Prediction for Mechanical Performance of Cold Rolled Ribbed Steel Bars Based on BP Neural Network with Dividing Variable Space According to Original Materials' Tensile Strength

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Abstract. This paper proposes a predictable method for mechanical performance of cold rolled ribbed steel bars based on BP network with dividing variable space according to original materials' tensile strength. It builds a sample variable space partitioning model according to the original materials' tensile strength. It also studies the performance prediction of cold rolled ribbed steel bars based on the 4-in & 1-out BP network and the performance prediction of cold rolled ribbed steel bars based on the 4-in & 2-out BP network. The results show that this method can reliably predict the mechanical performance of cold rolled ribbed steel bars, and the predictive effect of the 4-in & 1-out BP network model based on dividing variable space according to original materials' tensile strength is superior to the 4-in & 2-out BP network model.

Introduction

During the cold rolling process of ribbed steel bars, original materials are subjected to repeated rolling deal, and subjected to an integrated complex constraint. The rolling condition and status are changing constantly. Besides that, its process characteristics are very complex and difficult to be grasped. It is very difficult to establish precise mathematical physics equations between the original materials' tensile strength of cold rolled ribbed steel bars and product mechanical properties index from the perspective of material constraints and geometric deformations directly [2]. Therefore, this paper studies a predictable method for mechanical performance of cold rolled ribbed steel based on dividing variable space according to the original materials' tensile strength and BP neural network. It provides mechanical performance prediction of cold rolled ribbed steel bars with an economical, efficient method and basis by using divided sample subspace features and high precision approximation performance of BP neural network.

Dividing Variable Space according to Original Materials' Tensile Strength

When predicting the mechanical performance of cold rolled ribbed steel bars, according to the original materials' tensile strength, it divides the whole sample space into a number of subspaces. The relationship between the original materials' tensile strength and product mechanical performance parameters can be simplified to a certain extent within each subspace and the inputted samples are four-dimensional vectors. The tensile strength and the elongation of cold rolled ribbed steel bars show significant differences in the physical meaning and values. For the two properties indexes, it builds 4-in & 1-out BP network model and 4-in & 2-out BP network model respectively. Then, it uses the two models to predict the performance parameters of the product and analyzes the predicted results of two models.

Mechanical Performance Prediction of Product Based on 4-in & 1-out BP Neural Network Model [1-8]

The 4 inputs of BP neural network are the reducing amount of rolling △, drawing speed v, the amount of fluctuation in scroll wheel I and scroll wheel spacing s, which denoted by x_i (i = 1, 2, 3, 4) in network. The output of BP neural network is the tensile strength σ_b or the elongation δ_b of cold rolled ribbed steel bars, which denoted by y_k (i = 1, 2) in network.

When predicting the tensile strength of cold rolled ribbed steel bars, it uses 4 nodes hidden layer to BP neural network model and the structure is shown in Fig. 1. In the figure, the y_1 represents the tensile strength σ_b of cold rolled ribbed steel bars.

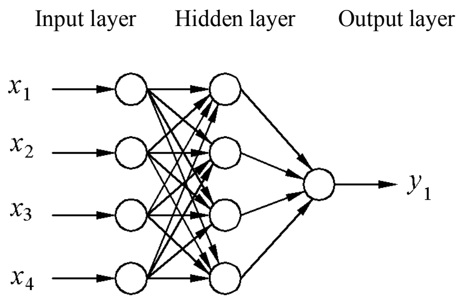

Fig. 1 4-in & 1-out BP neural network model structure for tensile strength prediction

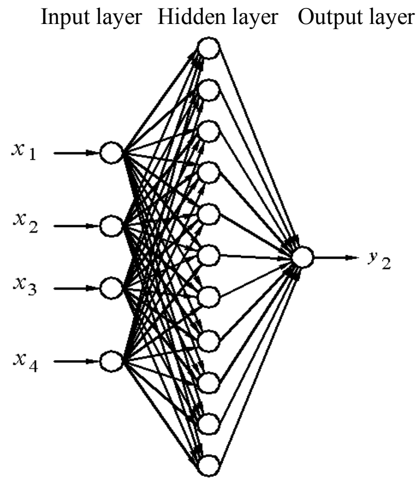

Fig. 2 4-in & 1-out BP neural network model structure for elongation prediction

When predicting the elongation of cold rolled ribbed steel bars, it uses 11 nodes hidden layer to BP neural network model and the structure is shown in Fig. 2. In the figure, the y_2 represents the elongation δ_b of cold rolled ribbed steel bars.

Sampling 1, 3, 7, 18, 11, 23, 14 and 24 for the test samples, the rest of the samples in their subspace are regarded as training samples. It uses 4-in & 1-out BP neural network model to predict the mechanical performance parameters of products. The experimental results and predictive results of test samples performance parameters are listed in Table 1.

Table 1 Predictive results of product mechanical performance based on 4-in & 1-out BP neural network with dividing variable space according to original materials' tensile strength

Test samples $\boldsymbol{x}^{(k)}$	Known sample variables $\boldsymbol{x}^{(k)}_i$ in $\boldsymbol{P}^{(k)}$	Tensile strength σ_b			Elongation δ_b		
		Measured values	Predictive values	Relative errors(%)	Measured values	Predictive values	Relative errors(%)
1	2、3、4、17、21	5.348	5.1015	4.61	10.8	9.9811	7.58
3	1、2、4、17、21	5.987	5.9191	1.16	9.0	9.0156	0.17
7	5、6、8、18、22	5.921	6.0114	1.53	9.3	8.3498	10.22
18	5、6、7、8、22	5.506	5.6135	1.95	10.3	9.8856	4.02
11	9、10、12、19、23	6.571	6.3872	2.80	8.1	7.9170	2.26
23	9、10、11、12、19	5.920	6.2458	5.50	8.4	8.4674	0.80
14	13、15、16、20、24	6.624	6.6332	0.14	7.2	7.2177	0.25
24	13、14、15、16、20	6.273	6.4357	2.59	8.1	8.1008	0.01

As it can be seen from Table 1, within the 16 performance parameters of cold rolled ribbed steel bars which predicted by 4-in & 1-out BP neural network model and the sample spaces are divided according to the original materials' tensile strength, there are 8 parameters which the relative errors between the predictive values and the measured values are less than 2%, accounting for 50% of the total number of predicted parameters. There are 13 parameters which the relative errors are less than 5%, accounting for 81.25% of the total number of predicted parameters, while there are 15 parameters which the relative errors are less than 10%, accounting for 93.8% of the total number of predicted parameters. The average relative error of the predictive results by the model is 2.85%, and the standard deviation is 2.82. The predictive effect is good.

The data in Table 1 also reflects that the predictive effect of the tensile strength is superior to the predictive effect of the elongation according to mechanical performance of cold rolled ribbed steel bars based on 4-in & 1-out BP neural network model.

Mechanical Performance Prediction of Product Based on 4-in & 2-out BP Neural Network Model [1-8]

When predicting the tensile strength and the elongation of cold rolled ribbed steel bars, it uses 11 nodes hidden layer to BP neural network model and the structure is shown in Fig. 3. In the figure, the y_1 represents the tensile strength σ_b of cold rolled ribbed steel bars and the y_2 represents the elongation δ_b of cold rolled ribbed steel bars.

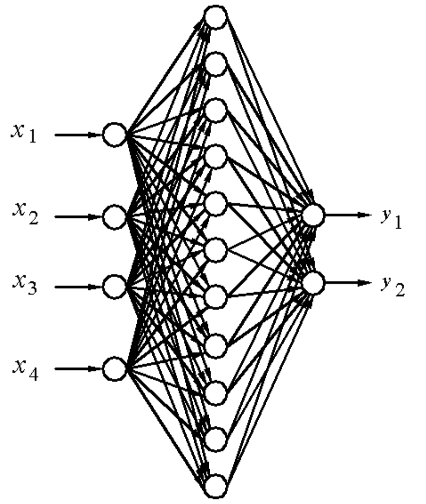

Fig.3 4-in & 2-out BP neural network model structure for product performance prediction

Sampling 1, 3, 7, 18, 11, 23, 14 and 24 for the test samples, the rest of the samples in their subspace are regarded as training samples. It uses 4-in & 2-out BP neural network model to predict the mechanical performance parameters of products. The experimental results and predictive results of test sample performance parameters are listed in Table 2.

As it can be seen from Table 2, within the 16 performance parameters of cold rolled ribbed steel bars which predicted by 4-in & 2-out BP neural network model and the sample spaces are divided according to the original materials' tensile strength, there are 8 parameters which the relative errors between the predictive values and the measured values are less than 2%, accounting for 50% of the total number of predicted parameters. There are 13 parameters which the relative errors are less than 5%, accounting for 81.25% of the total number of predicted parameters, while there are 16 parameters which the relative errors are less than 10%, accounting for 100% of the total number of predicted parameters. The average relative error of the predictive results by the 4-in & 2-out BP neural network model is 3.12%, and the standard deviation is 2.77. The predictive effect is good.

The data in Table 2 also reflects that the predictive effect of the tensile strength is superior to the predictive effect of the elongation according to mechanical performance of cold rolled ribbed steel bars based on 4-in & 2-out BP neural network model.

Table 2 Predictive results of product mechanical performance based on 4-in & 2-out BP neural network with dividing variable space according to original materials' tensile strength

Test samples $\boldsymbol{x}^{(k)}$	Known sample variables $\boldsymbol{x}^{(k)}_i$ in $\boldsymbol{P}^{(k)}$	Tensile strength σ_b Measured values	Tensile strength σ_b Predictive values	Tensile strength σ_b Relative errors(%)	Elongation δ_b Measured values	Elongation δ_b Predictive values	Elongation δ_b Relative errors(%)
1	2、3、4、17、21	5.348	5.1285	4.10	10.8	9.8182	9.09
3	1、2、4、17、21	5.987	5.9181	1.15	9.0	8.7740	2.51
7	5、6、8、18、22	5.921	5.9785	0.97	9.3	8.4185	9.48
18	5、6、7、8、22	5.506	5.6098	1.88	10.3	9.8595	4.27
11	9、10、12、19、23	6.571	6.3324	3.63	8.1	7.9663	1.65
23	9、10、11、12、19	5.920	6.2457	5.50	8.4	8.4785	0.93
14	13、15、16、20、24	6.624	6.6133	0.16	7.2	7.3198	1.66
24	13、14、15、16、20	6.273	6.4528	2.87	8.1	8.0999	0.0013

Conclusions

Compared predictive results based on the 4-in & 1-out BP neural network listed in Table 1 with predictive results based on the 4-in & 2-out BP neural network listed in Table 2, it is found that from the average relative error of predictive results, the former is 2.85% while the latter is 3.12%, and predictive accuracy of the former is higher than the latter's. However from the standard deviation of predictive results, the former is 2.82 while the latter is 2.77, and predictive stability of the latter is higher. So, from the whole point of view, the predictive effect of the two models is close to each other.

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