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Prediction and Analysis of Forged Workpiece's Precision in Hydraulic Press Based on BP Neural Network and Genetic Algorithm

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Abstract: Workpiece's precision is an important indicator of hydraulic press. In order to accurately predict the accuracy of the part, a method that combined the genetic algorithm and neural network is put out. Design of orthogonal experiment (DOE) is used to determine the input samples of neural network training and testing samples. The output samples are obtained by finite element analysed method (FEA). Through optimizing weights and thresholds of BP neural network using genetic algorithms, prediction model of workpiece's precision is established. The established predict model overcomes the shortcomings of slow to convergence and easy to fall into the local minimum point of BP neural network model . By comparing the neural network forecast result with FEA 's results, it can be seen that the established prediction model has good fitting and generalization ability. So the model can be used to predict the workpiece's precision.

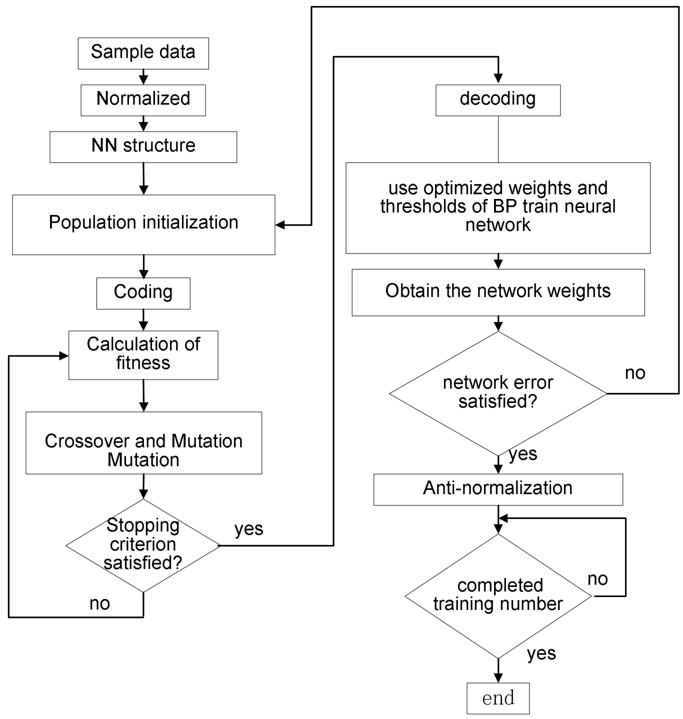
Introduction

Before production of *hydraulic machines*, users and manufacturers are very concerned about the accuracy of the workpiece that the hydraulic pressure can forged. However, because the accuracy of workpiece depends on not only the structure layout, but also the geometric parameters of the hydraulic press, and the affect among the parameters is often complex, also non-linear relation. So obtaining the best design parameters of the pressure that can obtained good *workpiece's precision* is often very difficult. The analytical model of *workpiece's precision* is constructed [1] using the finite element method and response surface model. But the factors taken into account as variable in the analytical model is only die parameters. If considered more parameters, the relations between the workpiece's precision and hydraulic parameters will became very complex. By using neural network for system recognition, and considering the system as black-box systems, the question of forecast and analysis the precision of the workpiece can be solved. Because *BP* (back-propagation) neural network has shortcomings of slow to convergence and easy to fall into local minimum points, genetic algorithm GA (genetic algorithm) can be used to optimize BP neural network initial weights and thresholds, and then constructs GA-BP neural network prediction model. This model can greatly improve BP neural network model prediction effect.

At present, more articles that using neural networks and genetic algorithms predict structural performance have published [2-8]. In this paper, base on the *workpiece's precision* data obtained by hydraulics' FEA, and use the advantage of BP neural network learning ability and powerful genetic algorithm global search capability, the forecast precision for workpiece is constructed.

Combination of BP neural network and genetic algorithm

BP network has the advantage of powerful nonlinear mapping ability, generalization ability. At the same time, it has the shortcomings of slow convergence and easy to fall into local convergence. While global convergence of genetic algorithm is GA's biggest advantage. Through combining BP network with GA, advantages and disadvantages of them can be complemented. Facing the features of complement of *GA* and *BP*, genetic algorithm optimizing neural networks mainly includes three aspects: network structure optimization; optimization of weights; optimization of learning rules. In this paper, weight's optimization mainly discussed. First of all, genetic algorithm is used to optimize the initial weight distribution in the solution space to find a better search space; and then, using BP algorithm searches the optimal solution. The method of genetic algorithm optimizing neural network weights is able to prevent search falling into local minimum point, increases the convergence speed and also solves the shortcomings of the BP network's unsatisfactory results of the evaluation on account of less test samples. Flow chart of Genetic algorithm trained neural network weights and threshold is shown in Fig.1.



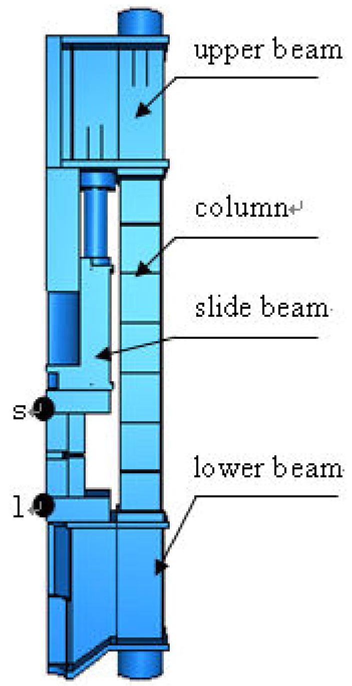


Fig. 1 BP+GA flow chart Fig. 2 Model of hydraulic pressure

For neural networks, once the network structure and training samples are identified, the neural network error is entirely defined by the value of the network's weight. So the neural network's training process is also the process of looking for a set of network's weight that makes the network has the smallest error of E. Network error E is defined as Eq. 1

$$\min E=\sum_{i=1}^{N}(y_i-\bar{y}_i)^2=\sum_{q=1}^{Q}\sum_{K=1}^{m}\left(y_{qk}-f\left(\sum w_{jk}u_i^n+q_j\right)+q_k\right) \tag{1}$$

Where y is the actual output for the network; $\bar{y}$ is the ideal output for the network; **u** is the variable; w is the weight value; **q** is the threshold.

Neural network model's establishment of workpiece's precision

Selecting input parameters of FEA based on DOE. Accuracy of neural network response surface depends on its generalization performance, whereas generalization performance depends on the effect of neural network training samples. So, the training samples set and test set is very important. If the *training samples* are less or the training samples have no representative, the network will not be able to reflect the mapping laws. If samples too much, there will be over learning problem. On account of orthogonal design method has balanced distributed feature, and can select an appropriate amount of the test points from a large number of test points and avoid redundant samples, so it is selected as the manner of experiment. Then according to standardized orthogonal table carry out finite element analysis in ABAQUS.

Definition of workpiece's precision. Hydraulic press mainly includes upper beam, lower beam, column, slide beam, bar and etc. The forming accuracy of the workpiece depends on the hydraulic pressure's deformation in vertical direction and the greater the vertical deformation, the lower the accuracy. Strictly speaking, value of workpiece's precision is upper die's center deflection minus lower die's center deflection .Usually this value is very small, so workpiece's precision in this paper is defined as the center deflection of slide beam minus the center deflection of the lower beam, as shown in Fig.2. The formula expressed as Eq. 2

$$f=\left|f_s-f_l\right| \tag{2}$$

Where, f is workpiece's precision, f_s, f_l is the activities of cross-section beam center deflection and the deflection under the cross-section beam center, respectively, unit is mm.

Test programs and test data. In order to establish neural network model, training samples are needed. Reasonable training sample's amount and distribution can express the exact relationship between the structures of the mapping. In the structure parameters of pressure, ten factors are selected, each factor has three levels. The ten parameters are lower beam'hight, the front and back plate'thick of lower beam, thick of longitudinal and transverse rib of upper beam,height of upper beam, top and bottom plate's thick of upper beam, rod's radius, thick of slide beam's outer plate, thick of colum's outer plate, width of colum. Their values are shown in Table1. *Orthogonal* table $L_{27}(3^{10})$ is select as the experiment plan. Table 2 lists a part of the experiment programs and experiment data obtained from a series of appropriately FEA analyses.

Table 1 Experiment plan table

level	x_1 mm	x_2 mm	x_3 mm	x_4 mm	x_5 mm	x_6 mm	x_7 mm	x_8 mm	x_9 mm	x_{10} mm
1	2 290	140	145	110	2 174	150	290	100	110	520
2	2 440	150	155	120	2 280	160	300	110	120	540
3	2 610	160	165	130	2 386	170	310	120	130	560

Table2 Prediction result of BP and BP+GA

No. of experiments	Finite analyse result	Neural network predictions		Combination of genetic and neural network predictions	
	precision mm	precision mm	error %	precision mm	error %
1	1.561846	1.561800	0.002945	1.561846	0.00000
2	1.545828	1.545800	0.001811	1.545828	0.00000
3	1.528367	1.528400	0.00216	1.528367	0.00000
…	…	…	…	…	…
20	1.494165	1.494200	0.00234	1.494165	0.00000
…	…	…	…	…	…
25	1.512487	1.5177	0.34466	1.510900	0.10456
26	1.489934	1.4983	0.56150	1.500900	0.73190
27	1.480747	1.533	3.52883	1.470900	0.64233

Model of BP neural network. Using ten main structure variables of hydraulic machine as the input of neural network and the workpiece's precision as the output of neural network. From 1 to 20 groups in Table 2 act as the training samples of neural network; the remained 7 group act as testing samples. Through research of structures in the network model and neurons, network of 10-16-6-1 (Figure 3) is established. The activate function in hidden layer are tansig and logsig. The largest training step is 1000. Performance parameter is 0.0001. Neurons in two hidden layer is 16 and 6 respectively. Through training the network, Simulation results is get (Table 2). From Table 2, it can be seen that the maximum error is 0.0032%. That is to say that the predicted performances are very consistence with the FET results t. Fitting results of training samples with the FEA results are shown in Figure 4. Through examine the accuracy of the established network by the back 7 groups, sample results and finite element analysis results see the contrast Figure 5. From the forecast (Table 2), the largest error is 3.528%. Therefore, the neural network model is feasibility.

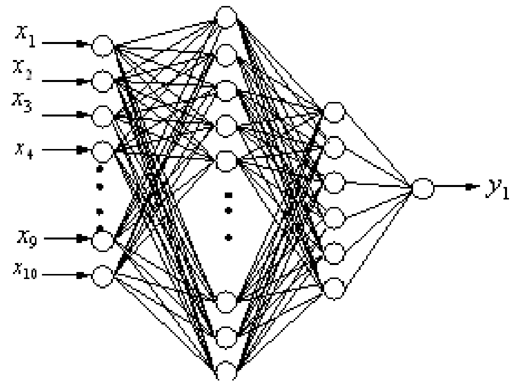


Fig. 3 Brief structure of BP

Fig.4 Comparison of BP network training result and FEA result

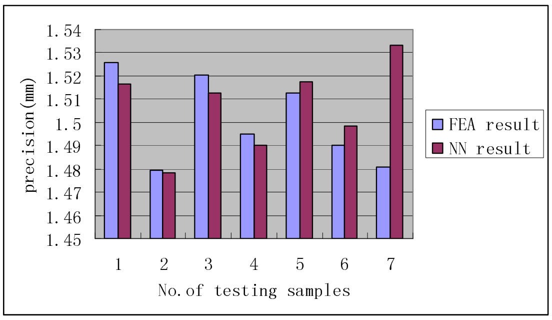


Fig.5 Comparison of BP network examine result and FEA result

Optimized BP neural network based on genetic algorithm. In order to avoid neural network falling into local minimum points, method of genetic algorithms combined with neural networks is used to forecasting workpiece'precision. In this method, the following issues need to be solved: identification of encoding; set the objective function and fitness function; the form that the BP network introduce GA. Encoding is used in binary.The parameters of the problem space is illustrated in the character set (0,1), which constitutes a chromosome bit string. The sum of squares error E acts as the objective value of genetic algorithm.

The software tool used to establish the model is Matlab7.0. In genetic algorithm, stocks number is 60, genetic algebra is 100, Crossover probability is 0.6, mutation probability is 0.1. When the trained network gets the error goal or maximum number of iteration step is reached, the square error obtained by simulation and curve of fit is obtained (Figure 6). From Figure 5, it can be seen that after about 70 Generation, the average fitness of chromosomes tends to stabilized. Fitting accuracy of the training samples and the relative error listed in the table2. From Table 2, it also can be seen that the values of training samples and accuracy of finite element analysis results is consistent in the effective number of number. Compare of the testing sample's output and the FEA result is shown in Figure 7. The maximum error of forecast is 1.60%, while the neural network error is 3.52%. So the use of genetic algorithm trained network has good generalization ability. Using GA+BP method, forecast accuracy is improved to a certain extent.

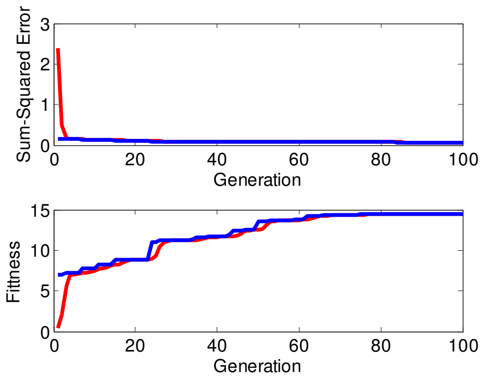


Fig. 6 Sum of squares error and curve fit curve

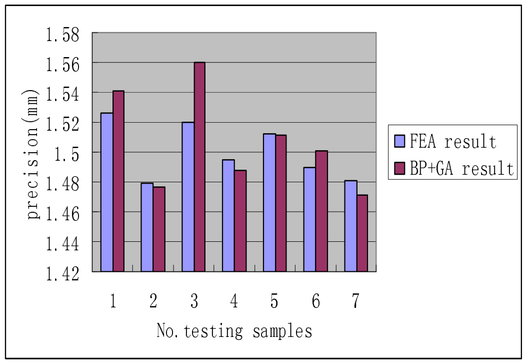


Fig. 7 Comparison of GA+BP network examine result and FEA result

Conclusion

Prediction model of workpiece's precision in hydraulic press based on BP Neural Network and *Genetic Algorithm* established. Comparing the *FEA* method, the *GA+BP* method significantly reduces the computing time, and the *prediction accuracy* meets the requirements.

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