Research on Optimization Design of Injection Mold for Automobile Filter Shell Model Based on BP Neural Network

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Abstract. According to the structural characteristics of the injection molded parts of a filter housing of a car, Moldflow is used to analyze the mold flow of the injection molded parts, and a BP neural network topology model with multiple inputs and multiple outputs is established, and the mold filling time is designed. Through training, the BP neural network model has a smaller relative error and better prediction ability. The network model can be used to optimize injection molding of automotive parts models. Practice has proved that the injection mold of the automobile filter housing model designed by BP neural network model has reasonable structure and high production efficiency.

1. Introduction

Injection molding is a common processing method in which thermoplastic materials can be molded into plastics of any complex shape [1-2]. Injection molding has the ability to efficiently form plastic parts. Plastic injection molding processes have been widely used for large-scale production. However, it is difficult to produce large parts by injection molding [3]. The quality of plastic products depends on the characteristics of the materials, the design of the mold and the process parameters, any of which is very important [4]. There are a variety of existing automotive filters [6], and the molds designed for different filters are also different, with good product consistency, easy operation, and low labor intensity of workers [5], but mainly it is a one-to-one cavity layout, and the production efficiency is still not high enough. Since the Moldflow software [7] performs the injection molding process simulation equivalent to the actual injection molding process simulation, if the numerical analysis results do not meet the technical requirements of the enterprise, it is necessary to adjust the initial process parameters or modify the finite element model. Start finite element analysis calculations. Moreover, it takes a lot of time to go through repeated simulation analysis to find the optimal combination of injection molding process parameters. The artificial neural network [8] has the characteristics of self-organization and self-learning. It can optimize the calculation and function approximation of complex nonlinear functions, so it can be used for rapid prediction and reasonable determination of injection molding process parameters.

In this paper, the process design of a car filter shell model is firstly carried out, and the Moldflow software is used to analyse the mold flow of each process plan in the orthogonal test, and the filling time, volume shrinkage and total warpage are obtained. Wait for the objective function value. The obtained
data is used as a sample to train the BP neural network. After comparison, it is found that the trained network has better prediction accuracy. On this basis, the trained BP neural network is used to predict the optimal process parameters, and the best combination of process parameters is obtained. And the mold opening and test mode were carried out, and the qualified model test model of the automobile filter shell was obtained, which further verified the good function of BP neural network in the plastic injection molding process.

2. Process analysis of injection molded parts for automotive filter housing

The car filter is divided into a bottom case and an upper case, and the mold design performed is the design of the bottom case mold. The material used for the bottom of the automobile filter is hard polypropylene, which has a complicated shape and a large number of side cores. The software used is SolidWorks2003, and the bottom part is shown in Figure 1. The automotive filter bottom case is taken as an example to illustrate the design process of the plastic injection mold of SolidWorks software and IMOLD plug-in. The design process is as follows:

2.1. Data Preparation
The data preparation function can process the 3D model of the plastic product to be designed and place it in the correct direction. In IMOLD, the direction of the parting is defined as the Z axis, and the data preparation function is to position the model in the same direction as the opening mode. It creates a replica by transforming the original model and then uses the replica for design work. The replica is always associated with the original model.

2.2. Program Control
After the data is prepared, the design work to be performed is program control. This is the entry module for the other IMOLD modules used, and all designs must start here. If you want to design a car filter bottom mold, you need to define some information about the design, and use this information in the later design. This information includes: the name of the program, the resin material used for the part, the shrinkage rate, and system information such as the working directory, the files needed, and so on.

2.3. Pouring system design
The gating system design module provides the functionality to design gates and runner systems. Standard gates and runners can be created in a parametric way and placed into the module structure. In the car filter bottom mold, the gate we use is the point gate through the direction of the product. Because the gate is small, the gate can be placed on the outer surface of the article for casting.

2.4. Mold frame, ejector, slider design
The formwork design function integrates various formwork structures of popular formwork manufacturers in a parametric manner. In the design, the mold frame can be selected according to the specific design conditions, and the parameters can be adjusted, and the mold frame structure can be adjusted, such as adding a template. It also provides the functionality of a custom formwork. In the mold frame design of the automobile filter bottom shell mold, the type of the mold selection frame is HASCO type A, and the length X width is: 400×500 mm, and the thickness of each template is determined according to actual conditions. In addition, you need to determine the location of the fixing screw holes and the guide posts. In the ejector design, the ram can be easily added to the mold. The extracted core profile is used to trim it while the cavity is cut in the core module and the template they pass through. Its length and diameter can be selected and edited, and the shape of the head of the ejector is designed according to the actual situation. The slider design feature is used to create sliders. You can choose one of the many standard slide devices available in the module at design time, or customize a more suitable slider structure depending on the part.
2.5. Cooling system design

Using the Cooling System Design Module, you can create a variety of simple and complex cooling circuits in your mold. The module uses 3D sketching techniques when designing the cooling circuit to observe and design complex cooling circuits. At the same time, in order to facilitate the processing, it can specify the drilling face and the over-drilled part. Each individual loop is a separate file located in a sub-assembly file. Once the design is complete, these cooling channels can form cavities from the modules or the stencils they pass through.

3. Optimization design of process parameters of automotive filter housing

When the automobile filter housing is injection molded, the process parameters affecting the injection molding process mainly include melt temperature, mold temperature, injection pressure, holding time and holding pressure. By selecting the proper melt temperature and mold temperature, defects such as shrinkage and warpage of the part can be reduced, and defects such as water ripples and dents can be prevented by appropriate injection pressure. Since the storage box has a large surface area and a thin wall thickness, short-acting phenomenon is likely to occur during the filling process. Therefore, it is necessary to establish an accurate condition for maintaining pressure during injection molding, and a reasonable holding time and a holding pressure are adopted. Moreover, compared with the traditional constant pressure linear holding pressure, the curve holding pressure can reduce the pressure at the gate and obtain a relatively uniform volumetric shrinkage distribution to avoid excessive pressure holding phenomenon [6], so this optimization time a curved pressure holding curve is used.

3.1. Establishment of BP neural network model

In this paper, melt temperature, mold temperature, injection pressure and holding pressure are used as input parameters of BP neural network model. The filling time, volume shrinkage and total warpage are taken as the output parameters of BP neural network model. A BP neural network topology model with 4 inputs and 3 outputs is established to quickly and accurately predict and train the injection results of the built-in storage box under different process parameters. Among them, the number of hidden layer nodes \( s \) can be determined by empirical formula (1):

\[
s = \sqrt{R + k} + \alpha
\]

Where \( R, s, \) and \( k \) are the number of nodes of the input layer, the hidden layer, and the output layer, respectively; \( \alpha \) takes a constant between 1 and 10. According to formula (1), \( s=6 \) can be initially selected, and the neural network can be adjusted in the later stage according to the actual situation.
3.2. Selection of training samples
The four factors of melt temperature (A), mold temperature (B), injection pressure (C), and holding pressure (D) were selected as the initial training parameters of BP neural network algorithm. Refer to the process parameters recommended by Moldflow software. The range of values, each process parameter is selected 4 levels, according to the design idea of Taguchi experiment [8], the analysis results of 16 groups of orthogonal experiments are extracted as samples to train BP neural network. In order to reduce the distribution range of the input data and the output data, the training samples can quickly converge and meet the accuracy requirements, and the data is normalized, namely:

$$\bar{x}_i = \frac{2(x_i - x_{min})}{x_{max} - x_{min} - l}$$  \hspace{1cm} (2)

Where $\bar{x}_i$ represents input or output data; $x_{max}$ and $x_{min}$ represent the maximum and minimum values in the data, respectively. The quasi-Newton algorithm (BFGS) is used in BP neural network training. This algorithm has faster convergence speed and less step size. The training function uses trainbfg, and the input layer function and the output layer function respectively use the nonlinear transfer function logsig and the linear transfer function purelin. The maximum number of trainings is 550, the rate is $10^{-2}$, and the network performance target error is $10^{-3}$.

3.3. Training and verification of the network model
Figure 3 is an error graph of BP network model training. It can be seen that after 550 trainings, the minimum error of the neural network output has stabilized at 10-3, meeting the accuracy requirements, and the network stops iterating.

In order to compare the BP neural network output value with the Moldflow analog value, the output value and the analog value comparison graph shown in Fig. 4 are plotted according to the data. It can be
seen from Fig. 4 that the output value of the BP neural network is very close to the analog value of Moldflow for each objective function after injection molding of the built-in storage box of the automobile.

4. Optimization of Process Parameters of Automotive Oil Filter Shell Mould Based on BP Neural Network

In order to obtain the optimal process parameter combination when the automobile oil filter casing is molded, all the other experimental samples are outputted by the BP neural network for the objective function, and the results of the objective function are compared to make the filling time shorter and the volume shrinkage ratio The small and warp deformation is lighter than the judgment basis, so that the corresponding optimal process parameters can be obtained as follows: melt temperature 220°C, mold temperature 50°C, injection pressure 100 MPa, dwell time 18 s and holding pressure 110 %-80%-0. In the injection molding model of the automobile oil filter casing in Moldflow, the combination of the optimal process parameters obtained by BP neural network optimization is re-inputted, and the filling + flow + cooling + warpage analysis is performed, and the filling time and volume shrinkage can be obtained. The deformation rate of the rate and the total warpage amount is as follows.

(1) After optimization, the filling time of the outer casing of the automobile oil filter is second, and the nodes on the left and right sides are 2.642 and 2.640s respectively. Since the distance between the
gates of the two wings is slightly farther, the filling time is longer. The nodes on the left and right sides are 2.792 and 2.790s, respectively, and the pouring process is completed almost at the same time.

(2) The volumetric shrinkage at the front and rear corners of the tray portion of the automobile oil filter housing is small, 0.8048%, 0.8016%, 0.8446% and 0.8304%, respectively. The volumetric shrinkage of the two wings is the largest, and the left and right nodes are 1.382% and 1.329%, respectively, but they do not exceed the maximum ideal value of 3% [6]. This shows that the BP neural network optimized process parameter combination can achieve the purpose of reducing the holding pressure and the pressure at the gate during the pouring process, so that the volume shrinkage near the gates of the built-in storage box of the automobile is reduced.

(3) The total warpage of the entire tray portion of the automobile oil filter housing after optimization is between 0.0240 and 0.4308 mm. Although the total warpage of the two wing parts is large, they do not exceed the tolerance range given by the company. It can be seen that the optimization of the process parameters, especially the adjustment of the pressure holding curve, is very effective for eliminating the warpage defects, thereby improving the molding quality of the mass production of the storage box parts.

According to the injection molding process plan, the design, processing and debugging of the injection mold of the automobile oil filter casing are carried out, and the production of the parts is carried out in relevant enterprises according to the improved process parameter combination. The surface quality of the automobile oil filter casing after molding is good, the reinforcing ribs are completely filled in the tray part, and there are no obvious defects such as warping deformation and melting marks, which meet the requirements of dimensional tolerance and the like. As shown in Figure 5.

5. Conclusion
In this paper, the BP neural network method and Moldflow are used to study the process parameters of the injection mold of a car's filter shell model. Through systematic analysis, it is found that the error between the predicted value of BP neural network and the simulated value of Moldflow is small. It shows that the multi-input-multi-output BP neural network model after training has better prediction accuracy. It can be seen from the results that the volume shrinkage rate and the amount of warpage of the filter casing model of the automobile are small, and the filling effect is good everywhere. Through the trial production of the parts, it was found that the surface quality of the molded casing model of the molded automobile was good and there were no obvious defects.

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