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Crane residual life estimation method based on artificial neural network

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ABSTRACT

With the estimation of the crane residual life, we could make an effective and identification to the disaster in the working process to make sure it's safety. This method is mainly used to study the uncertainty of the crane in the working process. The research object is bridge crane, use the cycles of different crane clusters of hoisting load when different rated hoisting crane is working with different load, through the estimation pattern of the residual life of crane with the neural network technology which based on two main theoretical foundation which are Miner fatigue cumulative damage theory and the theory of linear elastic fracture mechanic theory. Then finally estimate the residual life of the crane through the derivation which based on the two main theory and the formula. A series examples show the the laborer and resource input could be saved through the former two theories. The way of calculating crane's residual life is more practical,and the way of estimating is scientific and effective.

KEYWORDS

Bridge crane; Neural network; Crane residual life estimation.

INTRODUCTION

With the development of market economy, the hoisting machinery has an important proportion in the development of society, the crane in the equipment industry was regarded as a kind of special technology and equipment, crane in the construction process, if any fault occurs, the project caused great losses in the capital, has a great negative impact for the whole project. In recent years, more and more domestic and foreign for crane fault serious accidents, such as cranes in the process of construction, sudden fracture system, it makes the crane fatigue damage status of[1]. Comprehensive analysis based on the situation, the government and related testing department configuration both at home and abroad need to assess efforts to crane life analysis and estimation to the fault risk aspects.

Application of crane equipment in today's social economy in the hoisting machinery are used more and more widely, heavy machinery's task in the construction process is becoming more and more heavier. In this case, people have high requirements for engineering technology in the quality and safety. Therefore, relevant technology and means to detect the residual life of cranes are needed to grasp the safety of the crane structure configuration and the residual life of the crane's estimate. At present, the residual life of cranes estimation research has been a part of the field at home and abroad, On this basis, more new means to the residual life of the hoisting machinery estimation have been worked out[2].However, so far, there is no one reasonable theoretical system and estimate methods. This paper mainly use the special function in the specific construction process, make the bridge crane as the research object of this thesis, on this basis, this paper make an effectively estimate for the remaining life of crane with the technique of artificial neural network, finally through the example analysis to further illustrate the scientific and rationality to the method to the residual life of cranes based on artificial network.

ESTIMATING METHOD TO THE CURRENT LOADING WEIGHT OF CRANE

The crane residual life estimation of its construction system can help us monitor and control the accidents happens in the construction process, to make sure the safety at its working.

In the process of estimating, small faults may happen which finally formed an important feature called uncertainty because of the change of the weigh. And the final experimental result caused by this feature can not apply to the practice and project theory. Furthermore, in the specific construction process, Influenced by environment the crane can't bear big load.

In this case, the field investigation, in a specified time period in need of cycle number for different load calculation, use is rising load crane rated, the bearing capacity of artificial neural networks to the crane is estimated based on the way is reasonable and effective.

Neural network model of crane is constructed to obtain the equivalent load spectrum

Make the bridge crane as the research target, the two input items are rated load of crane and hoist load, output is the number of cycles within a specified period of time in the process of construction crane corresponds the input. The artificial neural network model consists of three layers, which include input layer, output layer and the hidden layer, the main feature of this model is the artificial neural network model of double input and single output[3]. Among them, the input layer of two neurons, the main function of the two neurons are used to input the rated lifting load and a lifting load, the output layer is arranged in a neuron, the purpose is to use the output layer as the cycle number crane construction in the process of[4].

In this paper, take the bridge crane as the object, thus we could build of artificial neural network model for the crane loading quantity shown as Figure1. Among them, there are 15 neurons in hidden layer, in the calculation process, we run it through the application extension of the corresponding node and deletion.

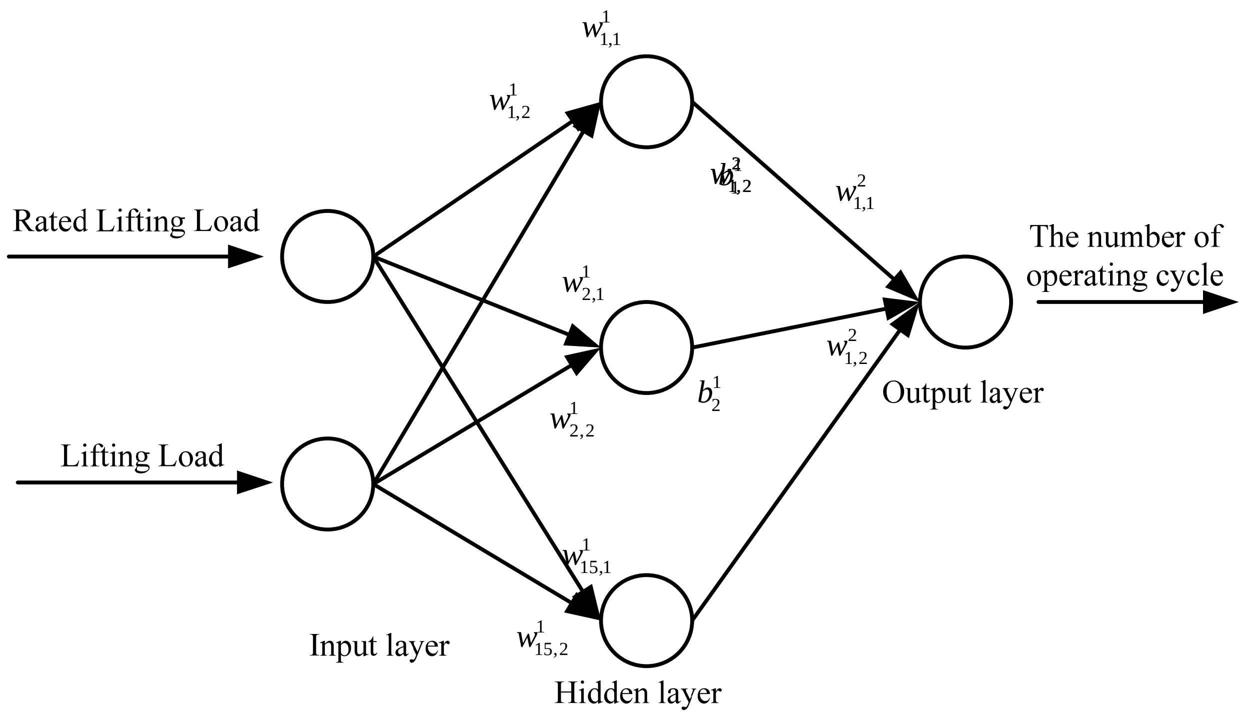

Figure 1 : Construction of artificial neural network structure based on crane loading quantity

Sample obtain

This sample is overhead traveling crane, the input quantity is the rated load of crane and hoist load, the corresponds output quantity is the number of cycles within a specified period of time in the process of construction crane. The corresponding case study research method to confirms this way is scientific and reasonable, for the sample, the rated lifting load value is divided into 8 samples. In order to improve the function of the performance of the artificial neural network of the study sample, collect the corresponding sample of weight bridge crane lifting until load another weight, and we should also take the corresponding records in the table in the construction process, such as whether it is in the normal the working state in the whole process, and number of cycle load.

LMBP neural network

Proper training of artificial neural network is convenient to get the required for bearing load in the process of construction, at the same time, we can grasp the safety of the quality in the construction process through the estimation to the residual life of cranes. Artificial neural network training process requires the corresponding adjustment of crane model structure in the input layer and hidden layer weights W, wherein the crane model structure in the hidden layer and output layer weights marked as WZ, the ultimate goal is to make the error between the artificial neural network sample output value and the expected value get smaller, and make it more convenient to make a better estimation of the of surplus value of crane.

Obtain of the number of operating cycle cluster

Based on the application of the example we talked earlier, which is to say we use the measurement of cycles corresponding trend between the bridge crane in a specified period of time in the process of construction crane.

TABLE 1 : The number of operating cycle cluster of general bridge crane's hoist load

Serial number	rated load	hoist load	cycle times	Serial number	rated load	hoist load	cycle times
1	100	93.75	53	25	160	150.00	53
2	100	81.2	70	26	160	130.00	66
3	100	68．75	58	27	160	110.00	74
4	100	56.25	48	28	160	90.00	50
5	100	43.75	40	29	160	70.00	37
6	100	31.25	35	30	160	50.00	24
7	100	18.75	3	31	160	30.00	3
8	100	6.25	0	32	160	10.00	0
9	120	112.50	47	33	180	168.75	54
10	120	97.50	64	34	180	146.25	69
11	120	82.50	72	35	180	123．75	77
12	120	67.50	56	36	180	101.25	44
13	120	52.50	36	37	180	78.75	24
14	120	37.50	31	38	180	56.25	26
15	120	22.50	2	39	180	33.75	14
16	120	7.50	0	40	180	11.25	0
17	140	131.25	49	41	200	187.50	52
18	140	113.75	64	42	200	162.50	67
19	140	96.25	72	43	200	137.50	76
20	140	78.75	54	44	200	112.50	42
21	140	61.25	38	45	200	87.59	35
22	140	43.75	29	46	200	62.50	24
23	140	26.25	3	47	200	37.50	9
24	140	8.75	0	48	200	12.50	0

The neural network method for obtaining process crane equivalent load spectrum

Flow chart of the number of crane load based on artificial neural network is as Figure 2.

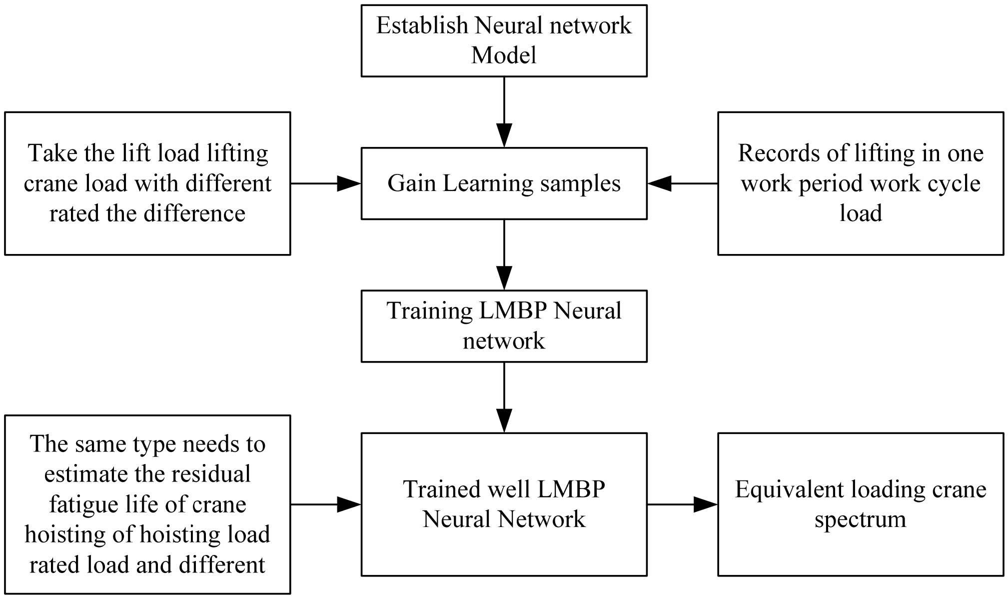

Figure 2 : Chart of the number of crane load based on artificial neural network

THE FORMULA OF RESIDUAL LIFE ESTIMATION OF CRANE

The miner linear cumulative damage theory

In this theory, in the process of crane residual life estimation, the degree of its damage is regarded as the mechanical cycle accumulation under the action of some force. When crane cumulative damage times reached critical mass, crane structure model will appears damaged situation[5].

Domestic researchers applied the Miner theory in the consolidation process of steel structure technology. In this paper, based on the crane structure of artificial network for life estimation process, the Miner linear cumulative theory is adopted. The basic nature of Miner theory is that in the construction process, after crane structure system never experienced a cycle of injury, damage value, total damage value is D.

The assessment formula of total number of fatigue damage crane in construction process is as follows:

$$D = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

$n_i --i$ means the number of construction cycle times;

$N_i --i$ means the number of Fatigue life of crane.

when the total value of cumulative damage reaches to 1, it means that the structure is broke.

Beyond that, The examples and related data of related research shows that in the concrete construction process, the crane can be used with the crane load instances in the same way, On this basis, the number of crane load estimation, and judge the crane load shed and value, and the same way can be used to settle the construction of the present situation of the accident in the process of solution. In this paper, the estimation methods of bridge crane artificial network surplus value formula based on equivalent stress amplitude is as following:

$$\sigma_{re} = \sqrt[m]{\sum \alpha_i \sigma_{ri}^{\ m}}$$

Based on the above Miner should be summarized and analyzed stress amplitude equivalent formula, this paper research process on the residual life of cranes, can be prefabricated Miner theory basis, the magnitude of stress change of degree in the variable amplitude loading crane equivalent stress amplitude, its main purpose is to simplify the stress amplitude equivalent formula.

Crane residual life based on the theory of crack dynamic

According to the fracture accidents of crane structure system in the above formula to analyze, there is a certain relationship between the fault and the crane model of the initial defect. The welding structure is in the main girder of overhead traveling crane to take measures, in the welding process, defects typically pores and other methods, which usually cause the crane in the construction process caused by fatigue crack, In the welding process of crane structure system, crane due to fatigue caused by the initial crack, the initial value of the crane in the construction process as the crack situation caused by fatigue.

In the acquisition of crane construction of initial defects, can also be carried out according to the damage degree of concrete size crane crack and crack, to estimate the residual fatigue life of crane[6].The above comprehensive analysis based on the residual life of cranes, this paper estimates the artificial network based on the fracture mechanics method, the residual life of main girder of overhead traveling crane welded joints were reasonable estimates, calculated by the formula of fatigue life, the residual life of heavy machine.

The estimating process of crane's residual life can be divided into three main stages, they are the crack expansion in the construction process, the welding crack expansion and crane girder crack quick-expansion stage. The main formula is as follows:

$$dl / dN = C(\Delta K)^n$$

$$\Delta K = K_{\max} - K_{\min} = Y\sigma\sqrt{\pi l}$$

The formula of residual life of Bridge crane metal composition called N_f is as follows:

$$N_f = (a_f^{t-n/2} - a_0^{1-n/2})\left[(1-n/2)C\pi^{n/2}(Y\sigma)n\right]^{-1}$$

PROJECT EXAMPLE

Target of evaluation

According to the bridge crane manufactured in an enterprise in 2006,the specification is 75 / 30t, the bridge span value is 28.5m, the following parameters in the process of research, namely the wheelbase 4.51TI, cranes rise height is about 14m, the speed of 1 / 9m /min, the speed of 50M / min, car speed is 20rn / min, on (the) cover plate thickness X of length 18min~800rnnl, web plate thickness and height 8inrnx2100n'nTl.

Setting of corresponding parameters

Through the definition of the bridge crane parameters, load and the estimation of the crane by the corresponding network technologies are quickly obtained, to estimate the related parameters of the residual life of cranes, we can obtain the specific invest amount of labor and resources during the construction process, the ultimate equivalent load of crane spectrum can be obtained in time accurate, and estimate the residual fatigue life of crane girder. Constant in the test material of bridge crane for C and n, where n =2 ~ 4[7]. The initial crack through tests to calculate the value of crane. In the specific application process,because the crane fatigue crack length caused by the welding defect about 0.5mm. Crack size of crane girder is [illegible] during the construction, the storage size varies 80 ~ 100mm, the crane load is 75t, the crack size [illegible] = 90mm.

To estimate the residual life of cranes

To estimate the residual life of crane structure system, can help us monitor and control of the crane effectively in the construction process of the accident, get effective guarantee to ensure the quality and safety of the crane in use. In the whole process of estimation, because of the continues changes in the quantity of crane bears, certain error of the test results emerges in the process, and finally form the most important characteristic of crane in the construction process, called uncertainty, And the final experimental result caused by this feature can not apply to the practice and project theory. Furthermore, in the specific construction process, Influenced by environment the crane can't bear big load. In this case, the field investigation, in a specified time period in need of cycle number for different load calculation, use is rising load crane rated, the bearing capacity of artificial neural networks to the crane is estimated based on the way is reasonable and effective. In this paper, based on the artificial neural network to estimate the residual fatigue life of crane in the process of bridge crane in the acquisition process, the equivalent load spectrum of the sample, equivalent load spectrum as shown in TABLE 2. The main construction process, fatigue of crane girder span dangerous point section stress spectrum; according to the basic theory of Miner calculated that the crane equivalent stress amplitude σ_{re} ,and then estimate the remaining life of the bridge crane. The measured during the whole calculation process results as shown in TABLE 3.

From the data in TABLE 3 shows, estimate the residual life of cranes in the research of artificial network, the remaining fatigue life of which is about 32.4 years. The experimental application of the spectrum calculation of the residual life is 35.6 years and the error is less than 10%, which means that the method of residual life of cranes based on artificial neural network estimation research and application is scientific and reasonable.

TABLE 2 : Prototype equivalent load spectrum

Serial number	rated load	hoist load	internet output of cycle times
1	75	70.3125	45
2	75	60.9375	65
3	75	51.5625	77
4	75	42.1875	50
5	75	32.8125	35
6	75	23.4375	25
7	75	14.0625	10
8	75	4.6875	0

TABLE 3 : Calculated and measured results of general bridge crane (75／30t)

lifting load quality m_{Qi} / t	Condition of equivalent load spectrum		The measured load spectrum		Relative error δ / %
	The number of operating cycle (N)	stress amplitude σ / MPa	The number of operating cycle (N)	stress amplitude σ / MPa	
70.3155	45	73.31	48	72.52	
60.9375	65	65.77	69	62.39	
51.5625	77	58.32	80	57.26	
42.1875	50	50.87	53	48.13	
32.8125	35	43.69	37	14.00	
23.4375	25	35.98	27	34.62	

14.0625	10	28.53	15	26.73	
4.6875	0	21.08	0	-	
residual life N / a	32.4		35.6		9.37

CONCLUSION

This paper is based on the artificial network, carries on the reasonable estimation for residual life of cranes in the process of construction, the load on the bridge crane spectrum acquisition, the core lies in that the uncertainty and randomness in the construction process, in this case, is proposed for estimating the way different from the traditional case, further effective estimation for residual life of cranes fatigue, and it is also the reasonable innovation on the basis of traditional test. In the case that application of crane equipment in the hoisting machinery is used more and more widely in today's social economy, the task of heavy machinery in the construction process is becoming bigger, the engineering technology is more and more high quality requirements in the aspects of safety, based on the good use of crane network model, quickly obtain load and the estimation of crane through the corresponding network technology, to estimated crane’s residual life, do bigger purpose, can greatly save the crane human in the construction process and the source input, the final equivalent load of crane spectrum can be obtained timely, and accurately estimate the residual fatigue life of crane girder can be done.

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