Fault Diagnosis System Research of Large-scale Linear Vibrating Screen

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Abstract. The paper takes side panel cracks of large-scale Linear vibrating screen as research object and designs the hardware and upper computer diagnosis interface of fault diagnosis system. The side panel vibration signals have been de-noised and the wavelet packet energy feature has been extracted in Matlab with wavelet analysis theory. Meanwhile, the fault characteristic is sent to genetic neural network for identification. The practical manufacturing application shows that this kind of side panel crack fault diagnosis system of large-scale vibrating screen based on wavelet analysis has high fault recognition ability, classification precision and speed.

Introduction

Vibrating screen is a kind of common large-scale mine-used screening equipment which is mainly used for grades screening and impurities separation of coal and ore. Because of high costs and key position in production of vibrating screen, a huge economic loss could be caused once the fault occurs. Large-scale line vibrating screen is one of the most common used vibrating screen whose side panel crack fault is most common and the harm brought is maximum[1-2]. So, the research and monitoring for side panel crack of large-scale line vibrating screen has very important practical significance. This text takes the side panel cracks of large-scale line vibrating screen DZK2466 as research object and the fault diagnosis system is designed and constructed which can detect side panel cracks and alarm early. The control system uses the software such as Data Base, Visual Basic and Matlab to process, analyze and identify fault data based on wavelet analysis and neural network algorithm. The system has obtained high fault accuracy diagnosis by practical production use.

System Construction

Research Scheme of the System

The side panel crack detection system of large-scale line vibrating screen DZK2466 includes two parts of hardware circuit and software design. The hardware circuit mainly performs the acquisition and storage of data while the software can process, convert and analyze the data collected. Four stages are needed to perform the program. The first stage is field investigation in which we can understand the production operation status, the reason of cracks caused and change so that the corresponding maintenance measures can be taken. The second stage is determining system diagnosis scheme and designing system hardware and software. The third stage is system simulation and debugging in
laboratory. The last stage is field detection and application. Where, the diagnosis system is improved continuously through long term tracking measurement and is applied to practical production finally.

**System Control Flow**

The flow chart of the system to realize side panel cracks diagnosis of large-scale line vibrating screen DZK2466 is shown in Figure.1.

**System Hardware Structure**

The system hardware is constructed mainly with sensors, charge amplifier, micro-controller, upper computer and LCD etc. The signal is collected by three-axis accelerometer and sonar sensor simultaneously. The charge amplifier amplifies the original signals and converts them to standard voltage signals which are converted into digital signals through ADC. The microcontroller doesn’t only storage and preprocess digital signal but also analyzes, processes, storages, identifies and outputs signal for further through communication with upper computer. The system hardware structure diagram is shown in Figure. 2.

**Wavelet Analysis**

Three-axis accelerometers are placed on different position of two side panels of vibrating screen in order to acquire vibration signals with 512Hz and 2048 points of sampling frequency. Through observation and analysis with signals collected from the sensors, we found that the only useful signal was the Z-direction signal amplitude of three-axis accelerometers.

**Data Process with Wavelet Decomposition**

One-dimensional discrete wavelet transform of Z-direction vibration signal is taken and the noise reduction in every layer is done in Matlab. The soft threshold decomposition, default threshold decomposition and mandatory threshold decomposition are taken
separately to reduce the noise of signals combined with concrete signal noise characteristic in Matlab programming. Wavelet db5 is selected for noise reduction by comparison. The author found that the way of setting threshold at each node respectively is better than that of setting a global threshold in reduction process. The wavelet noise reduction result with three ways of Z-direction signal is shown in Figure 3.

By comparison we found that the relatively smooth waveform in Figure 3 is the result of mandatory decomposition with which method some useful signals may be missing. The author adopts the way of given soft threshold to reduce the noise of signal in this paper whose wavelet packet decomposing program is as follow.

```matlab
load m2466;
x=m2466;
% three layer wavelet packet decomposition
t=wpdec(x,3,'sym4');
% display the tree structure
plot(t);
% set the global threshold
  t1=t;
sorh='h';
  thr=wthrmngr(wp1ddenoGBL,'penalhi',t);
cfs=read(t,'data');
cfs=wthresh(cfs,sorh,thr);
t1=write(t1,'data',cfs);
plot(t1);
% set threshold at every node separately
  t2=t;
sorh='s';
  thr(1)=wthrmngr('wp1ddenoGBL','penalhi',t);
  thr(2)=wthrmngr('wp1ddenoGBL','sqtwologswn',t);
  tn=leaves(t);
  for k=1:length(tn);
    node=tn(k);
    cfs=read(t,'data',node);
    numthr=rem(node,2)+1;
    cfs=wthresh(cfs,sorh,thr(numthr));
    t2=write(t2,'data',node,cfs);
  end
plot(t2);
```

**Fault Feature Extraction of Vibrating Screen**

The cracks of vibrating screen side panel are divided into four levels according to the actual production and maintenance requirements of large-scale line vibrating screen DZK2466. Four kinds of crack length and the corresponding hierarchy is shown in Table 1.
Wavelet transform is very effective for joint analysis in time and frequency domain for signal. But the analysis effect for low frequency signal is better than that for high frequency signal. On the contrary, the wavelet packet analysis can analyze the high frequency signal for further which hasn’t been analyzed in wavelet transform process through dividing the signal frequency band into multi-layer. Meanwhile, wavelet packet decomposition way can adaptively select the frequency band which can match the signal according to the analyzed signal feature. Thus, the time-frequency resolution is improved.

After being divided for three-layer with db4 wavelet of Z-direction signal of vibrating screen DZK2466 side panel, we can see that it is high frequency component that creates the original spike component because there is a high agreement degree between the signal peak and the lowest frequency component while this corresponding relationship doesn’t occur in other frequency components.

The extraction method and steps of wavelet packet energy feature [4] according to the characteristics of vibrating screen fault vibration signal are as follow:

(1) Set $x(t)$ as the vibration signal collected, $N$ as acquisition point number. Use db4 wavelet to decompose $x(t)$ into three layers of wavelet packet to get 8 successive sub-band signals $s_0$ to $s_7$ whose frequency band width is $f_w/8$, where $f_w$ is the highest frequency of signal.

(2) Calculate $S_0$ to $S_7$ for each band signal energy.

$e_i = \sum_{j=1}^{N} |s_i(j)|^2, \quad i = 0, 1, \cdots, 7 \quad (1)$

(3) The signal energy distribution of different fault state in 8 different frequency band is also different. If $E = [e_0, e_1, \cdots, e_7]$ represents fault state, feature vector $F$ can be gotten by normalization processing of $E$:

$$F = \frac{E}{\max_{0\leq i \leq 7}(e_i)} \quad (2)$$

The fault feature energy of vibrating screen side panel typical vibration signal collected can be extracted according above steps. The wavelet packet energy feature can obtained by calculation program of Matlab.

Three fault feature vector diagrams obtained through Visual Basic programming in upper computer are shown in Figure. 4. We can see from wavelet packet energy distribution of frequency bands after normalization that the energy frequency band distribution of different state is also different obviously which can be used to represent the types of fault states. Therefore, it is an efficient fault feature extraction way.

<table>
<thead>
<tr>
<th>crack value/mm</th>
<th>crack level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0~5</td>
<td>0</td>
</tr>
<tr>
<td>20~40</td>
<td>2</td>
</tr>
<tr>
<td>6~20</td>
<td>1</td>
</tr>
<tr>
<td>above 40</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Table of crack scale.
System Fault Diagnosis

Wavelet Genetic Neural Network

Bp neural network [5-6] of large-scale vibrating screen DZK2466 to identify side panel cracks is established targeting wavelet packet energy fault feature inputs. The neural network is optimized with genetic algorithm and is trained and simulated in Matlab [7-8]. The classification and recognition of vibrating screen side panel cracks is realized by observing input characteristic vector value and output value. The fault diagnosis accuracy of this wavelet genetic neural network can reach more than 96% with higher fault diagnosis accuracy and speed.

Upper Computer Diagnosis System Based on Visual Basic

In upper computer software design, the real time data in single chip microprocessor is called by Visual Basic program. While function module in Matlab is called through programming interface provided by Matlab so as to realize wavelet decomposition, energy calculation and normalization [9].

In Figure. 5 of wavelet analysis window, the acquisition signal of corresponding channel can be checked selectively. The wavelet packet decomposition program of Matlab can be directly called and the signal waveform after noise reduction can also be displayed by clicking the “Noise reduction” button. The layer number and the thresholds of every layer can be set separately through this window. These parameters can be embedded in Matlab noise reduction program automatically once setting has been finished [10-11]. So we realize the intelligent soft threshold decomposition processing. At the same time, wavelet packet energy calculation can be finished and the fault feature can be displayed in form of bar chart by selecting automatic energy calculation.

Conclusions

This paper takes side panel crack fault of large-scale linear line vibrating screen DZK2466 as research object and constructs the fault diagnosis system based on wavelet analysis and genetic neural network.

The function of wavelet analysis in signal noise reduction and fault feature extraction are dealt with in detail. Meanwhile, the genetic neural network in Matlab is constructed through training and simulation for fault identification. Data automatic acquisition, noise reduction and fault feature extraction has been performed with upper computer.
diagnosis system which can be executed in real time. The practical application shows that this system has high crack identification accuracy and fault diagnosis speed.

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References


