Prediction of mechanical properties of hot rolled strips by BP artificial neural network

Yamei Wu
The College of Metallurgical and Materials Engineering
ChongQing University of Science & Technology
ChongQing 401331 China
chuyunprincess@163.com

Yong Ren
The College of Metallurgical and Materials Engineering
WuHan University of Science &Technology
WuHan 430081 China
renyong5800@163.com

Abstract—Based on analysis of artificial neural network model theory and modeling methods, combining with parameters of a certain factory strip research unit and mechanical performance inspection data, Through choosing Traingdm to train network, then, the determination of the input and output parameters, the hidden layers of the network, cell numbers of hidden layers, learning rate lr, momentum factor α and training accuracy called goal, this paper established the three layers of BP artificial neural network performance forecast model. The analysis of experimental results showed that it had the high coincidence between prediction results of yield strength; tensile strength; elongation through the training and measured data. Therefore, the BP artificial neural network performance forecast model had higher forecast precision and practicability. Therefore, it can be used in forecast calculation in the production process of strip steel.

*Keywords- **BP artificial neural network; mechanical properties; prediction***

I. INTRODUCTION

Artificial neural network which is the reaction to simulate human brain builds artificially pattern recognition research methods. It provides a new way for the study of the nonlinear system and the prediction and control of the unknown system. Artificial neural network has the strong processing power and superiority in dealing with the relationship of nonlinear input and output [1] [2], Therefore, artificial neural network is used widely in steel-rolling production. Artificial neural network is widely applied to predict rolling pressure[3], the size of grain [4], the deformation resistance[5], the control of strip shape[6], and it can obtain satisfactory results. This paper is the forecast of mechanical properties of strip products based on artificial neural network.

II. THE BASIC PRINCIPLE OF BP ARTIFICIAL NEURAL NETWORK

The BP artificial neural network is one of the most widely applied to a neural network. Back-Propagation Neural Network is one-way transmission to the multi-layer forward network, its structure chart is shown as follow:

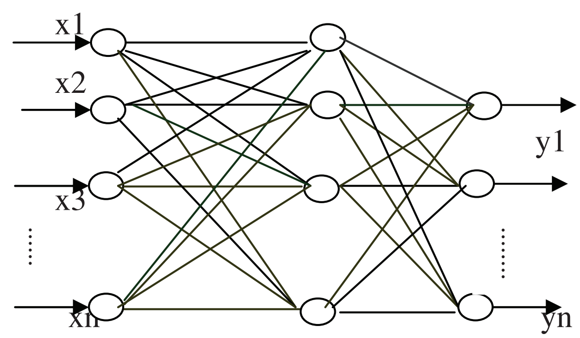

Figure 1. The structure chart of BP network

BP neural network includes input layers, hidden and output layers. For a hidden or multilayer, tree nodes are not any coupling. The input signals are from the nodes of input layers, through the nodes of hidden layers in turn, then to the nodes of the output layers. The node output of each layer affects only node input of the next layer. The unit characteristics is Sigmoid, but in the output layer, sometimes, the characteristics of unit nodes are linear. If the output layer can't reach the expected output, it will turn back propagation process. The error output signal is along the original connected pathways to return. So the node neurons weights of each layer make overall the minimum error by repeatedly modifying.

BP network can be regarded as the height nonlinear mapping from input to output, and it is thought that it is approximatively complex function, through simple linear function composite several times.

BP algorithm belongs to a training method, the

978-0-7695-4522-6/11 $26.00 © 2011 IEEE
DOI 10.1109/ICM.2011.14

neurons characteristics of the underlying layer and the output layer:

$$netp_j = \sum_j w_{ij} o_{pi} \quad (1)$$

$$Opj=fj(netpj) \quad (2)$$

The above formula:

P—The current input data;

Wij—The connection weights from neuron i to j;

Opi—The current input of neurons j;

Opj—The current output of neurons j;

fj—Nonlinear function.

If output error of network is:

$$E_p = \frac{1}{2}\sum_j (T_{pj} - O_{pj})^2 \quad (3)$$

Tpj will be for ideal output, If E=∑Ep is the sum of output error of all samples of the whole training.

III. THE ESTABLISHMENT OF THE BP NEURAL NETWORK MODEL

In order to establish proper artificial neural network forecast model, the structure of the neural network must be determined,e.g: the input and output parameters, hidden layers of network, cell numbers of hidden layers, appropriate training parameters of neural network: learning rate, momentum factors, training accuracy.

A. The determination of input and output parameters of the BP neural network

The original composition and production process parameters are the effect of the main factors of finished product mechanical properties, so the important parameters as inputs are set: chemical composition, carbon, aluminum, silicon, phosphorus, manganese, sulphur, calcium content and the inlet velocity, the inlet temperature, finishing temperature, coiling temperature and thickness. Output is to measure the main index: yield strength, tensile strength and elongation.

B. Determination of learning parameters

This paper selects Traingdm to train network. Learning parameters of Traingdm are mainly learning rate lr, momentum factor α and training accuracy. Changing one, fixing in addition two, all can be realized parameters to forecast performance influence.

1) The influence of learning rate lr

Selected initial learning precision and momentum factors, lr changes from 0.1 to 0.9. The research shows that, with the increase of lr, function convergence speeds. But, when the learning rate lr increases to 0.5, function begins to concuss. Thereby, it cannot be serious convergence. At the same time, with the increase of the learning rate, output precision of network is decreased. When the learning rate changes in a narrow range, precision changes little. If accuracy permits, with the increase of the learning rate, it can improve the speed of network convergence.

2) Momentum factors impact on properties

Also selected the learning rate(e.g.0.1) and network training accuracy(e.g.0.6), momentum factors transform from 0.2 to 0.8. Researched on the situation about momentum factors which impact on network properties, and it shows, with the increase of momentum factors, the speed of network convergence is accelerated. However, the speed is not obvious. Meanwhile, the increase of momentum factors impacts on network accuracy little. Some momentum factors will make the network appear concussion seriously in the training process.

3) Training accuracy goal impacts on properties

The network precision is a optimal value of network training time. If the network is overtraining, inspection error may even increase. The result shows that the higher of inspection error is namely the inaccuracy of the network forecast precision. When the inspection error changes from 0.04 to 0.06, the network precision is accurate; When reducing network training accuracy, forecast precision becomes poor.

4) The initialization of neural network

Because of the nonlinear relationship between input and output of feedforward neural networks, There is a great relationship between the initial value of the weights and training whether sets into local minima and could be convergence. Generally, when initial weights are in the state of input, status values of each neuron accumulate close to zero. So, it can assure that it can’t fall on the flat area of error curve at the beginning of iteration.Therefore, when the network is initiating, the weights of random numbers are set. If the value scope is from -0.5 to 0.5,a stringent effect will be satisfactory.

IV. THE LEARNING AND PREDICT RESULTS

This paper chooses the network parameters: the learning rate lr=0.1, the momentum factor α =0.3, training accuracy goal=0.06. The numbers of training sample is 180 groups, 35 groups are used for testing. 35 groups of input data are for inspection, and the results are as follows:

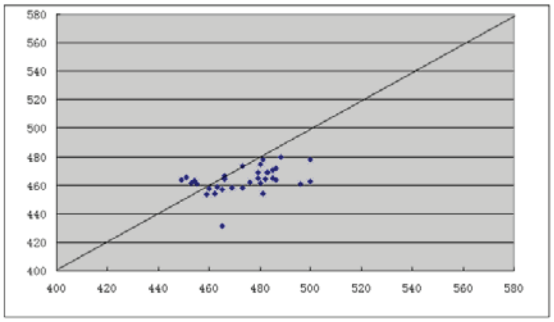

Figure 2.Comparison between actual value and prediction of yield strength

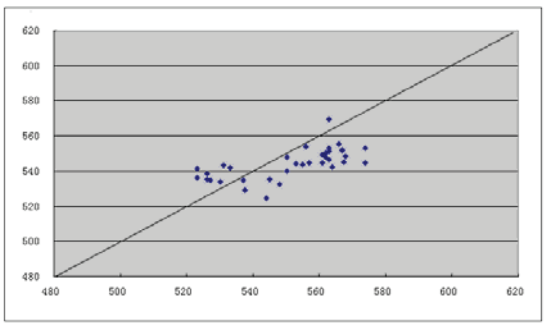

Figure 3.Comparison between actual value and prediction of tensile strength

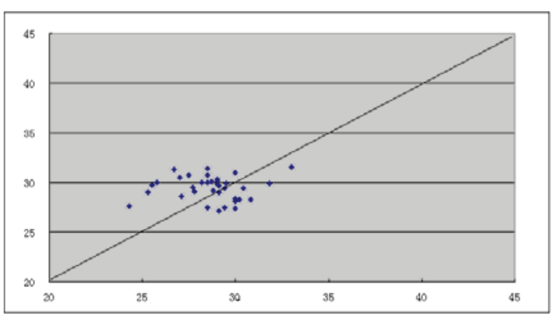

Figure 4.Comparison between actual value and prediction of elongation

By forecasting results, the largest prediction error of yield strength is 7.51%, and the 88.43% of relative error forecast of yield strength fall on 5%. The largest prediction error of tensile strength is5.16 %, and the 97.84% of relative error forecast of tensile strength fall on 5%.The relative error forecast of the yield strength and tensile strength are less than 10%,in the range of allowable error, meeting the requirements. Compared the forecast of elongation with yield strength and tensile strength, the elongation error is a little larger. The largest prediction error of elongation is 17.25%, and the 76.23% of relative error forecast of elongation fall on 5%. But overall 97.64% of relative error forecast is controlled in less than 10%, achieving the expected forecast purpose.

The yield strength forecast of average relative error is -2.16%; tensile strength is -1.34%; elongation is 2.69%. All of the absolute values are within 5%.Therefore, by artificial neural network forecast, it is a high precision in mechanical properties of products and it is feasible to forecast mechanical properties.

V. CONCLUSION

By BP artificial neural network model, realizing the relationship between the technical parameters of the strip products and mechanical properties, it is a theoretical foundation under the online precontrol. It is a very high precision for BP artificial neural network model to forecast mechanical performance of hot rolling strip steel. In addition, extended to any kinds of the strip production, by setting up parameters database of production process, according to the product specification and performance, aided the changes of mechanical performance in the hot-working process , it is a broad application prospect to reduce product development time, the loss of metal, production cost, and to improve the production efficiency including economic benefits.

REFERENCES

[1]X.kong , P.D.Hodgson The application of constitute and artificial neural network models to predict the hot strength of steels ISIJ 1999 991～998

[2]Li xiaoan. The introduction of neural network and neural computer. [M].Xi an: Northwestern polytechnical university press,1994,20-25

[3]Shi jing. Batch annealing process optimization and recrystallization texture research. Beijing University of Science and Technology,1998.

[4]Guan xiaojun, Panwei, Zhoujiajuan,etc Effect of composition on properties of extra low carbon and high strength bake hardening sheet steel,Special Steel,1999,20(6)

[5]Yasunori Katayama,Masaki Nakajima Hiroshi Koyama. A neural fuzzy control system for rolling mills .Steel Technology International,1992;189～196

[6]Liuzhenyu,Wangshaodong,Wangguodong,etc The prediction of C - Mn steel mechanical properties by using neural network. Journal of Iron and Steel Research, 1995

[7]Draeger,Engell S,Ranke H.Model Predictive Control Using Neural Networks,IEEE control Systems,1995 (10).61～66

[8]Yao Zhang,Sen P,Hean G E.An Online Trained Adaptive Neural Controller,IEEE control systems,1995 (10).67～75