# Development of fault diagnosis system for wind power planetary transmission based on Labview

## Abstract

The article uses LabView to develop a fault diagnosis system for wind power planetary transmissions. First, use LabView software to create a signal acquisition system. Then, the built wind turbine planetary transmission experiment platform was combined with the NI9171 data acquisition card and the upper computer. The hysteresis brake was used in the laboratory to simulate the external wind environment, and the planetary gear transmission planetary gear crack fault diagnosis and testing experiments were performed. The frequency domain signal is obtained from the initial time domain signal obtained by the experiment through the EMD and envelope demodulation method. The frequency of the corresponding planetary gear crack in the frequency domain signal is compared with the theoretical calculation of the planetary gear crack failure frequency. The results show that the frequency of the corresponding planetary gear cracks in the frequency domain spectra obtained by the experiment is basically consistent with the theoretical calculation of the frequency of cracks in planetary gears. The fault diagnosis system developed by LabView is reliable. The experiment provides a theoretical basis for fault diagnosis, optimisation design, and life prediction of wind turbine planetary transmissions.

## 1 Introduction

The virtual instrument is a product of deep-level combination of modern computer technology and instrument technology. It is an effective combination of hardware resources of computer, instrument, and measurement and control system, and virtual instrument software resources [1]. The data acquisition card is an indispensable hardware for virtual instrument testing. The outside signal needs to be collected by it. After a series of signal conditioning, it is input to the virtual instrument testing system. LabView uses a graphical language, the interface operation is simple, friendly, and intuitive, and the LabView-designed virtual instrument can be used without the LabView development environment. The end user sees an operation panel similar to the actual hardware instrument [2–9]. Planetary gears inside a wind turbine planetary transmission are widely used in various industrial fields [10, 11] because of their compact structure and strong bearing capacity.

In the mid-1980s, NI Corporation of America first proposed the concept of virtual instrument and introduced LabView, a graphical software development platform. As it is for engineers rather than professional programmers, the human–computer interaction interface is very friendly and the programming is easy to learn. In recent years, LabView has been rapidly promoted in China's testing technology and education. Data acquisition cards can be divided into two categories: One is provided by National Instruments and National Instruments offers hundreds of drivers. LabView supports such capture cards. Therefore, no special driver is required to use this type of data acquisition card to acquire data in the LabView environment; the other type is the non-NI data acquisition card. LabView does not support, you need to write the corresponding driver to be identified by LabView, so as to complete the data acquisition jobs.

Here, we use the NI9171 acquisition card combined with the wind turbine planetary transmission test bed and the LabView developed wind turbine planetary transmission fault diagnosis system to realise the acquisition of the fault signal of the planetary gear transmission planetary gear crack. After the adaptive envelope demodulation of the acquired time domain spectrum, the planetary gear fault frequency in the frequency domain map was obtained. At the same time, the fault frequency of the planetary gear cracks was theoretically calculated. The two kinds of fault frequency data were compared and the development based on LabView was obtained. The wind turbine planetary transmission fault diagnosis system has reliable conclusions.

## 2 Method and principle

### 2.1 Planetary gear train fault characteristic frequency analysis

Gear faults are generally divided into distributed faults and partial faults, and gear crack faults are local faults. The ring gear is fixed, the planet carrier, the sun gear, and the planet gear are rotated, and the corresponding meshing frequency is

\[
f_m = f_{Z_r} = (f_{m}^s - f_{c}Z_s)
\]

In the above formulae, \(Z_{r}\) and \(Z_{s}\) are the numbers of teeth of the ring gear and the sun gear. \(f_{c}\) is the rotation frequency of the planet carrier, and \(f_{m}^s\) is the absolute rotation frequency of the sun gear.

When the sun gear teeth crack, during its rotation, the fault gear meshes with both the inner ring gear and the sun gear, and an impact occurs. If the two impact amplitudes are different, the fault feature frequency is

\[
f_{ss} = \frac{f_m}{Z_{s}}N
\]

In the above formula, \(N\) is the number of planets and \(N\) is 3.

When the planetary gears are partially damaged, the faulty gears simultaneously mesh with the ring gear and the sun gear during the rotation of the planetary gears. If the two impact amplitudes are different, the fault feature frequency is

\[
f_{pp} = \frac{f_m}{Z_{p}}\]

In the above formula, \(Z_{p}\) is the number of teeth of the planetary gear.
Here, the time domain signal collected by LabView is converted into the required frequency domain signal through EMD and envelope demodulation method, and the frequency of the planetary gear crack failure frequency required by the experiment is obtained through the frequency domain signal.

EMD is an adaptive time-frequency analysis method that is particularly suitable for non-linear, non-stationary signal analysis and also for linear and stationary signal analysis. Especially for the analysis of linear and stationary signals, the physical meaning of signals can be better reflected than other time-frequency analysis methods. The essence of the EMD method is to smooth the signal and gradually break down the fluctuations and trends of the signals in different scales to generate a series of data sequences with different characteristic dimensions. Each sequence is an IMF component. When dealing with bearing fault signals, it is necessary to perform demodulation processing. The principle of demodulation is to obtain the envelope of the signal through Hilbert transform. The Hilbert transform consists of shifting the phase of the test signal by 90°, and then composing the signal after moving the phase and the original signal to form a parsed signal is the sought envelope signal [12–14].

2.3 System development and process

LabView laboratory virtual instrument engineering platform is a G-based laboratory virtual instrument integrated software development tool introduced by NI company. It utilises the powerful functions of computer system and the corresponding hardware to greatly break traditional instruments in data processing and display. It has great advantages in data storage and system maintenance and expansion. Fig. 1 shows the test parameter setting interface written by LabView.

The basic parameter setting interface (Fig. 1) contains two parts: file parameters and sampling settings. The file parameters need to set the name of the test, the storage path, and the test group number and test object. Sampling settings need to set the sampling frequency, experimental conditions, and sampling mode.

Fig. 2 shows the LabView collection acquisition interface. The data acquisition system is based on a computer or other dedicated test platform to collect non-electricity or electric signals from sensors or other devices under test, and send them to the upper computer for analysis, processing etc. to achieve convenient and intuitive measurements. In the system, we use the NI9171 acquisition card to integrate the LabView language for frequency domain signal acquisition.

3 Experimental process

The wind turbine planetary transmission test bed is mainly composed of a motor, a torque power meter, a rotary torque sensor, acquisition analysis software, a planetary gear box, and a brake. Its system layout and field test bench are shown in Fig. 3.

1. servo motor; 2. torque sensor; 3. gear box; 4. brakes; 5. conditioning circuit and acquisition card; 6. PC acquisition software; and 7. torque sensor

The AC servo motor is used to provide power, the vibration acceleration sensor is used to measure the vibration signal of the planetary gear box, the rotary torque sensor is used to measure the speed and torque, and the torque meter is used to display the speed and torque and power parameters. Magnetic powder brake is used as the load of the planetary gear box to be measured, and its size can be changed by changing the input current of the magnetic powder brake. The experimental steps are as follows:

(i) First check whether the connection between each sensor and the device is normal, and recalibrate the vibration acceleration sensor.
(ii) Connect the acquisition card with the host computer software, and set the initial test parameters, check whether the acquisition card and the host computer software communication is normal, and observe the oscillographic data are correct.
(iii) Planetary gearboxes under normal conditions collect multiple sets of test data from low-to-high speeds, from low-to-high loads.
(iv) Repeat steps (1) and (2) to perform planetary gearboxes with planetary gear failure from low-to-high speeds, and collect multiple sets of test data from low-to-high loads in sequence.

4 Experimental results

The basic parameters of the wind turbine planetary transmission are shown in Table 1. The sampling frequency was 15.6 kHz, the sampling time was 5 s, and the input shaft rotation speed was 1140, 1500, and 1860 rpm, respectively. The vibration signals collected at three different input speeds were analysed and studied. According to the parameters of each gear, the meshing frequency of the gearbox and the frequency conversion of each component at three different input speeds were calculated as shown in Table 2. By formula (1)–(4), the characteristic frequencies of the sun gear at three different input speeds are calculated as shown in Table 2.
Table 1 Basic parameters of a wind turbine

| Gear | z  | M, mm | α(°) |
|------|----|-------|------|
| s    | 18 | 0.5   | 20   |
| p    | 44 | 0.5   | 20   |
| r    | 108| 0.5   | 20   |

Table 2 Frequency of gears, meshing frequency and failure frequency of planetary gears

| Rotating speed/rpm | 1140 | 1500 | 1860 |
|--------------------|------|------|------|
| f_p/HZ             | 293.1| 385.7| 478.3|
| f_m/HZ             | 19   | 25   | 31   |
| f_c/HZ             | 7.8  | 10.2 | 12.7 |
| f_c/HZ             | 2.7  | 3.6  | 4.4  |
| f_pf/HZ            | 6.7  | 8.8  | 10.9 |

Diagnosis experiments. The experimentally acquired planetary gear tooth crack fault time domain signals are processed by EMD and envelope demodulation methods to obtain frequency domain signals such as Figs. 4a–c. The marked points in the figure are the corresponding coordinates of the planet gear failure frequency.

5 Conclusion

In this article, LabView was used to develop a wind turbine planetary transmission fault diagnosis system, and a wind turbine planetary transmission test bed was combined with an NI9171 data acquisition card and an on-board computer to diagnose and detect planetary gear cracks in wind turbine planetary transmissions. Domain signals are processed via EMD and envelope demodulation methods to obtain frequency domain signals. The frequency of planetary gear cracks is calculated theoretically, and the results are compared with experimentally obtained planetary gear cracks. The results show that the wind turbine planetary transmission fault diagnosis system developed by LabView is reliable. LabView as the most representative graphical programming language in the development of virtual instruments is one of the most widely used data acquisition and control development environments in the world [15]. It replaces the traditional program code with icons, wiring, and block diagrams, and can easily diagnose and detect wind turbine planetary transmissions through the operation of the instrument software.

6 Acknowledgments

This study was partially supported by the Science Funds of the Beijing Key Laboratory on Measurement and Control of Mechanical and Electrical System (KF20181123305), scientific research project of Beijing Municipal Education Commission (KM201811232023).

7 References

[1] Hu, J.K., Lu, R.: ‘LabView-based mine gas remote monitoring system’, Ind. Min. Autom., 2007, (2), pp. 64–66
[2] BISHOPRH.: ‘Labview practical tutorial’ (Publishing House of Electronics Industry, Beijing, China, 2005)
[3] Wang, J.Z., Huang, L., Wang, H., et al.: ‘LabView-based ‘marius law verification’ experiment’, Univ. Phys. Exp., 2011, 24, (4), pp. 66–69
[4] Liu, K., Zhou, X.L., Wang, D. Z., et al.: ‘Virtual experiment design of university physics based on LabVIEW’, Univ. Phys. Exp., 2011, 24, (6), pp. 81–85
[5] Sheng, Er.N., Zhang, Z.G.: ‘LabView-based research on a portable rotary machinery fault diagnosis system’, Coal Mine Mach., 2012, 33, (7), pp. 251–253
[6] Feng, Z.Y., Zhang, Z.Q., Xu, Y.H., et al.: ‘Based on LabView implementation of satellite RF components intelligent detection system’, Modern Electron. Technol., 2012, 35, (13), pp. 128–137
[7] Zhou, H.X., Zhou, Y.P., Wang, Y.: ‘Using the autocorrelation method to measure the lateral velocity’, Phys. Exp., 2012, 32, (53), pp. 6–8
[8] Liu, Y.F.: ‘The realization of lissajous graphics based on LabView software’, Univ. Phys. Exp., 2009, 22, (1), pp. 97–99
[9] Zhang, Z.R., Yu, X.H., Zhang, S., et al.: ‘LabView-based oxygen concentration real-time online monitoring system software design’, J. Atmospheric Environ. Opt., 2008, 3, (6), pp. 454–460
[10] Sun, Z.M., Ji, L.H., Shen, Y.W.: ‘Nonlinear dynamics of 2K-H planetary gears’, J. Tonghua Univ. Sci. Technol., 2003, 43, (5), pp. 636–639
[11] Sun, T., Shen, Y.W., Sun, Z.M., et al.: ‘Nonlinear dynamic model and equation of planetary gear transmission’, Mech. Eng. News, 2002, 38, (3), pp. 6–10
[12] Luo, J.S., Yu, D.J., Peng, F.Q., et al.: ‘Multi-scale morphological demodulation method based on EMD and its application in mechanical fault diagnosis’, J. Vib. Shock, 2009, 28, (11), pp. 84–86
[13] Zhu, H.M.: ‘Research on fault diagnosis method of rolling bearing based on EMD and resonance demodulation’, Shanghai Normal University, Shanghai, 2011
[14] Guo, Q., Li, L.M., Meng, Q.F.: ‘EMD trend analysis method and its application’, J. Vib. Shock, 2007, 26, (8), pp. 98–100
[15] Yang, L.P., Li, H.T., Zhao, Y., et al.: ‘LabVIEW advanced programming’ (Tsinghua University Press, Beijing, China, 2003)