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Research on measuring pipe tray processing man-hour quota based on genetic neural network

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ABSTRACT: Tray is the unit of infield fabrication of the ship pipes. The number of pipes in each tray is different, and the structure of pipe itself is complex, resulting in more difficulty in determination of the entire pipe tray processing man-hour. In order to exactly measure the pipe tray man-hour quota, this paper analyzes main characteristic quantity of the pipe tray and selects the relevant information of 60characteristic quantities of the pipe tray for analysis based on the genetic neural algorithm, and uses MATLAB software simulated data curve to construct a model for measurement of tray pipe processing man-hour, and substitute into new tray pipe man-hour data for verification. The research results show that it is feasible to use this method to predict the pipe tray processing man-hour. The conclusion has some reference values for the prediction of the pipe tray processing man-hour.

Keywords: pipe tray; man-hour quota; genetic algorithm; neural network algorithm; MATLAB

1 INTRODUCTION

In the shipbuilding process, pipe processing has a greater impact on the product cycle and quality, which is the second working unit with the largest processing volume besides the hull manufacturing, so the accuracy of measuring the pipe tray processing man-hour is of great importance to guaranteeing the pipe manufacturing plan and hull manufacturing process. At present, in the development of the man-hour quota, China’s shipbuilding enterprises are mainly subject to rough estimation of artificial experience estimation, which is time-consuming and has a low accuracy. If there is a way to improve the measurement accuracy of pipe tray man-hour, it is of practical significance on the prediction of ship offer and actual costs.

The domestic and foreign scholars have conducted a lot of researches on the measurement of man-hour quota. The related researches are as follows: based on the current situation of the workshop, the literature [1] combines with the statistical analysis method and the neural network method, and uses work sampling to measure the welding work ratio, and uses the neural network algorithm to predict the basic time of pipe welding, thereby predicting the pipe welding man-hour with the unit of tray; the literature [2] presents that the material, size feature and quality characteristic are three core elements of the pipe manufacturing PWBS, and carries out process analysis of pipe manufacturing through research of the pipe manufacturing PWBS; the literature [3] uses the reasoning logic of the knowledge base for precise measurement of the man-hour quota, and finally verifies the effectiveness of the extraction model and the measurement method through system research and development and the practical application of the enterprise; based on the ship welding data extracted from TRIBON, the literature [4] combines with the calculation method of ship welding man-hour to build the ship welding quantity/man-hour database, and design the ship welding quantity/man-hour system; the literature [5] researches the ship welding process, material, man-hour, plan and other issues; based on the idea of energy conservation, the literature [6] uses the knowledge base and rule-based reasoning to realize the calculation of welding man-hour quota; on the basis of the construction of ship welding engineering management database, the literature [7] further researches the relationship between the ship welding quantity and welding

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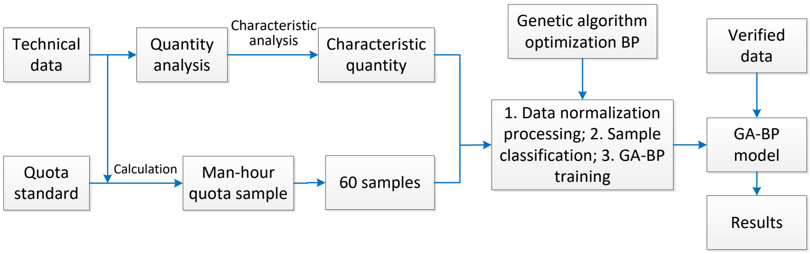

Figure 1. Quota standard optimization model based on genetic neural network

man-hour, and uses the iterative calculation formula of the welded joint sectional area to further accurately calculate the amount of welding consumables; in the calculation of the welding man-hour quota, it uses the law of energy conservation to construct the mathematical model of welding wire melting rate and design the intelligent calculation process of the ship welding man-hour.

On the basis of reference to the domestic and foreign research results, this paper researches the intrinsic relationship between the characteristic quantity of pipe tray and processing man-hour, and uses the genetic algorithm to optimize the initial weight and threshold value of BP neural network, improve the prediction accuracy and overcome shortcomings of the above estimation method. On this basis, combined with a variety of characteristic quantity, based on the historical data, this paper constructs the non-linear relationship between the characteristic quantity and the pipe tray man-hour through training, and outputs a relatively precise predicted value of pipe tray man-hour quota after nonlinear transformation.

2 IDEAS ON MEASURING MAN-HOUR QUOTA BASED ON GENETIC NEURAL NETWORK

In the process of product manufacturing, the shipbuilding enterprises would accumulate a large number of actual performance operating data of man-hour quantity via a refined dispatch list, thus forming a big database of enterprise production and operation. On this basis, the cluster analysis, characteristic analysis and other tools are used to abstract, generalize, summarize and define the characteristic information of various quantities accumulated, thus forming the quantity characteristic and attribute definition standards as the foundation and basis for correction of the man-hour quota. In addition, this paper acquires the relevant technical data from the production design, and carries out the following processing: 1) to sort out the tray pipe quantities and carry out characteristic analysis and obtain the relevant characteristic quantity; 2) to calculate the man-hour quota through combination with the quota standard, and take out 60 groups of data as samples; 3) to combine with the characteristic quantity and 60 groups of data for normalization processing, classification and GA-BP training; 4) to substitute the verified data into GA-BP model and obtain the results; the quota standard optimization model based on genetic neural network is shown in Figure 1.

3 CHARACTERISTIC QUANTITY ANALYSIS OF PIPE TRAY PROCESSING MAN-HOUR QUOTA AND INPUT INDEX PROCESSING

3.1 *Analysis of characteristic quantity*

The measurement of the pipe tray man-hour quota is mainly affected by the number of pipes in the tray, number of compound plate, number of flange and welding base, while there is a lot of difference in the basic information of pipes in the tray (pipe number, name, type, grade, subordinate part number, specification and model, processing material, length, weight, pipe diameter, drift diameter, thickness, casing pipe, branch pipe and so on), pipe bending information (radius of bent pipe, direction of bent pipe, feeding length, bend, corner and so on), pipe connection information (number of two adjacent parts, connection category, X coordinate, Y coordinate, Z coordinate and so on), and the existence of these differences has different impacts on the pipe man-hour. According to the knowledge of management consulting and informationalized services in the shipbuilding industry that has been accumulated by the author's research team over the years, the quantity measured for the pipe tray man-hour quota is extracted, and the results are shown in Table 1.

According to the characteristics of the pipe man-hour measurement and the statistical analysis of the previous pipe man-hour quota measurement: pipe diameter, drift diameter and thickness of pipe wall directly affect the weight of pipe, thereby indirectly affecting the pipe processing man-hour. Therefore, the difference in the pipe diameter, drift diameter and pipe wall can be classified into the weight of pipe; the casing pipe is used to connect with the pipe; the more the number of casing pipe is, more installation man-hour will be consumed, without affecting the pipe processing man-hour; the welding base will be welded only when the pipe in the tray is installed, so the consumed man-hour belongs to the installation man-hour. However, the number of pipes, length, weight, number

Table 1. Analysis of characteristic quantity of pipe tray

1. Processing materials: there is less difference in the relevant processing materials of the pipes in the same tray, and the difference in the materials has less impact on the relevant processing man-hour, and the man-house consumed is almost the same.
2. Number of pipe: the more the number of pipe is, the more the pipe required to being manufactured by the workers, and the more man-hour will be consumed.
3. Total length of pipe: the longer the pipe is, the more the straightening and other processes are required, and the more man-hour will be consumed.
4. Total weight of pipe: the heavier the pipe is, the more difficult in processing and installation, and the more man-hour will be consumed.
5. Pipe diameter: the greater the pipe diameter is, the greater the pipe is, and the heavier the weight is.
6. Drift diameter: the greater the drift diameter is, the greater the pipe is, and the heavier the weight is.
7. Thickness of pipe wall: the thicker the pipe wall is, the heavier the pipe is.
8. Number of casing pipe: the casing pipe is used to connect with the pipes. The more the number is, the more man-hour will be consumed for connection and installation.
9. Number of branch pipe: the branch pipe needs to be tapped by the header pipe and requires incision and welding. The more the number is, the more man-hour will be consumed.
10. Number of bent pipe: the bent pipe needs to increase the bending and straightening processes. The more the number is, the more man-hour will be consumed.
11. Number of compound plate: the compound plate needs to be installed and welded. The more the number is, the more man-hour will be consumed.
12. Number of flange: the flange needs to be welded and polished. The more the number is, the more man-hour will be consumed.
13. Welding base: the welding base needs to be welded and polished. The more the number is, the more the welded joints are, and more man-hour will be consumed.

of flange, number of bent pipe, number of branch pipe and number of compound plate increase or decrease with the number, weight and length, which is closely related with the man-hour. On the basis of the above analysis, the influencing factors of the characteristic quantity of pipe tray processing man-hour are ultimately determined as the number of pipe, total length of pipe, total weight of pipe, number of flange, number of bent pipe, number of branch pipe and number of compound plate. The above seven indicators are used as input of the genetic neural network, and the pipe tray processing man-hour is used as the output to construct the pipe tray processing man-hour model based on the genetic neural network. The genetic algorithm is used to optimize the initial weight and threshold value of BP neural network. According to the historical pipe tray processing man-hour data, the linear relationship between the characteristic quantity and the required processing man-hour is established, and the trained network is sued to calculate the man-hour of the new project.

3.2 *Input index processing*

In the original samples, the characteristic quantity indicators of the pipe tray processing man-hour are different, and the data level is very different. In order to make the input data of different dimensions keep in the equal important position, it is necessary to avoid too large absolute value of the net input to saturate neurons, and thereby carrying out normalization processing for the data. In the factor analysis, we have identified seven factors as the relevant index input. For the number of pipe (M), total weight of pipe (G), total length of pipe (L), number of bent pipe (N), number of branch pipe (m), number of flange (n) and number of compound plate (T) and other indicators, they are normalized according to the following formula:

$$\hat{x}=\frac{x-x_{min}}{x_{max}-x_{min}}$$

Where: X is the input data; X is any value among M, G, L, N, m, n, T; X_{max} and X_{min} are respectively the maximum value and minimum value of the index in historical data.

4 BP NEURAL NETWORK OPTIMIZED BASED ON GENETIC ALGORITHM

BP neural network has a strong nonlinear mapping capability, but there are also some problems, such as too slow learning convergence rate, easy to fall into the local minimum value, and difficult to determine the network topology [8]. The genetic algorithm has a better global search capability, and it is easy to obtain the global optimal solution in the operation process. Therefore, the optimization of BP neural network model by using the genetic algorithm can accelerate the convergence rate of the network and improve the prediction accuracy of the network model. This paper uses the genetic algorithm to optimize BP neural network, and mainly uses the genetic algorithm to optimize the weight and threshold value of the network [9].

4.1 *Selection of parameters*

Too many network layers and an excessive number of neurons will weaken the generalization ability of the network, and decline the predictive ability of the network. With only one neural network at the hidden layer, as long as the nodes at the hidden layer are enough, any accuracy can be approach to a non-linear function. In training of the genetic neural network, the selection of some parameters should be consistent with the traditional BP neural network. The genetic neural network adopts three layers of network structure. The number of neurons at the input layer and the output layer is 7 and 1 respectively. According to the Kolmogorov's theorem, the number of neurons at the hidden layer is 2m+1 (m is the number of neurons at the input layer), that is, 15.

The learning rate ìis 0.01, the maximum number of training is 10,000 times, and the target error is 0.001. The optimal individuals trained by the genetic algorithm are used to optimize the weight and threshold value of the network.

4.2 *Implementation steps of BP neural network optimized by the genetic algorithm*

Implementation steps of BP neural network optimized by the genetic algorithm are as follows:

(1) Individual coding and population initialization

The weight learning of neural network is a complex continuous parameter optimization issue. Binary coding has some errors in dealing with continuity problems. In order to obtain high precision weight and threshold value, real number coding is used [11]. The code length of this method is as follows:

$$S = n \times m + m \times t + m + t$$

Where: m is the number of nodes at the hidden layer, n is the number of nodes at the input layer, and t is the number of nodes at the output layer.

The size of population has a great impact on the global search performance of the genetic algorithm. Therefore, the size of population should select appropriate amount according to the specific problem. The size of initial population in this experiment is 60.

(2) Setting of fitness function

In this paper, the fitness function is set as the error sum of squares and reciprocal of the neural network:

$$f = \frac{1}{\mathrm{SE}}$$

Where, SE is the error sum of squares between the predicted output of the neural network and the desired output. Viewing from the fitness function, the smaller the predicted error of the neural network is, the greater the corresponding fitness function is, and the better the adaptability is.

(3) Selection of individuals

Selection of individuals can be carried out according to the probability value. The formula is as follows [12]:

$$P_i = \frac{f_i}{\sum_{i=1}^{k} f_i}$$

Where: f_i is the fitness value for individual i; k is the number of population individuals.

(4) Crossover operation and mutation operation

The crossover operation is not given to the optimal individuals, but they are copied directly into the next generation. For other individuals, the crossover probability Pc is used for crossover operation of the two individuals, in order to generate another two new individuals. Similarly, the crossover operation is not given to the optimal individuals, but they are copied directly into the next generation.

For other individuals, the mutation probability P_m is used for mutation operation, in order to generate another new individual. In this experiment, Pc is 0.5, P is 0.08, and the evolutionary algebra is 60.

(5) Cyclic operation

To circulate the above step (2) - step (4) until the training target reaching the set requirement or the number of iterations reaching the set target.

4.3 *Simulation*

In the test, the characteristic quantity of 60 pipe trays and the calculated man-hour quota are used as training samples, and the genetic algorithm is used to optimize the weight and threshold value of BP neural network and construct the genetic neural network model. The pipe tray data are shown in Table 2.

The simulation of GA - BP neural network can be realized by using the neural network toolbox function programming. The results of the simulation value and predicted value are shown in Figure 2.

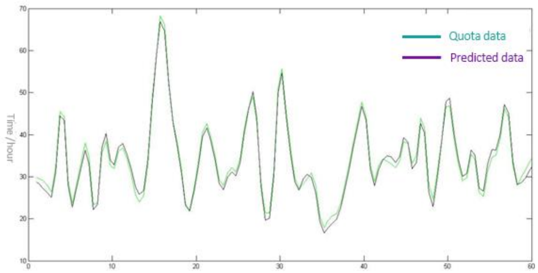

Figure 2. Pipe tray man-hour prediction for GA-BP neural network model

5 EXAMPLE VERIFICATION

For the above calculation model based on the genetic neural network, the simulation experiment of network learning and training is carried out in MATLAB2014a environment. The simulation results are shown in Table 3.

Table 3. Comparison with test sample output and actual data

Tray number	Man-hour	Predicted man-hour	Predicted difference	Relative error
TEBO8CC1	30.32	30.88	0.56	1.846%
TEBO8CT1	45.48	46.16	0.68	1.495%
TEBO9CC1	49.85	49.19	-0.66	-1.323%
TEBO9CT1	42.46	41.95	-0.51	-1.201%
TEBO9CT2	50.19	50.02	-0.17	-0.339%

Table 2. Historical pipe tray man-hour data

No.	Tray No.	Number of pipe	Weight of pipe /kg	Total length of pipe /m	Number of branch pipe	Number of elbow pipe	Number of flange	Number of compound plate	Man-hour quota
1	PHBO1PU1	32	251.9	35.06	6	3	14	0	29.76
2	PHBO1SU1	31	243.7	34.78	7	1	13	0	28.82
3	PHBO1SU2	27	223.2	32.71	5	5	11	1	25.61
4	PHBO2PU1	56	457.3	65.11	11	3	8	0	52.08
5	PHBO2SU1	23	178.7	28.81	4	2	10	0	21.36
6	PHBO3PU1	33	273.1	37.73	6	2	15	0	30.69
7	PHBO3SU1	43	349.2	51.31	8	4	24	1	40.49
8	PHBO3SU2	19	152.7	22.78	4	1	7	0	17.67
9	PHBO4PU1	44	355.8	53.36	7	4	17	1	41.42
10	PHBO4SU1	32	249.3	36.11	5	2	13	0	29.76
11	PHBO4SU2	41	324	51.06	6	3	22	0	38.13
12	PHBO5PU1	35	286.7	41.32	8	2	12	1	33.05
13	PHBO5SU1	25	188.7	30.81	5	2	10	0	23.25
14	PHBO5SU2	27	226.2	33.71	6	5	12	1	26.21
15	PHBO6PU1	58	467.3	67.11	10	3	9	0	53.94
16	PHBO6SU1	78	619.7	89.97	14	6	27	1	72.94
17	PHBO6SU2	49	375.8	55.36	7	3	17	0	45.57
18	PHBO7PU1	38	306.7	47.32	7	4	16	0	35.34
19	PHBO7SU1	21	162.7	24.57	4	2	9	0	19.53
20	PHBO7SU2	32	247.3	35.81	6	2	12	0	29.76
21	PHBO8PU1	47	375.8	55.36	8	4	17	1	44.21
22	PHBO8SU1	41	322.1	51.26	6	4	20	0	38.13
23	PHBO8SU2	27	227.2	33.21	6	6	14	1	26.41
24	PHBO9PU1	35	282.7	40.32	8	3	12	0	32.55
25	PHBO9SU1	33	277.1	38.93	6	4	12	0	30.69
26	PHBO9SU2	48	375.2	56.36	9	4	18	1	45.14
27	TAGO1CU1	54	437.3	61.11	10	3	8	0	50.22
28	TAGO1CU2	23	176.7	27.81	4	2	8	0	21.39
29	TEOOSG1	23	178.7	29.13	5	2	10	0	21.39
30	TEOOSS	65	527.3	77.11	12	5	22	1	60.95
31	TE20CG1	43	332.6	54.26	8	4	16	0	39.99
32	TE20PG1	28	237.2	34.21	6	4	14	1	26.54
33	TE20SG1	31	242.3	35.11	6	2	8	0	28.83
34	TE20SG2	34	257.6	37.84	7	3	12	0	31.62
35	TE30SG1	18	149.7	21.97	5	1	7	0	16.94
36	TE30SG2	22	168.7	25.56	4	2	8	0	20.46
37	TE90G1	23	172.4	28.47	6	3	9	0	21.39
38	TEBO1CC1	33	247.3	35.74	6	3	10	0	30.69
39	TEBO1CT1	43	337.6	54.89	8	3	19	1	40.49
40	TEBO2CC1	54	437.4	61.14	10	3	11	0	50.22
41	TEBO2CT1	29	239.3	32.81	6	2	12	0	26.97
42	TEBO2CT2	37	273.2	37.34	8	3	12	0	34.41
43	TEBO3CC1	36	257.3	36.23	5	2	12	0	33.48
44	TEBO3CT1	34	247.5	35.81	6	3	9	0	31.62
45	TEBO3CT2	43	337.1	54.87	8	3	17	1	40.49
46	TEBO4CC1	33	243.7	35.13	7	3	9	0	30.69
47	TEBO4CT1	52	427.4	60.04	12	5	16	0	48.36
48	TEBO4CT2	23	176.7	28.83	5	1	10	0	21.39
49	TEBO5CC1	37	278.1	38.5	5	5	15	0	34.41
50	TEBO5CT1	54	434.4	61.04	8	3	10	1	50.72
51	TEBO6CC1	38	283.2	39.34	9	4	10	0	35.34
52	TEBO6CT1	29	239.6	32.86	6	2	12	0	26.97
53	TEBO6CT2	41	324.3	51.87	8	4	17	0	38.13
54	TEBO7CC1	24	179.7	28.61	6	3	8	0	22.32
55	TEBO7CT1	37	278.1	38.2	8	6	14	0	34.41
56	TEBO8CC1	38	283.7	41.5	8	5	16	0	35.34
57	TEBO8CT1	53	429.8	61.34	12	5	16	1	49.79
58	TEBO9CC1	29	239.3	32.81	6	2	12	0	26.97
59	TEBO9CT1	33	244.2	35.42	8	4	9	0	30.69
60	TEBO9CT2	37	279.1	40.6	8	6	13	0	34.41

Five sets of sample data are used as the prediction samples to test the trained network. In the predicted results, the minimum relative error is -0.337%, and the difference is -0.17; the maximum error is 1.846%, and the difference between the actual material cost and the material cost predicted by the neural network is 0.56. Overall, it can basically meet the requirements of pipe tray processing man-hour, with a better model generalization ability and more successful model. However, the individual error is large, indicating that the network learning for some characteristics is not enough, because the number of learning samples is limited. With the enrichment of samples and accumulation of data, the error will be constantly reduced, and finally a very ideal effect will be achieved. The research results show that the pipe tray man-hour is mainly determined by the following factors, such as the number of pipe, length, weight, number of flange, number of bent pipe, number of branch pipe and number of compound plate. When the shipyard receives a new order of the ship products, the network model can be used to predict the man-hour changes of the new pipe tray.

6 CONCLUSION

For the problems in estimation of man-hour of ship tray processing in the current shipbuilding process, this paper uses the genetic algorithm to optimize the weight and threshold value of BP neural network, and improve the network convergence rate and budget precision, constructs the budget model based on the genetic neural network and compares with the estimated results and the measured results to prove that the man-hour estimation method combined with the genetic neural network algorithm can effectively reflect the relationship between the characteristic quantity of the pipe tray processing man-hour and the processing man-hour, and can accurately and quickly calculate the unknown pipe tray processing man-hour.

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