significant capabilities of ANNs.

2. Experimental Details

In this experimental study, the fabric to be machined is PVC with diverse chemical compositions shown figure 2 (Amit, et al, 2014). Examination of system row fabric polyvinyl chloride (C_2H_3Cl)n become finished the usage of as in step with the requirement. The system operations are taken as in step with the situations given through the layout matrix randomly if you want to keep away from mathematical errors. The Cycle time may be taken as the output of this study.

Fig. 2 Injection molding machine and Product (Amit, et al, 2014).

3. Result and Discussion

The upper (+1) and lower (-1) levels of all the four parameters and their designations are shown in Table 1. The number of experiments shown in Table 2 was obtained from previous work (Amit, et al, 2014). As there are four input parameters namely Filling Time, Refill Time, Tonnage Time, Ejector Retraction Time therefore total 31 experiments were studied. The output response selected for these experiments is cycle time.

Table 1. Factors and their levels

Symbol	Factors	Units	+1	0	-1
FT	Filling Time	Sec	23	24	25
RFT	Refill Time	Sec	36	37	38
TT	Tonnage Time	Sec	68	70	72
ERJ	Ejector Retraction Time	Sec	1.36	1.38	1.4

Table 2. Experimental Data for actual Cycle Time

No. Exp	FT	RFT	TT	ERT	Actual Cycle Time
1	23	36	0.68	1.36	95.03
2	25	36	0.68	1.36	96.88
3	23	38	0.68	1.36	95.89
4	25	38	0.68	1.36	96.96
5	23	36	0.72	1.36	95.68
6	25	36	0.72	1.36	97.27
7	23	38	0.72	1.36	95.25
8	25	38	0.72	1.36	97.5
9	23	36	0.68	1.4	95.61
10	25	36	0.68	1.4	97.3
11	23	37	0.68	1.4	95.37
12	25	38	0.68	1.4	97.45
13	23	36	0.72	1.4	95.76
14	25	36	0.72	1.4	97.7
15	23	38	0.72	1.4	95.89
16	25	38	0.72	1.4	97.5
17	23	37	0.7	1.38	95.9
18	23	37	0.72	1.38	95.85
19	24	38	0.72	1.38	96.2
20	24	38	0.7	1.38	96.1
21	24	37	0.68	1.38	96.13
22	24	36	0.72	1.38	96.18
23	24	36	0.7	1.36	96
24	24	37	0.68	1.4	96.33
25	24	37	0.68	1.36	96.2
26	24	37	0.72	1.36	96.3
27	24	37	0.7	1.4	96.5
28	24	38	0.72	1.4	96.78
29	24	37	0.7	1.38	96.68
30	24	37	0.72	1.38	96.45
31	24	36	0.7	1.38	96.4

The actual values of the cycle time obtained by the experimental and the predicted values of the cycle time calculated using ANN model are shown in Table 3.

Table 3: The actual values and the predicted values of tensile strength

No. Exp	FT	RFT	TT	ERT	Actual Cycle Time	Prediction Cycle Time (ANN)
1	23	36	0.68	1.36	95.03	95.9
2	25	36	0.68	1.36	96.88	96.9
3	23	38	0.68	1.36	95.89	95.9
4	25	38	0.68	1.36	96.96	97.4
5	23	36	0.72	1.36	95.68	95.7
6	25	36	0.72	1.36	97.27	97.4
7	23	38	0.72	1.36	95.25	95.7
8	25	38	0.72	1.36	97.5	97.5
9	23	36	0.68	1.4	95.61	95.6
10	25	36	0.68	1.4	97.3	97.3
11	23	37	0.68	1.4	95.37	95.4
12	25	38	0.68	1.4	97.45	97.5
13	23	36	0.72	1.4	95.76	95.7
14	25	36	0.72	1.4	97.7	97.1
15	23	38	0.72	1.4	95.89	95.9
16	25	38	0.72	1.4	97.5	97.5
17	23	37	0.7	1.38	95.9	95.9
18	23	37	0.72	1.38	95.85	95.9
19	24	38	0.72	1.38	96.2	96.2
20	24	38	0.7	1.38	96.1	96.1
21	24	37	0.68	1.38	96.13	96.5
22	24	36	0.72	1.38	96.18	96.2
23	24	36	0.7	1.36	96	96.0
24	24	37	0.68	1.4	96.33	96.3
25	24	37	0.68	1.36	96.2	96.2
26	24	37	0.72	1.36	96.3	96.3
27	24	37	0.7	1.4	96.5	96.4
28	24	38	0.72	1.4	96.78	96.8
29	24	37	0.7	1.38	96.68	96.3
30	24	37	0.72	1.38	96.45	96.5
31	24	36	0.7	1.38	96.4	96.4

To validate the ANN model, a comparison between the actual values and the predicted values of cycle time is presented based on the mean absolute percentage error (MAPE) value. This value was calculated using equation (1). This value was 1.4%, which indicates that the model is having good prediction accuracy. Also, Figure 3 shows the comparison between the actual values and the predicted values of cycle time. It can be seen from Figure 3 that the ANN models can reflect the actual value of the cycle time.

$$MAPE = \frac{\sum_{i=1}^{n} |A-P| / A}{n} * 100\% \qquad (1)$$

Where:

A: The actual value for cycle time.

P: The predicted value for cycle time.

n : Number of Experimental.

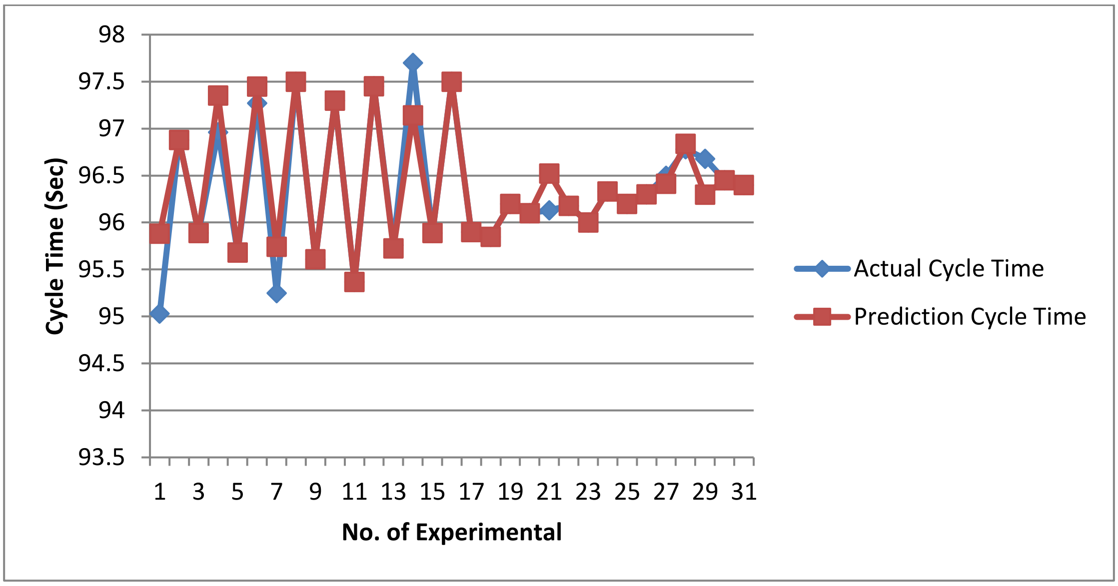

Fig.3.The comparison between the actual values and the predicted values of Cycle Time

4. Conclusions

In the study, an Artificial Neural Network (ANN) was implemented to predict the cycle time of PVC (C2H3Cl)n material on an injection molding machine are explained. The ANN models presented excellent predictions, and the comparison between the predicted values and the experimental values was carried out based on the mean absolute percentage error. The ANN model gave a Mean Absolute Percentage Error (MAPE) of 1.4 % which confirms the accuracy of the model. It can be inferred that ANN is an effective modeling technique for accurate prediction and improving the performance of the cycle time in an injection molding machine.

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