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Intelligence Monitor and Diagnosis to High Speed Brushes Aeration Mechanics Based on Turbulent Flow Displacement Sensing Theory

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Abstract: High Speed Brushes Aeration Mechanics are the effective aeration equipments which are widely used in the environmental protection. Because of the big span of main spindle and its high speed when it is working, the breakdown sometimes occurs. It is very importance to monitor its condition and diagnose its breakdowns. Turbulent Flow Displacement Sensors are the non-contact types which are based on eddy current effect. It has many advantages, such as good linearity, wide frequency response scope, convenience installment and so on. So it is very suitable for the main spindle's vibration signals of a high speed brushes aeration mechanic are monitored. With the development of Artificial Neural Networks technology, the equipment breakdown diagnosis has realized intellectualization. The recognition of equipment failure types is one of the most important studying domains of Artificial Neural Networks at present. Based on the research of eddy current effect and Artificial Neural Networks, we build up a test system which can monitor condition and diagnose breakdown to a GSB-12 high speed brushes aeration mechanic. With the help of it, the vibration signals of the measurement points on the main spindle are measured at two mutually vertical positions. The signals' base frequency and multiplicative frequency are taken as characteristic value. Six common breakdowns are selected and to be taken as the standard sample and there are 3 lays in the neural network. Using FBP algorithm, we get a satisfied effect. The experiment has confirmed that this method is advanced, reliable and practical. It provides a new method about intelligent monitor and breakdown diagnosis to high speed brushes aeration mechanics' condition.

Introduction

High Speed Brushes Aeration Mechanics are the effective aeration equipments which are widely used in the environmental protection. With the development of science, technology and the production, the highly effective, great span and high speed brushes aeration mechanics begin to appear. Its characteristic is: big power, big span and high efficiency. But in practical application because of these, the main spindles breakdown sometimes occurs. If the accidents cannot be removed, it will not only affect its use, but also brings to the enterprises and the country big economic loss. Therefore, it is very important to monitor its condition and diagnose its breakdown when a high speed brushes aeration mechanic works.

There are many methods which can be used in mechanics breakdown diagnosis, for example, vibration signals monitor, oil type analysis and temperature monitoring and lossless examination.

With the development of Artificial Intelligence technology, equipment failure monitor diagnosis technology is also enormously impelled. The method the paper mentioned is that: the vibration signals of a high speed brushes aeration mechanic are gathered and processed. After the characteristic parameters are obtained it may be monitored on-line and its breakdown may be diagnosed by artificial Neural Network. A GSB-12 aeration mechanic's construction is shown in Fig. 1.

Breakdown Monitor and Diagnosis Mechanization

The power of a GSB-12 high speed brushes aeration mechanic is 75KW, its span is 12000mm and its rotation rate is 85r/min, we can see its characteristic of great span, high speed and big power. Therefore, when the High Speed Brushes Aeration Mechanic works, it will produce obvious vibration. The idea mentioned in this paper is that its vibration signals are picked up and measured by some turbulent flow displacement sensors.

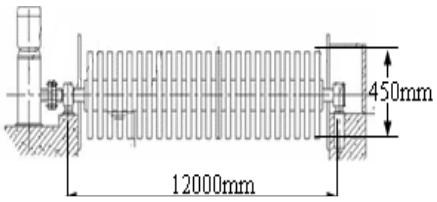

Fig.1 GSB-12 aeration mechanic's construction

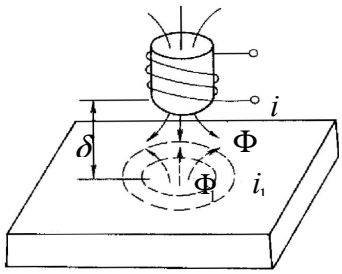

Fig.2 Turbulent Flow Displacement

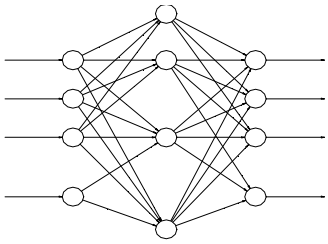

Fig.3 FBP structural model

There are many factors which can make a High Speed Brushes Aeration Mechanic vibrate, for example, the impeller imbalance, the main spindle eccentric, the foot bolt becomes less crowded as well as the manufacture installment quality and so on. All these will bring some influence on monitoring of a High Speed Brushes Aeration Mechanic. For this problem, there are many overlapping parts, primary and secondary contradictory is chaotic. Because of the Artificial Neural Networks have the characteristics of CuoRong and self optimization, it can be used to monitor and breakdown diagnosis to a High Speed Brushes Aeration Mechanic's condition with the help of some turbulent flow displacement sensors.

Turbulent Flow Displacement Sensors. The character of Turbulent Flow Displacement Sensors is that who doesn't contact with the part surface, it is highly suitable for a main spindle of a High Speed Brushes Aeration Mechanic when it needs to be monitored vibration. Turbulent Flow Displacement Sensors' principle is shown in Fig. 2

According to the electromagnetic theory, if there is high frequency alternating current "i" goes through a coil, it will get magnetic flux "Φ". When the magnetic flux through a metal object, its surface will produce induced current "i_1" and alternating flux "Φ_1". This kind of electric current in the metal object is closed, therefore it is called eddy current. The direction of alternating magnetic field produced by eddy current is opposite to it of the magnetic field produced by the coil. As a result of the magnetic field function produced by eddy current, the coil's equivalent impedance "Z"changed. The change relates to the spacing "δ".

Analysis on this indicated that, the coil's self-inductance and the spacing are in reverse proportion, but it is proportional with the magnetism cross-sectional area, it can be expressed as following:

$$L = \frac{w^2 \mu_0 A}{2\delta} \tag{1}$$

Where w is the number of turns, μ_0 is the vacuum magneto conductivity ($\mu_0 = 4\pi \times 10^{-7} H/m$)

Principle of Artificial Neural Networks. Artificial Neural Network is a kind of information management system which imitates human brains' structure and function. There are many kinds of model for it. BP is one of the most widely used and successful network at present. An algorithm called error spread fast backward (FBP) is an improvement to BP. It may transform the non-linear optimization question as the linear optimization question. It may use the linear optimization's many positive achievements. It overcomes BP algorithm's the questions of slower convergence rate and so on. FBP structural model is shown in Fig.3.

There is a little difference between FBP and BP, that is: one layer in a neuron to one index. It optimizes the performance index through the method of the network weight improvement. Thus the question of the neural network adjustment has transformed for the sub-optimized one which is dispersed the neuron level as unit's lamination. Its optimized index is:

$$J_i = \sum_{p=1}^{n} (\sum_j (\hat{Y}_{ij}^p - Y_{ij}^p)^2) \tag{2}$$

Where p is training pattern serial number（ $p = 1 \sim N$， N is training pattern number）, $\hat{Y}_{ij}^p$ is i st lay j nd node weighted sum expectation output when p st layer sample input, Y_{ij}^p is i rd j th node actual weighted sum output when p st lay sample input.

Therefore

$$Y_{ij} = \sum_{k=1}^{n_i - 1} \omega_{ijk} x(i-1)k = \phi_{i-1}^T \theta_{ij} \tag{3}$$

Here, $\phi_{i-1}^T = [x_{(i-1)1}, x_{(i-1)2,} \cdots, x_{(i-1)n_{i-1}}]$, $\theta_{ij} = [\omega_{ij1}, \omega_{ij2}, \cdots, \omega_{ijn_{i-1}}]$. Where J_i can be wrote :

$$J_i = \sum_{p=1}^{N} \sum_j (\hat{Y}_{ij}^p - \phi_{i-1} \theta_{ij})^2 \tag{4}$$

Because J_i item in the formula (4) does not contain the non-linear items, those linear optimization conclusions can be applied directly. Thus the question of the performance index's minimum value (θ_i) is a standard smallest two multiplication optimization.

Step 1 Initialize p_i， θ_{ij} ($p_i = 10^3 \sim 10^6 I$， θ_{ij} may be gave some values randomly, it belong to(0, 1))；

Step 2 for each pair of input and the output:

Input signal disseminates forward

$$Y_{ij} = \sum_{k=1}^{n_i - 1} \omega_{ij} \omega_{(i-1)k} \tag{5}$$

$$X_{ij} = f(Y_{ij}) \tag{6}$$

Input error signal disseminates backward

Output layer

$$\delta_{lj} = f^{-1}(\hat{X}_{lj}) - Y_{lj} \tag{7}$$

Hidden layer

$$\delta_{ij} = f^{-1}(X_{ij}) \sum_{k=1}^{n_{i+1}} \delta_{(i+1)k} \omega_{(i+1)kj} \tag{8}$$

Calculation

$$\begin{cases} M_{i+1}(k+1) = P_i(k) / (\lambda_i + \Phi_{i-1}^T P_i(k) \Phi_{i-1}) \\ P_i(k+1) = (P_i(k) - M_i(k+1) \Phi_{i-1}^T p_i(k)) \lambda_i^{-1} \end{cases} \tag{9}$$

Renewal of weight

Output layer

$$\theta_{ij}(k-1) = \theta_{ij}(k) + M_i(k+1)(f^{-1}(\hat{X}_{ij}^p) - X_{ij}) \tag{10}$$

Hide lay

$$\theta_{ij}(k+1)=\theta_{ij}(k)+M_i(k+1)\mu\times f^{'}(\hat{X}_{ij}^{p}\sum\delta(i+1)k^{\omega}(i+1)kj) \tag{11}$$

Step 3 Repeating step 2 until convergening or achieving the fixed study step.

Step 4 If training successfully, then freezing weight, otherwise going back to step 1, designating the starting value, repeating step 1 to step 3.

Test Research

Test System Design. In order to realize that a GSB-12 high speed brushes aeration mechanic can be monitor and its breakdown can be diagnosed, a "Pico" electron signal electroscope reflector which is made in Israel is used to gather and measure the signals. A connection electric circuit is designed between the electron signal electroscope reflector and a computer. So a test system which is used to monitor on-line and diagnose breakdown of a GSB-12 high speed brushes aeration mechanic is build up. It is shown in Fig. 4.

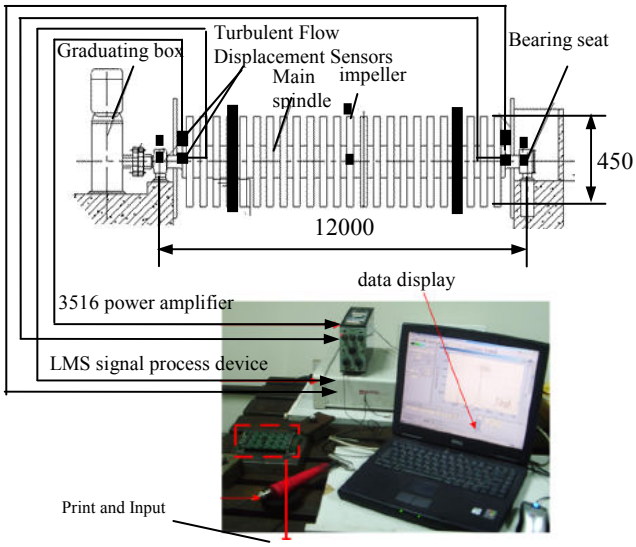

Fig. 4 Brushes Aeration Mechanics Test System

Sample Data Extraction. Four Turbulent Flow Displacement Sensors are placed on both sides of the main spindle but near the bearing seats, along horizontal and vertical direction. The vibration signals are measured at the same direction. Taking the signals' base frequency and multiplicative frequency as characteristic value, meanwhile normalizing those selected dates. In this experiment, 1600Hz is divided into eight frequency bands; each frequency band is 200Hz. Then various frequency bands spectrum energy divides the total energy in order to obtain the sample data. This sample data highlights the proportion that energy occupies frequency component. This plays a part of energy weight coefficient in breakdown recognition. At the same time the precision that the neural network structure training and the sample data extraction are enhanced.

There are many factors which can lead to aeration mechanics' main spindle vibration, for example, the Impeller mass unbalances, not to, the gaps of bearings which support the main spindle are oversized, the foot bolts become less crowded as well as the current of water and so on. Six common breakdowns are selected to take them as the standard sample in the test. Through processing the data which are from each kind of breakdown, the date of each samples' energy distribution belonged to different frequency band are obtained. It is shown in Table 1.

Diagnosis Test. In the test, there are 3 layers in the neural network, 5 nodes in the input layer, 2 nodes in the hidden layer and 6 nodes in the output layer. It is optimized for 1550 times, the overall error is 0.005. Table 2~ table 5 have listed the data of the neural network weight, the threshold value

matrix, the sample actual output and the ideal output as well as the output result of the sample data diagnosed in turn.

Table 1 Each samples' energy distribution belonged to different frequency band

Frequency band / sample	0-200	200-400	400-600	600-800	800-1000	1000-1200	1200-1400	1400-1600
Main spindle X direction	0.40	0.60 32.0	0.20 45.0	0.07 4.00	0.05 0	0.04 3.00	0.05 8.00	0.20 9.00
Main spindle Y direction	0.03	0 32.0	0.20 89.0	0.72 4.00	0.12 9.00	0.04 9.00	0.05 0	0.20 9.00
Impeller X direction	0.03	0 56.0	0.5 92	0.13 5.00	0.34 8.00	0.08 6.00	0.08 0	0.03 3.00
Impeller Y direction	0.03	0 54.0	0.40 78.0	0.20 9.00	0.24 9.00	0.23 2.00	0 0	0 0
Bearing seat X direction	0.07	0.20 89	0.10 98	0.34 2.00	0.14 4.00	0.07 2.00	0.07 0	0 0
Bearing seat Y direction	0.07	0.20 89	0.10 98	0.34 2.00	0.14 4.00	0.07 2.00	0.07 0	0 0

Table 2 Hidden lay's weight and threshold value

Weight value of input lay to Hidden lay		Hidden lay 1	Hidden lay 2
input lay	1	4.8947	-1.5734
	2	11.7865	7.4320
	3	5.6754	40.8723
	4	-3.78211	-32.6723
	5	-12.8001	18.4077
Hidden lay threshold value		1.1278	-5.8795

Table 3 Output lay's weight and threshold value

Weight value of hidden lay to output lay		hidden lay 1	hidden lay 2	Output lay's threshold value
output lay	1	53.6239	28.7821	-63.8788
	2	24.8932	-79.6543	-75.8765
	3	69.8456	-45.8565	-45.2312
	4	26.1298	-98.6754	-8.9564
	5	-29.6754	24.7877	-13.8721

Table 4 Sample data' actual output and ideal output

actual output	ideal output
0.999 0.000 0.001 0.001 0.000	1.0 0.0 0.0 0.0 0.0
0.001 0.999 0.001 0.000 0.000	0.0 1.0 0.0 0.0 0.0
0.000 0.001 0.999 0.000 0.000	0.0 0.0 1.0 0.0 0.0
0.000 0.001 0.001 0.999 0.000	0.0 0.0 0.0 1.0 0.0
0.000 0.001 0.000 0.000 0.999	0.0 0.0 0.0 0.0 1.0

From Table 5 we can see, when the frequency is in the scopes of 1000~1200Hz, the vibration displacement quantity becomes bigger. After inspecting, anglicizing and researching on the aeration impeller, the main spindle bearing gaps, the bearing seat foot bolts, we thought the possible reason of vibration displacement bigger is the resonating produces. This judgment is confirmed after repeating

the test. Therefore, this frequency band should be avoided as far as possible in the actual use. The actual output precision of the sample diagnosed is between 0.995~0.999, which satisfies the requirement of the overall error on 0.005.

Table 5 Output result of sample data diagnosed

Frequency band / Displace	0-200	200-400	400-600	600-800	800-1000	1000-1200	1200-1400	1400-1600
Main spindle X direction	0.15	0.16	0.19	0.20	0.22	0.35	0.28	0.27
Main spindle Y direction	0.18	0.20	0.22	0.24	0.26	0.39	0.29	0.27
Impeller X direction	0.2	0.23	0.26	0.28	0.29	0.45	0.31	0.30
Impeller Y direction	0.22	0.26	0.28	0.29	0.31	0.45	0.31	0.31
Bearing seat X direction	0.05	0.07	0.08	0.09	0.10	015	0.11	0.11
Bearing seat Y direction	0.06	0.07	0.09	0.09	0.11	0.15	0.11	0.11
Training precision	0.998	0.999	0.997	0.999	0.996	0.997	0.998	0.995

Conclusions

The theory and the experimental study indicates that it is feasible that picking up the vibration signals by Turbulent Flow Displacement Sensors and then monitoring the condition of High speed brushes aeration mechanics.

It has many advantages, such as responding quickly, high sensitivity, work reliable and structure simple to use Artificial Neural Networks to diagnosing revolving machinery's breakdowns

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