Optimization of injection molding of display panel based on PSO-BP neural network

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ABSTRACT: aiming at the practical production problem of large thin-wall plastic parts with large warping deformation and shrinkage during injection molding, the injection process parameters were optimized by CAE technology and neural network prediction method, to obtain high quality plastic finished products. Particle swarm optimization (PSO) algorithm was used to improve the BP neural network, and based on the neural network, the prediction model between injection process parameters and warpage deformation, volume shrinkage was constructed. The min-variables of the two parameters are accurately predicted by the model, and the best injection molding parameters are obtained. Through the verification of the mold test, the molding quality of the plastic parts is improved, the production cycle of the mold is shortened, and the economic benefit of the mold production is improved.

1. Introduction
Display panel products are characterized by large size and thin thickness. The fluidity of plastic melt in the mold cavity is poor, so multi gate filling is needed, which is easy to cause the problems of uneven filling, uneven cooling shrinkage, short shot, warpage, shrinkage mark, weld mark and other defects that affect the appearance quality of the product [1]. In the trial and proofing stage, it costs a lot of time, manpower and capital to repair the mould and adjust the injection molding process. Therefore, the CAE analysis method is used to simulate the process parameters, and then the actual injection molding, which reduces the number of blind test, and improves the production efficiency[2]. The PSO-BP Neural Network optimized by particle swarm optimization (PSO) has a wide range of applications and can improve the defects of the BP neural network mentioned above. The best results in the combination of multi-quality results and injection process parameters are obtained, in order to achieve high efficiency, high quality injection molding purposes [3].

2. CAE flow analysis of display panel

2.1 plastic part analysis of this l display panel 3d model
The Outer Contour size is: 920mm*430mm*73.8 mm, wall thickness detection, tmax = 3.55 mm, tmin = 0.61 mm. The Wall thickness is constant in most areas, about 2.3-2.5 mm, and the interval of ventilation holes is relatively thin. More internal support structures and stiffeners.
2.2 CAE model construction
Using Moldflow software, a two-layer grid is created, the correction aspect ratio is less than 10, the matching rate of the grid is close to 90%, and the accuracy of the analysis is guaranteed. The gating system uses a 6-point hot runner valve gate with the following dimensions: Gate 2mm, vertical runner 10mm taper 6°, distributor 10mm, main runner 10mm taper 6°. The pre-set of pouring point needs to be optimized later. Cooling System Piping layout to try to avoid fasteners, thimbles, such as holes in the runner, to prevent material leakage. Pipe diameter 10mm, inlet nozzle cross-layout. As shown in Figure 1.

![Gate System Model](image1.png)

![Cool System Model](image2.png)

Fig. 1 CAE modeling of display panel

2.3 Injection molding process settings
Through the process settings wizard, filling control is set to: Automatic; pressure control is set to: % filling pressure and time; v/p switch is set to: automatic. Cooling Setting: Melt Temperature 210°C, injection + holding pressure + cooling time 30 seconds, mold opening time 5s; warping setting: Check consider die thermal expansion, consider separate warping reason.

| Plastic material | Mold temp | Melt temp | Ejection temp | Melt-max temp | Max- Shear rate | Warp | Molding Time |
|------------------|------------|-----------|---------------|---------------|----------------|------|--------------|
| PC+ABS (ChiMeiPA757) | 30-70°C | 180-240°C | 84°C | 260°C | 10^4 l/s | Thermal | 30s |

2.4 CAE aided simulation analysis
This research mainly focuses on the analysis of warping defects. As shown in Fig. 2, the deformation caused by the uneven z direction of contraction is shown as the most important deformation. The main deformation occurs in the left and right bottom corner of the Red Circle, the shrinkage deformation in other areas is more uniform. The reason for this defect is that the holding time is too long.

![Uneven Cooling](image3.png)

![Uneven Shrinkage](image4.png)

Fig. 2 Warping deformation analysis

Based on this single objective and single quality defect, the orthogonal method can quickly find the best combination of process parameters, and for 2 or more defects, due to the further enhancement of the nonlinear relationship between the process parameters and the multi-objective, the model test problem becomes very complicated. Through the neural network based on PSO-BP Algorithm
Component, the factor level of the input parameters is adjusted tendentiously, and the adjusted input parameters are carried out through the PSO-BP neural network, finally, the process parameter combination corresponding to the final quality target is obtained, thus the optimal process parameter combination is obtained.

3. Orthogonal test for injection molding

In order to study the non-linear relationship between warpage deformation Q, shrinkage and injection molding process parameters, it is necessary to combine the injection molding machine test to obtain the samples needed for BP network construction.\(^5\) During the mold test, 6 parameters in the injection molding process are selected to analyze. The six parameters are: t1, T2, T3, P4, T5, t6, which represent injection time, cavity temperature, melt temperature, holding pressure, holding time and cooling time. In order to ensure the integrality of the process parameters, the injection molding experiment was carried out with the orthogonal scheme of 6 factors and 4 levels.

4. Injection prediction of display panel based on PSO-BP neural network

4.1 Improved particle swarm optimization with weight PSO

Particle swarm optimization (PSO) algorithm is a global random search algorithm based on swarm intelligence, which is inspired by the artificial life research results and simulates the migration and swarm behavior of birds in the foraging process, PSO has good practical effect for BP neural network applied in complex industrial model. For weights and thresholds in the network, the iterative formulas for Particle Velocity \(v_{ij}\) and position \(x_{ij}\) are shown in (1) and (2).

\[
\begin{align*}
    v_{ij}(t+1) &= \omega \times v_{ij}(t) + c_1 \times \text{rand}(\ ) \times [p_{ib}(t) - x_{ij}(t)] + c_2 \times \text{rand}(\ ) \times [g_{ob}(t) - x_{ij}(t)] \\
    x_{ij}(t+1) &= x_{ij}(t) + v_{ij}(t+1)
\end{align*}
\]

In the formula, \(i=1,2; j\) is the Dimension Space Number; \(x_{ij}\) is the Particle Location; \(v_{ij}\) is the Particle Movement Vector; \(p_b\) is the individual extreme value of fitness; \(g_b\) is the global extreme value of fitness; \(c_1, c_2\) is the identification factor; \(t\) is the iteration number; \(\text{rand}(\ )\) is a random free number, \((0 \sim 1)\); \(\omega\) is the inertia weight.

4.2 Construction of PSO-BP neural network

BP Neural Network has good fault tolerance, simple structure and strong nonlinear processing ability. It can achieve the approximation of any nonlinear function by using 3-layer network. The optimization of BP neural network using PSO is as follows.

(1) The particle dimension is \(n = n_1 \times n_2 + n_2 \times n_3 + \theta_j + \gamma_k\), and the corresponding mapping relation is \((w_{ij}, v_{jk}, \theta_j, \gamma_k)\).

(2) Network parameters include particle number \(m\), weight \(\omega\), Identification Factors \(c_1, c_2\), particle velocity domain and position.

(3) given the number of ITERATIONS \(t_{\max} = 100\), the Error Control Value \(E_{\min} = 0.000021\); the fitness function for calculating the velocity and position of the randomly determined particle is shown in (3).

\[
MSE(\gamma_o) = \frac{1}{n} \sum_{i=1}^{n} (y_o - y_i)^2
\]

The fitness values obtained by this formula are compared with those of \(p_b\), \(t_b\), \(g_b\) to judge whether the particle velocity is updated or not. If update is needed, the optimization is continued until the number of iterations meets \(t_{\max}\) or the error \(E_{\min} = 100\) to obtain the optimal neural network weights and thresholds. The smaller it is, the higher the model accuracy, and vice versa, the lower.

4.3 PSO-BP network model

In the model, the process parameters are 6 and the quality objectives of the study are 2. Therefore, the model adopts the construction mode of 6 inputs and 2 outputs. The middle layer function is determined as shown in formula (4), and the hidden layer function’s excitation function is s type function, the output layer excitation function is a linear function.
In the formula: \( P \) is the number of intermediate neurons; \( n \) is the number of input neurons; \( m \) is the number of output neurons; \( a \) is the adjustment parameter. It can be seen that the number of intermediate neurons \( P \) can be selected from 3 to 12 neurons. After calculation, \( p = 10 \) is more suitable. When the network structure is determined, the Particle Dimension \( n = 92 \), population \( m = 30 \), Iteration \( t_{\text{max}} = 1000 \), precision setting \( f = 0.001 \), \( c_1 = c_2 = 2 \), particle velocity field \([-0.12, 0.12]\), location field \([-1, 1]\), \( w_{\text{max}} = 0.9 \), \( w_{\text{min}} = 0.5 \) can be obtained by correlation calculation.

5. Optimization of injection molding process

5.1 Optimization principle

From the foregoing, the non-linear relationship between the final quality of the plastic part and the molding process parameters can be described as shown in formula (5).

\[
(\Delta L, \Delta V) = f(t_1, T_2, T_3, P_4, t_5, t_6)
\]  

(5)

The aim of process optimization is to obtain a set of process parameters \((t_1, T_2, T_3, P_4, t_5, t_6)\), so that the quality \((\Delta q, \Delta v)\) can be optimized, because of the complexity of operation, the conventional optimization method cannot meet the actual requirements of injection molding optimization, so the conventional optimization method needs to be further improved.

In the optimization of PSO-BP network, fitness function is very important to the optimization of Algorithm, fitness function mainly refers to the degree of correlation between quality results, the higher the degree of correlation, the better the adaptability, otherwise, the worse. In view of the optimal expectation of the quality \((\Delta q, \Delta v)\) target, we hope that the minimum of both at the same time is the best. Therefore, for the optimization of this example, we can take the grey correlation degree as the evaluation function of this example PSO algorithm, as shown in (6), (7).

\[
\text{fitness}(\Delta L, \Delta V) = \sum_{j=1}^{n} \varepsilon_{o_j}
\]

(6)

\[
\varepsilon_{o_j} = \frac{A_1 + \rho A_2}{[\Delta L_0 - \Delta L_j - \Delta V_0 + \Delta V_j] + \rho A_2}
\]

(7)

In the formula: \( \rho \) for Identification Parameter, the value is 0.5; expectation value, prediction value is \( \Delta L_0, \Delta L_j - \Delta L \).

5.2 Search for excellence results

According to the above, Matlab Software neural network toolbox is used to simulate the network. At the beginning, the optimal expectation value of quality \((\Delta q, \Delta v)\) target is set as \([0, 0]\), Search for excellence ,The result is shown in Fig. 3.
The results show that the PSO converges rapidly when the iteration is 10 generations, the grey relational fitness of the quality index \((Δq, Δν)\) is 0.0895, and the corresponding index is \([1.125, 3.54\%]\), the corresponding process parameters is shown in Table 2.

| No. | \(t_1(s)\) | \(T_2(\degree C)\) | \(T_3(\degree C)\) | \(P_d(Mpa)\) | \(t_5(s)\) | \(t_6(s)\) |
|-----|-------------|-----------------|-----------------|-------------|-------------|-------------|
| 1   | 3.345       | 71.85           | 213.36          | 52-73       | 12.5        | 13.7        |

5.3 CAE simulation validation
The above optimized process parameters are compared and analyzed by CAE simulation, and the primary results of warpage deformation and shrinkage are obtained as shown in figure 5. The results show that the injection molding quality can be effectively improved, the warping deformation can be controlled below 2.82mm, the shrinkage can be reduced by 7.17\%, and high quality plastic parts can be obtained by injection molding. in shown figure 4.

(a) Comparison of warpage deformation  (b) shrinkage

6. Conclusion
the BP neural network is improved by particle swarm optimization (PSO) algorithm. Based on the neural network, a nonlinear relationship model between injection molding process parameters and warpage deformation and volume shrinkage is established, the minimum variables of warpage and shrinkage are predicted accurately, and the optimized injection molding process parameters are obtained, and verified by CAE simulation. The results show that the quality of plastic parts, such as Air Hole, weld line and so on, can be well controlled. The experimental results show that the quality of plastic parts is effectively controlled, the production cycle of the mould is greatly shortened, the potential risk of the mould production is reduced, and the economic benefit of the mould production is improved.

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