STUDY ON PERFORMANCE OF LARGE ROTATING MACHINERY SYSTEM WITH COMPUTER VIRTUAL TECHNOLOGY

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Abstract - Large rotating machine is one of the frequently used motive power machine in machinery engineering, thus more accurate and convenient instruments are needed to monitor system performance of large rotating machine. Using virtual instrument to design test system to monitor system performance, the number of hardware instrument used would be significantly decreased, application cost decreased, and measurement accuracy improved. Thus, LabVIEW software and virtual instrument technology were introduced. Take vibration performance of mechanical system as an example, hardware of vibration measuring system is studied based on vibration features and theory of vibration test of large rotating machine. And selection of hardware sensors, filter parameter setting and data acquisition card (DAQ Card) were introduced. Finally, LabVIEW software development platform was used to build software for vibration measurement system, includes signal acquisition, analyze, processing, storage and display. Simulation analyze was done to vibration test system using hardware and software. Those simulation results were verified by frequency spectrogram obtained by applying those software built by LabVIEW software.

Keywords: large rotating machine, virtual instrument technology, simulation, LabVIEW;

1. Introduction

Monitoring technology of large rotating machine vibration is a technology monitoring operating state to define whether the machine operates normally over all or partially and predicting the fault progress by define machine malfunction and its reason [1-2]. Vibration intensity increases with increasing equipment runtime which results in severe damage to the equipment. Thus, vibration monitoring technology is vital to improve safety performance and increase service life of equipment [3]. Data acquired by vibration monitoring technology were used to measure operating status and analyze the reason for malfunction [4-5].

Vibrating monitoring technology includes signal analysis and processing technology, computer and network technology, testing technology and mechanical dynamics [6]. One of the most important steps of vibrate monitoring technology is testing to obtain vibration signal. Traditional vibrate monitoring technology uses instruments with high cost and poor maintenance, which is inconvenient [7-8]. In recent years, with the rapid development of science and technology, traditional instrument is replaced by virtual instruments [9]. Virtual instrument technology is a computer-based software instrument. It is convenient to extend and modify vibration testing system built by virtual instrument technology and the greatest advantage of this system is modularized hardware [10-11], and monitoring, analyzing and diagnosing vibration with software technology [12].

LabVIEW is one of the widely used analytical software of platform of virtual instruments. It’s a graphical programming language but has the same general function as C and C++ [13]. After vibrate test and analytical technology were studied, virtual instrument technology was used to built vibrate test system W and vibrate signal analytical software platform based on LabVIEW. Thus, vibrate state of large mechanical equipment was monitored.

2. Virtual instrument technology

2.1 LabVIEW development environment

LabVIEW is an open developing system of virtual instrument and a graphical programming language instead of text program, with functions such as simulation, data collection, instrument control, measurement analysis, and data display [14]. LabVIEW has hardware to support protocols such as GPIB, RS-232, RS485 and VXI as well as communication functions of DAQ Card [15].

High efficiency of program development is the greatest advantage of using LabVIEW as virtual instruments development platform. Icons were used to program like drawing as LabVIEW provided large signal processing functions and advanced signal analysis functions. Besides, LabVIEW program is easy
to integrate with data collect hardware, communicate with industrial field bus, and link to most data base with general standard. For the convenient of testing program, frequently used program debugging tool such as single step and breakpoint were provided by LabVIEW software.

### 2.2 Virtual instrument technology

Virtual instrument technology is a computer based, which combines high performance hardware module and flexible software together to test, measure and automatic measure and control. Virtual instrument is made of hardware and software.

Hardware is used to complete tasks in different testing system and software is used to complete part of the tasks of different testing system.

Virtual instrument is made up of hardware, mainly computer hardware and measurement hardware (Figure 1 Hardware needed); whose functions are mainly collecting, transmitting, processing and display signal [16]. I/O interface equipment includes data collecting card of computer bus, GPIB bus instrument module, VXI bus instrument module, PXI bus instrument module, LXI bus instrument module, serial bus module and the field bus instruments.

![Figure 1 Hardware composition of virtual instruments](image1)

Technical core of virtual instrument is software, which is made up of user interface (UI), data processing and hardware driver. Computer software was used to replace hardware, thus production cost was lowered and extension and system flexibility was improved.

### 3 Vibration measuring system design for large rotating machine

#### 3.1 General design scheme for vibration measuring system

Vibration test for large rotating machine is one of the important ways to ensure safety its running. Vibration measurement instruments also need improvement as large rotating machine and testing techniques were improved. Testing and analyzing apparatus studied is designed based on virtual instrument, thus hardware devices are needed for testing. A complete vibration testing system is mainly made up of sensor, charge amplifier, signal recorder, data acquisition card and signal analyzer.

First, sensor was fixed on large rotating machine to monitor its vibration signal and convert the collected signal into electrical signal [17, 18]. Then, those signals were input into charge amplifier and signal recorder was used to store signal for further analyzing. Finally, data acquisition card was used to collect signal to PC and vibration testing system of LabVIEW software was used to analyze and display signal. Figure 2 shows general plan of software design using virtual instrument.

![Figure 2 Design scheme of vibration testing system](image2)
3.2 Hardware design scheme
Hardware of vibration testing system was used to preproccess collected vibration signal, which is made up of sensor, charge amplifier, signal recorder, data acquisition card and PC.

Sensor

To get more accurate test result, contact sensor was used during research because of high vibration frequency of large rotating machine. Piezoelectric accelerometer CA-YD-107 was used, which is featured small in size, high sensitive, impact-resistance and high-performance. Performance index of acceleration sensor see table 1.

<table>
<thead>
<tr>
<th>Index</th>
<th>Axial sensitivity (20±5°C)</th>
<th>The maximum axial sensitivity</th>
<th>Frequency response</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>50pC/g</td>
<td>≤5%</td>
<td>0.5~6000Hz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Index</th>
<th>Normal polarity</th>
<th>Operating temperature range</th>
<th>Impact limit</th>
<th>Piezoelectric materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>Positive direction</td>
<td>-40~150°C</td>
<td>800g</td>
<td>PZT-5</td>
</tr>
</tbody>
</table>

Sensor and measured object need to contact well, thus sensor installation is important. Under certain circumstance, sensor and measured object need fix joint. General installation methods use steel bolts, permanent magnet, handle probe, insulation bolt and mica washer, adhesive, and agglutination bolt [19]. If it didn’t contact well, there will be poor contact will horizontally and vertically, which will lead to serious error of test results.

Charge amplifier
Vibration signal collected with accelerate sensor is very week, thus charge amplifier is needed to put signal into signal recorder. Charge amplifier has negative feedback capacitance, thus output signal and output voltage of charge amplifier is in direct proportion [20].

Signal recorder
Magnetic tape recorder is used to record alternating electric signal or transient change of power. Theory of magnetic tape recorder is when current passes loops on head magnetic, iron of head magnetic would generate magnetic flow which is in direct proportion to current and magnetic powder of magnetic tape would be magnetized. When magnetic tape removed from head magnetic, there would be residual magnetization on magnetic tape, which reserves signal on the magnetic tape permanently [21-22].

Data acquisition card
The main function of data acquisition card is to convert analog signal into digital signal.

Sound card was used to record sound signal. Sound card can convert sound signal in tape or light disk into digital signal for PC to process.

3.3 Software design scheme
Software design is after the complete of hardware platform. LabVIEW was used to design software. Virtual instrument was used instead of traditional measurement instrument, thus PC was used to acquire, analyze, process, storage, and display data.

A whole system is consisted of two parts front panel and program flow chart. Front panel was used to test and display data. Program flow chart is the core of the whole program which combines function modules together using graphic language. Next, program flow chart was analyzed.

Data Acquisition module
Vibration testing system is based on data acquisition module. In terms of follow-on work of vibration testing system, it’s important to increase sampling frequency and precision because accuracy of collected vibration signal and results of data process were related to data acquisition. Data acquisition function based of LabVIEW was used to program data acquisition function. Figure 3 show the program.

![Figure 4 VI sub-program of elliptic filter](image-url)
4 Performance test to vibration testing system of large rotating machine

4.1 Test scheme

Vibration of gas engine in China Huaneng Group was monitored to measure machine work. Measurement scheme see table 2.

<table>
<thead>
<tr>
<th>Test object</th>
<th>Vibration of gas machine in China Huaneng Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>The test speed</td>
<td>Idle speed</td>
</tr>
<tr>
<td>Test content</td>
<td>Vibration signal, time-domain waveform and spectrogram of gas machine shell</td>
</tr>
</tbody>
</table>

4.2 Test validation

(1) Parameter setting

Data acquisition and filter parameters need to be set up before vibration testing. During vibration testing in the plant, anti-aliasing filtering is followed up by A/D convert. Anti-aliasing filter means low pass filter was used to filtering vibration signal. In practical, it’s hard for low pass filter to get ideal work result, thus sample frequency need to be relevantly higher than ideal conditions. Generally, sampling frequency is set as 5 to 10 times of the maximum vibration signal frequency [25]. For this test, sampling frequency was set as 44000, sampling bits was set as 16bit, abandon the initial sampling number was set as 1000. Filter was set as rectangular window function, and the lower rate limit is 15 Hz and the upper rate limit is 1 KHz.

(2) Vibration signal analyzing

Designed testing system was used to measure gear box and cryogenic of gas machine in China Huaneng Group. After the vibration signal needs to test was reserved, magnetic tape recorder was connected to the computer. Thus, sound card of the computer was used as data acquisition card. Input signal into vibration testing system to analyze signal spectral.

Gear box is a power machine, and the low speed end of gear box was connected to the engine while the high speed end was connected to gas engine.

Figure six shows vibration testing spectrum of gear box of the plant’s No. 1 gas engine.
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5. Conclusions

To test vibration performance of rotating machine, LabVIEW was used to design vibration testing system based on failure characteristics of large rotating machine and virtual instrument technology. This system is of extension performance because module design is adopted to match selected hardware configuration. Main functions of this system are includes data acquisition, signal processing, file management, time-domain analysis, frequency-domain analysis and joint time-frequency analysis. Further progress was expected to make because this testing system can be improved.

6. References


It is known from figure 6 that in terms of No. 1 gear box, basic frequency of high speed end in axial direction is 85Hz while in low speed end, 49Hz. It is known from the spectrum that amplitude of 99Hz and 171Hz is higher than others. And frequency at 99Hz point is the double of basic frequency at low speed end while frequency at 171Hz point is the double of frequency of high speed end.

Thus, it is conclude that amplitude of the two end of gear box is asymmetry, thus vibration of gas machine rotor was unbalanced.

Figure 7 shows amplitude spectrum of natural gas cryogenic facility. This machine is working normally when axial displacement and vibration test numerical of gear box and compress is normal.

Figure 6 Vibration testing spectrum of gear box of No. 1 of gas engine

Figure 7 Test spectrum of cryogenic vibration device

![Figure 6](image6.png)

![Figure 7](image7.png)


