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Invention and Application of Synthetic Experiment System of Machine Equipment Fault Diagnosis

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Abstract: All kinds of faults were engendered during machine equipment working process. Diagnosing them accurately has important significance in actual production. The invention and manufacturing of the synthetic experiment system of machine equipment fault diagnosis filled in the blank of this kind of experiment equipment in China and obtained national practical new type patent. By the motor speed regulation system, machine equipment fault imitation system, measuring and monitoring system and analysis and diagnosis system of the synthetic experiment system, students can regulate motor speed arbitrarily, imitate multi-kinds of machine equipment parts fault, collect the signals of acceleration, speed, displacement, force and temperature and make multi-kinds of time field, frequency field and figure analysis. The application of the synthetic experiment system in our university's teaching practice has obtained good effect on fostering professional eligibility in measuring, monitoring and fault diagnosis of machine equipment. If the systematic software was installed in portable computer, user can fulfill measuring, monitoring, signal processing and fault diagnosis on multi-kinds of field machine equipment conveniently. In this paper, the three dimensions waterfall spectrum matrix analysis was made on two compact mesh gears. Energy attenuation analysis was made on vibration signal. Wavelet analysis was made on bearing fault. *Copyright © 2014 IFSA Publishing, S. L.*

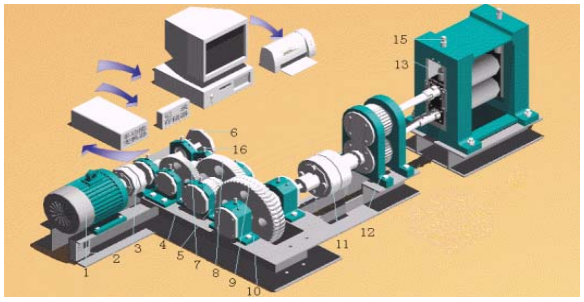
Keywords: Machine equipment fault diagnosis, Synthetic experiment system, Three dimensions waterfall spectrum matrix analysis, Energy attenuation analysis, Wavelet analysis.

1. Introduction

With the continuous development of computer and test technology, the practical application of machine equipment fault diagnosis technology can not only help us find fault and avoid accident, but also can bring us huge economy and society benefit. Fault diagnosis is the judgement of equipment working status and abnormal condition based on the information obtained from machine equipment status monitoring [1]. The research on machine equipment fault test and diagnosis technology has important actual significance [2]. The members of our subject group have gone about the work on engineering measurement and machine equipment fault diagnosis for many years. We not only know the performance of multi-kinds of field machine equipment, but also know that it needs lots of engineering technician on equipment management, equipment measurement, trend prediction and fault diagnosis in modern factory. While, some universities can not provide the experiment equipment used to simulate, show and

experiment multi-kinds of machine equipment fault for students because of lacking of experiment environment, equipment and condition. So, our subject group invents, researches and manufactures the synthetic experiment system of machine equipment fault diagnosis. The synthetic experiment system mainly contains the motor speed regulation system, machine equipment fault imitation system, measuring and monitoring system and analysis and diagnosis system. Its practical object figure and work principle figure are shown as Fig. 1 and Fig. 2.

Fig. 1. Practical object figure of the synthetic experiment system.



1 – three-phase alternating motor, 2 – frequency conversion governor, 3 – shaft coupling device, 4 – base, 5 – rolling bearing and its bearing base, 6 – dynamic balance disk, 7 – straight-gear, 8 – oblique-gear, 9 – heringbone-gear, 10 – sliding bearing and its bearing base, 11 – shaft coupling device, 12 – rolling bearing and its bearing base, 13 – universal coupling device, 14 – rolling mill, 15 – measurement force transducer, 16 – may be acceleration, speed, displacement and temperature transducer.

Fig. 2. Work principle figure of the synthetic experiment system.

2. Motor Speed Regulation System

Motor speed regulation system is the power foundation of the synthetic experiment system of machine equipment fault diagnosis. It mainly contains three-phase alternating motor and frequency conversion governor. Frequency conversion governor has the functions of increase speed, reduction speed, positive revolution, reverse revolution, show frequency order, output frequency, input electric current and program etc. Three-phase alternating motor revolution speed within rated revolution speed can be regulated arbitrarily by frequency conversion governor, so as to change the work frequency of machine equipment fault imitation system.

3. Machine Equipment Fault Imitation System

Machine equipment fault imitation system avoided only focus on single part in previous machine equipment fault diagnosis experiment. The system made a synthetic design contained multi-kinds of non-destructive and defective parts such as straight-gear, oblique-gear, heringbone-gear, rolling bearing, sliding bearing, shaft coupling device, universal coupling device and dynamic balance disk etc. So, lots of familiar fault of multi-kinds of machine equipment parts in production practice can be imitated by machine equipment fault imitation system. For example, break gear and point corrosion of straight-gear, oblique-gear, heringbone-gear, ball, inner ring and external ring point corrosion, sliding bearing wearing, uncoaxiability between motor axle and machine equipment fault imitation system input axle, unnormal gear meshing caused by centre distance over error scope and rotation machine dynamic imbalance etc. These can realize multiple purposes on one system.

4. Measuring and Monitoring System

Measuring and monitoring system mainly contains acceleration, speed, displacement, force and temperature transducer and multiple functions changer. The signals of acceleration, speed, displacement, force and temperature of multi-kinds of machine equipment parts under normality and fault status can be measured and monitored by measuring and monitoring system. From these, user can obtain lots of information of multi-kinds of machine equipment under normality and fault status.

5. Analysis and Diagnosis System

The analysis and diagnosis system software interface has the characters of Chinese downward draw multiple layer menu, input and output data by interview between user and computer, figure conversion analysis between time field and frequency field. These make the operation more convenient. By the data collection main menu, user can realize sampling from single channel, double channels and multiple channels and looking up sampling data. In order to obtain exact and quick A/D sampling frequency, the operation mode of inside timer touch and interrupt data transmission were adopted. A program timer/counter chip 8253 was installed on

PCL-711B data collection card. Exact periodic toucu pulse can be produced by connecting the channel 1 and channel 2 of chip 8253. This mode is an ideal choice on high speed A/D conversion。It can be used with interrupt data transmission [3-5]. The configuration figure of chip 8253 is shown as Fig. 3.

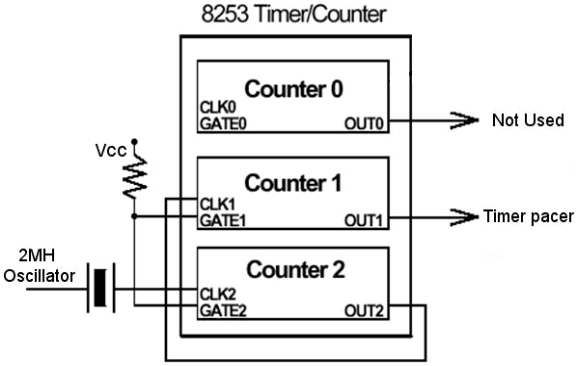


Fig. 3. The configuration figure of chip 8253.

By the time field analysis main menu, user can realize real time signal analysis, self-correlation function analysis, inter-correlation function analysis, time field mean analysis and signal mathematical statistics analysis. By the frequency field analysis main menu, user can realize FFT analysis, self-power spectrum density function analysis, inter-power spectrum density function analysis and reverse spectrum analysis. By other analysis main menu, user can realize three dimensions waterfall spectrum matrix analysis, monitoring and diagnosis on transient locus of rotation axle center and frequency component computation of rolling bearing. By the figure analysis main menu, user can realize figure analysis on time field and frequency field. By the help information main menu, user can acquire the method of using this system and some theory knowledge of signal analysis and fault diagnosis. The analysis and diagnosis system software was programmed by MSC language. So, it has the advantages of easy quadratic exploitation, augmentable analysis and processing function and small error etc. The virtual system build base was built in measuring analysis system, on which student may build different virtual apparatus and program by system software and add it to system such as intelligentized control single channel FFT analysis apparatus.

6. Three Dimension Waterfall Spectrum Matrix Analysis of Two Compact Mesh Gears

Lots of experiment on fault imitation and relevant measuring, monitoring and fault diagnosis of multi-kinds of gear and bearing have been done by the synthetic experiment system of machine equipment fault diagnosis. Now, it takes three dimensions waterfall spectrum matrix analysis as an example. When the meshing between gear 1 and gear 2 is over compact, the three dimensions waterfall spectrum matrix analysis figure composed of FFT analysis spectrum matrix under different motor revolution speed 300 rpm, 600 rpm and 1200 rpm can be drawn, which is shown as Fig. 4. We can know from Fig. 4 that the FFT frequency spectrum value relevant to the character frequency 5 Hz, 10 Hz and 20 Hz of gear 1 under revolution speed 300 rpm, 600 rpm and 1200 rpm. Simultaneously, the FFT frequency spectrum value increase with motor revolution speed. According to the same principle, user can judge the work status of main parts and machine equipment fault imitation system by observing the frequency spectrum value change on relevant character frequency under different motor revolution speed of main parts within motor rated revolution speed.

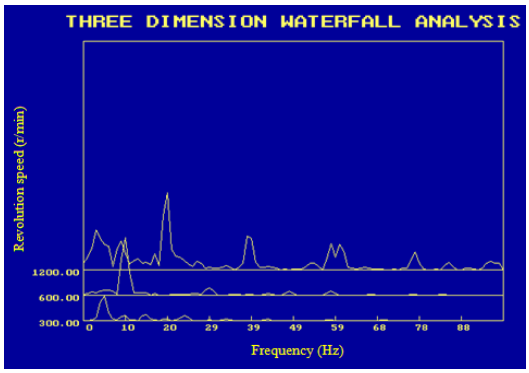


Fig. 4. Three dimension waterfall spectrum matrix analysis figure of actual test signals.

7. Energy Attenuation Analysis of Vibration Signal under Transfer Course

In order to investigate the energy attenuation status of vibration signal under transfer course, the vibration signals of many test points on machine equipment fault imitation system were collected, analyzed and managed. The actual place figure of relevant test points is shown as Fig. 5.

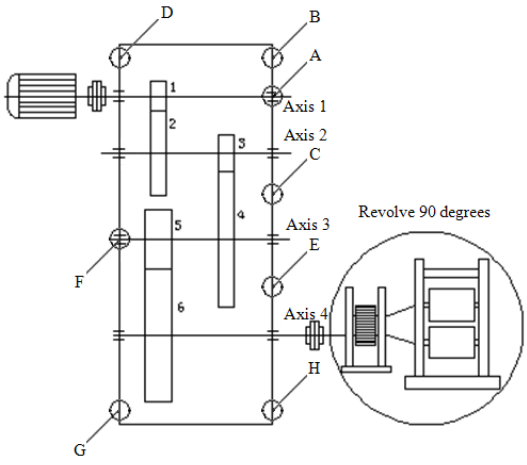


Fig. 5. The actual place figure of relevant test points on machine equipment fault imitation system.

It takes test point A, D and G as an example, the relevant time field wave shape figures and self-power spectrum analysis figures of above test points vibration signals are shown as Fig. 6 to Fig. 11. In Fig. 5, the distance from point A to B, C, D, E, F and G are 80 mm, 140 mm, 212 mm, 260 mm, 287 mm and 538 mm.

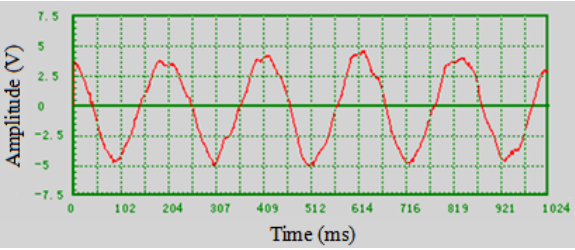


Fig. 6. The time field wave shape figure of vibration signal on vibration cradle.

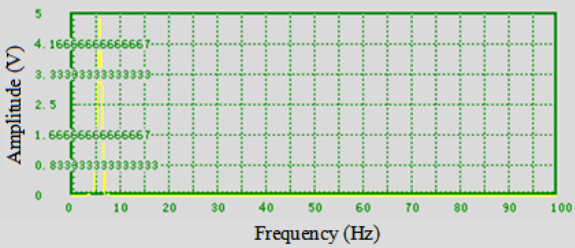


Fig. 7. The self-power spectrum analysis figure of vibration signal on vibration cradle.

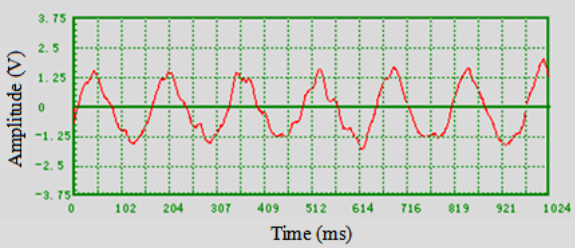


Fig. 8. The time field wave shape figure of vibration signal outside vibration cradle 212 mm.

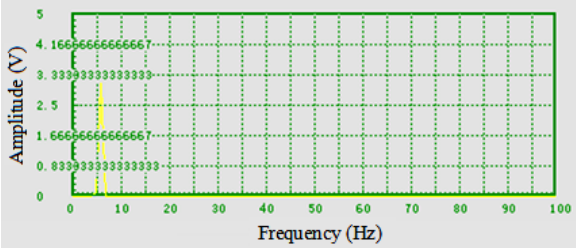


Fig. 9. The self-power spectrum analysis figure of vibration signal outside vibration cradle 212 mm.

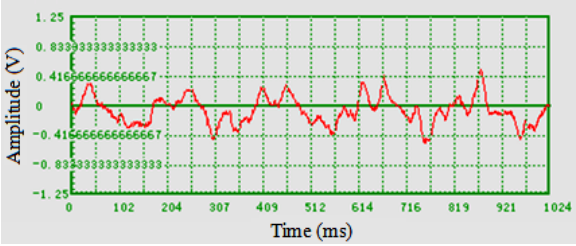


Fig. 10. The time field wave shape figure of vibration signal outside vibration cradle 538 mm.

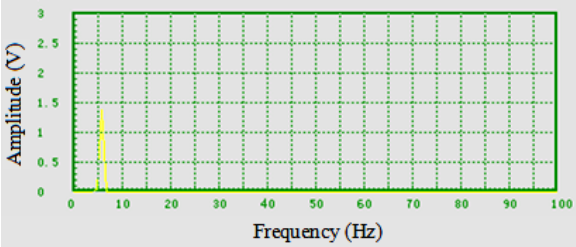


Fig. 11. The self-power spectrum analysis figure of vibration signal outside vibration cradle 538 mm.

From the mathematical statistics analysis and self-power spectrum analysis of vibration signals on test point A to H, the energy attenuation statistics of test point A to G can be obtained, which is shown as Table 1.

Table 1. Energy attenuation statistics.

Test point	Distance outside point A (mm)	Maximum (V)	Peak-peak Value (V)	Equal square difference value (V)	Self-power spectrum character value (V)
A	0	4.648	9.648	9.367	4.8910
B	80	2.747	5.981	3.002	4.7606
C	140	2.195	4.753	1.970	3.6737
D	212	2.063	3.850	1.076	3.1302
E	260	1.221	2.371	0.354	2.6302
F	287	0.823	1.909	0.133	2.1737
G	538	0.525	1.055	0.039	1.3912

From Table 1 we can know that the maximum, peak-peak value, equal square difference value and self-power spectrum character value of vibration signals from test point A to G all reduce gradually with distance increase. It shows that the energy of vibration signals under transfer course will attenuate gradually with distance increase.

8. Wavelet Analysis of Bearing Fault

The main work of extracting weak signal feature by wavelet transform is wavelet elimination noise. Some fault features can be seen directly by wavelet elimination noise. Some signals need wavelet elimination noise firstly, then, frequency spectrum was adopted on analyzing reconstructed signal. FFT spectrum and envelope spectrum analysis method were applied on analyzing reconstructed signal so as to find fault feature [6, 7]. Fig. 12 is the waveform of collected bearing vibration signal on axis 2 under normal bearing status. Fig. 13 is the waveform of collected bearing vibration signal on axis 2 under fault bearing status. Sensor was set on H point. Sampling frequency is 1 kHz. There are obvious impact components on vibration signal in Fig. 13 by the comparison of Fig. 12 and Fig. 13. But it can not be determined the specific fault kind.

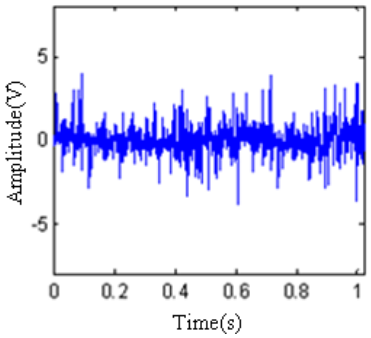


Fig. 12. The waveform of collected bearing vibration signal on axis 2 under normal bearing status.

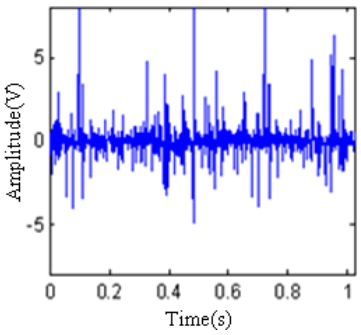


Fig. 13. The waveform of collected bearing vibration signal on axis 2 under fault bearing status.

Four layer wavelet decompositions by orthogonal wavelet basis were made on the relative vibration signal. Every layer approximation signal of wavelet decomposition is shown as Fig. 14. Every layer detail signal of wavelet decomposition is shown as Fig. 15.

The periodic impact signal was seen from d2 detail signal obviously. In order to extract obvious fault feature, Hilbert envelope spectrum analysis was made on d2 detail signal under fault bearing status. Corresponding result is shown as Fig. 16. Likewise, Hilbert envelope spectrum analysis was made on d2 detail signal under normal bearing status. Corresponding result is shown as Fig. 17.

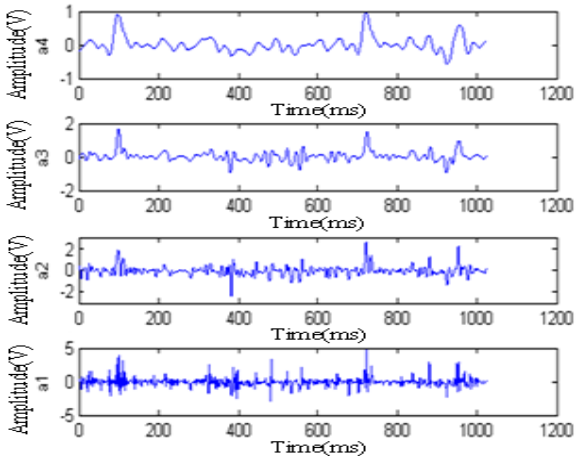


Fig. 14. Every layer approximation signal of wavelet decomposition.

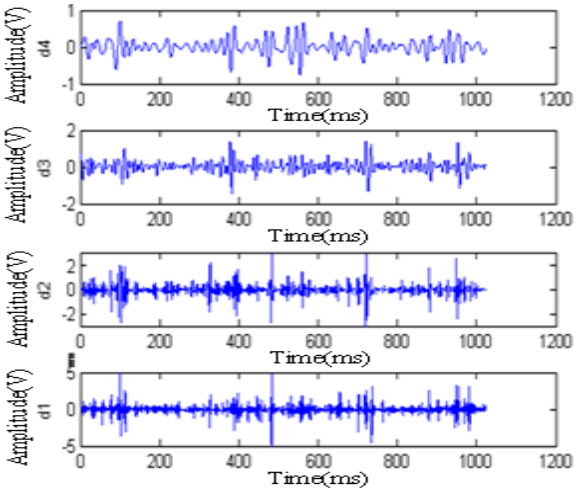


Fig. 15. Every layer detail signal of wavelet decomposition.

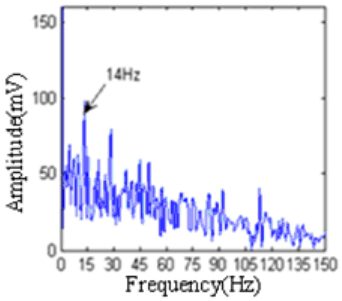


Fig. 16. Hilbert envelope spectrum analysis of d2 detail signal under fault bearing status.

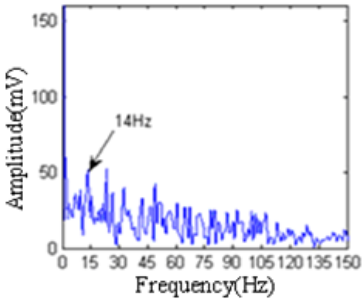


Fig. 17. Hilbert envelope spectrum analysis of d2 detail signal under normal bearing status.

By comparison between Fig. 16 and Fig. 17, it can be seen that the amplitude change is obvious on frequency 14Hz or so and its multiple frequency. It is accordant with bearing outside circle fault feature frequency. So, the fault is caused by bearing outside circle injury.

9. Conclusions

By the sub systems of the synthetic experiment system of machine equipment fault diagnosis, user can imitate multi-kinds of familiar faults of machine equipment parts, make multi-kinds of analysis and processing on collected signal and make right diagnosis on multi-kinds of familiar faults. Three dimensions waterfall spectrum matrix analysis, energy attenuation analysis and wavelet analysis are all effective analysis means on machine equipment fault diagnosis. The system has important significance on training engineering practice ability of student and practical operating personnel in machine equipment fault diagnosis field.

Acknowledgements

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