Prediction of Coal Ash Fusion Characteristics of Blending Coals for Gasification Based on Genetic Algorithm and BP Neural Network

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Abstract: For the problem that prediction of coal ash fusion characteristics of blending coals for gasification,using genetic algorithm (GA) to optimize BP neural network on two aspects. Firstly, optimizing hidden layer nodes by binary coding,and getting the best optimal topology of network.Then using real encoding to optimize the network parameters.The optimization results are assigned to the network as initial weights and thresholds,and establishing GA-BP network prediction model.Combined with traditional BP network to do simulation experiment simultaneously.The results show that the prediction of GA-BP network is higher than traditional BP network.Appling it on the prediction of coal ash fusion characteristics of blending coals for gasificationt is feasible and effective.

Introduction

The high temperature melting property of coal ash is one of the important factors to afffect gasification and liquefaction. It is related with chemical compositions of ash from coal.The coal with high ash melting point as the raw material for gasification,adopting the method that blended with low one to reduce the ash melting point in general[1]. High temperature melting property of coal ash will affect the degree of difficulty to extract harmful elements from coal ash,and the structure of slag layer deposited on the surface of gasifier heat exchanger.If the gasifier discharges slag in solid, it is required that the coal ash fusion characteristics is lower to discharge slag conveniently. The change of coal ash fusion characteristics of blending coals isn't simple summation of that from single coal, but non-linear relationship.

Coal ash fusion characteristics is measured by three kinds of temperature of coal ash in general,such as deformation temperature,softening temperature and flow temperature.In this article, using BP neural network algorithm to establish non-linear neural network model between chemical compositions and ash fusion characteristics of blending coals. By predicting three kinds of temperature of coal ash, realizing the prediction of coal ash fusion characteristics of blending coals.Using the raw coal with high ash melting point to blend with 8 kinds of coals in different proportions respectively.Selecting 22 groups data of chemical compositions ash fusion characteristics of blending coals[2]. Taking the 10th to 17th group as training samples, and the 18th to 22th group as checking samples. Taking five kinds of oxide as the input of the network, such as

SiO_2, Al_2O_3, CaO, Fe_2O_3 and MgO,and the DT, ST, FT of which as the output. Establishing a BP network.

The Analysis of BP Neural Network Algorithm

Neural network is a non-linear information processing and computing systems,which is based on simulating the structure and function of human brain. Mainly through continuous learning and training, realizing the storage, memory, reasoning and induction of data. Training network by the calculation method that error back deliver is called BP neural network. The local searching capability of BP neural network is strong. But the drawback is that network structure is difficult to be determined, and it is easy to fall into local minimum value. GA has adaptability, global optimization and hidden layers parallelism, but the drawback is that local searching capability is not strong. Therefore, we can use GA to optimize the structure and network parameters of BP network to improve performance of the network .

Genetic Algorithm Optimizes BP Neural Network

The Optimization of Network Structure

Structure of the network includes the number of input and output layer nodes, the number of hidden layer and the number of hidden layer nodes. This article uses BP network with a single hidden layer.The number of input layer nodes is 5, and the number of output layer nodes is 3. The determination of number in the hidden layer nodes has no clear way. Most using trial and error to get an approximate range, then choosing one. So using GA to optimize the structure of the network, and determining the optimal number of hidden layer nodes.Using genetic algorithm to optimize the structure of BP neural network by binary coding,and the encoding length is 4. The steps of the algorithm are as follows:

Step1 Encoding and decoding. Normalizing the input and output samples of the network.Setting the range of the hidden layer nodes and encoding it by binary. Generating N chromosomes randomly, and each chromosome constitutes the corresponding network after decoding.

Step2 Training. Training each network with different initial weights.

Step3 Fitness value. Calculating the sum of the squared errors of expected output and predicted output of BP network corresponds to each code string .

Step4 Selecting several individuals that the fitness value is minimal as parent.

Step5 Using genetic operators that crossover and mutation, etc on current generation, and creating a new generation group.

Step6 Repeating steps that 2) to 5), and it doesn’t terminate until the individual with the smallest fitness produce, its corresponding network structure is the optimal.

Using Sheffield toolbox to train the network. The setting of GA parameter is as follows. The population size that N is 40. The maximum number of iterations is 50. The gap of genetic is 0.9.Select function is sus. Crossover operator is xovsp. Crossover probability that Pc is 0.8. Mutation operator is mut. The transfer function of hidden layer is tansig ,and that of output layer is logsig. After using genetic algorithm to optimize the structure of the network, obtaining a optimal network with a single hidden layer and the number of hidden layer nodes is 11. The variation curve of fitness function during the process of evolution was shown in Figure 1.

Optimization of The Network Parameters

In the premise of the network structure is determined, using genetic algorithm to optimize the

weights and thresholds of the network. The progress that genetic algorithm optimizes BP neural network parameters is as follows:

Step1 Carring on real encoding for weights and thresholds of network , and producing N chromosomes randomly.

Step2 Decoding each chromosome in contemporary.Obtaining the set which connect weights and thresholds, and constituting N neural networks.

Step3 Calculating the sum of the squared errors of expected output and predicted output of BP network corresponds to each code string.

Step4 Selecting several individuals that the fitness value is minimal and reserving them to the next generation.Carring on genetic operations,such as crossover and mutation ,ect. to produce a new generation.

Step5 Repeating steps that 2) to 5), and it doesn't terminate until reach the maximum generation. Initializing weights and thresholds of BP network with the best individual in the current population.

Step6 Training network with the preset parameters, and calculating the sum of the squared errors of network. It terminates when reaching the maximum generation .

The Design of Network Topology Structure

The settings of GA-BP network parameters: the encoding length that S=5 × 8+8 × 3+8+3=75.The size of the initial population that N is 30. Select function is roulette. Crossover function is arithXover. Mutation function is nonUnifMutation.The maximum number of iterations is 100. The transfer function of hidden layer is logsig. The transfer function of output layer is tansig.The training function adopts trainlm. Learning function adopts learngd.According to the model that genetic algorithm optimizes BP network aboved, and by Matlab software programming, the weights and thresholds which is between the layers of BP network through real encoding can be obtained . The variation curve of fitness function during process of evolution was shown in Figure 2.

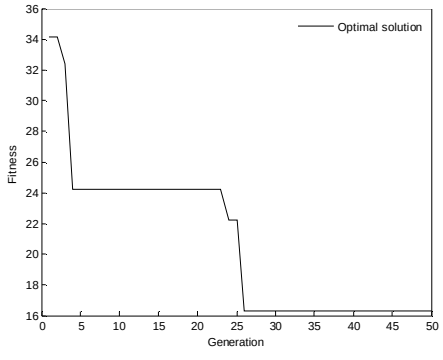

Fig. 1 variation curve of fitness function

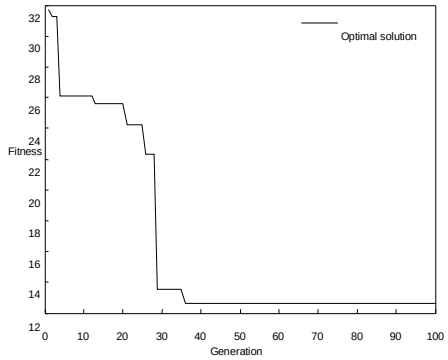

Fig. 2 variation curve of fitness function

Analysis of Experiment Results

The comparison about prediction errors and absolute mean errors of the 18th to the 22th samples by BP and GA-BP network was shown in the following tables:

Table 1 Comparison of DT prediction error by BP and GA-BP

Error Number	18	19	20	21	22	MAPE
Prediction error by BP	73.088	47.406	57.133	19.118	25.120	0.035
Prediction error by GA-BP	18.502	7.109	2.761	5.836	13.124	0.007

Table 2 Comparison of ST prediction error by BP and GA-BP

Error Number	18	19	20	21	22	MAPE
Prediction error by BP	35.089	32.151	37.372	84.954	8.680	0.030
Prediction error by GA-BP	39.457	27.251	45.831	75.140	17.242	0.031

Table 3 Comparison of FT prediction error by BP and GA-BP

Error Number	18	19	20	21	22	MAPE
Prediction error by BP	16.986	35.737	86.685	62.067	24.025	0.033
Prediction error by GA-BP	2.121	3.150	43.440	17.409	59.219	0.018

We can know that the maximum prediction error of traditional BP network is 86.685 from Table 2,3 and 4. The maximum error of GA-BP network is 75.140. There are 11 ash fusion characteristics that the prediction errors of BP are greater than GA-BP network in the 15 coal ash fusion characteristics predicted.The average absolute error of DT, ST and FT precdited by BP network respectively is 0.035,0.03 and 0.033. The mean absolute error of DT,ST and FT predicted by GA-BP network respectively is 0.007,0.031 and 0.018. The precdition error of FT of the 20th sample and ST of the 21th sample predicted by BP network have exceeded 80^{o}C. The errors of the 18-22th samples precdited by GA-BP network are all in 80^{o}C,and the average absolute errors of precditon are lower.

Conclusions

According to the need of ash fusion characteristics precdition of blending coals, determining a optimal network.Compared with traditional method which determines the number of hidden layer nodes by trial and error is more convenient and faster .

For the characteristics that BP algorithm is easy to fall into local minimum value and the prediction accuracy is lower, using genetic algorithm to optimize the weights and thresholds of BP network.The errors of coal ash fusion characteristics of blended coals precdited by GA-BP network are all in 80^{o}C, and the average error is lower.The prediction accuracy is improved greatly.

The simulation results indicate that the margin of prediction error has been reduced, and the network performance has been improved greatly after genetic algorithm optimizing the structure,weights and thresholds. Using GA-BP network to predict coal ash fusion characteristics of blending coals is effective and feasible.

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