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Fault simulation platform of gear transmission system based on Labview

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Abstract. The feature signals of gear fault are often covered with the vibration signals of various machine and heavy noise environment. Hence it is difficult to extract some feature signals of the early gear faults. To overcome this problem, a test platform of gear transmission system is proposed to simulate vibration signals of the faults including gear wear and tooth breakage. Some vibration signals of gear transmission with and without faults for different speeds and loads can also be acquired. The test platform can provide a good foundation for the fault diagnosis of the geared system in the later stage work.

1. Introduction

As a very important device in almost all rotating machinery, gearbox is applied to transmit or arrange power as per the process need. For the purpose of simulation and vibration-based condition monitoring of a geared system, it is crucial to monitor the gear condition based on solid knowledge about the fault mechanism [1]. Owing to the complicated structure, harsh operation environment, and flexible excitations, the geared system is prone to damage to some degree [2]. In case of a sudden change in operating conditions such as excessive load, inadequate lubrication, local non-homogeneity of material quality [3], gear tooth may suffer from bending fatigue damage which can eventually result in gear tooth breakage in the tooth root.

Many scholars have carried out lots of experimental research on the gear fault diagnosis. In [4], a test rig based on a 5.5 kW wound rotor induction generator, shaft connected to the planetary gear through a high-speed shaft and couplings, was utilized for validation of the tooth localized fault detection. In [5], vibration signals of normal gear, gear with tooth root crack, chipped tooth in width or length, missing tooth and surface wear were collected in different speed and load conditions. In [6], frequency domain averaging of intrinsic mode functions after their dynamic time warping was done to perform fault diagnosis of a gearbox for fluctuating speeds. In [7], frequency responses of the gear pair in healthy state and those suffering from different faults were analysed based on the dynamic equations of a single-stage gear pair. In [8], the fault symptoms generated by a single cracked tooth of the planet gear was extracted, and the health condition of the planet gear was assessed by comparing the differences among the signals of all teeth of the planet gear. To effectively diagnose gear failure at an early stage, a multi-order fractional Fourier transform self-adaptive filter based on segmental frequency fitting was proposed to separate the feature components with curved frequency from the gearbox's transient conditions in [9].

Gear fault diagnosis relies heavily on the scrutiny of vibration responses measured. In reality, gear vibration signals are noisy and dominated by meshing frequencies as well as their harmonics, which



oftentimes overlay the fault related components [10]. In order to study the influence of gear faults on gear vibration signal characteristics, a set of gear fault test-bed is developed to simulate vibration signals of the gear wear and tooth breakage. Based on the platform, some simulation experiments can be carried out to lay the foundation of fault diagnosis for the typical gear system.

2. Test platform of gear transmission system

Figure 1 displays the structure of the experimental system used in this study. The test rig is composed with a gearbox, an AC motor, two coupling, a magnetic brake, a data acquisition system (DAS) and other accessorial components. The AC motor is driven by an inverter whose output frequency is 0~300 Hz. The rated power of motor is 0.75 kW, and the rotating speed can be adjusted manually from 0 to 1500 rpm. The load is provided by the magnetic powder clutch brake connected to the output shaft, and the output torque can also be adjusted from 0 to 5 N·m by a brake controller. There are two shafts inside the gearbox, which are mounted to the gearbox housing by four rolling bearings. The teeth number of pinion and gear are 55 and 75 respectively, and the bearing specs is N205.

The DAS mainly consists of four piezoelectric acceleration sensors, a data acquisition card-USB-4716 and analysis software running on windows. Four piezoelectric acceleration sensors, FYC-SD-02, are used for acquisition of vertical displacement data of rolling bearings on driving shaft and driven shaft which are mounted on the outer case of gearbox, in which they are powered by 24 V DC voltage source provided by switching power supply. The DAS card-USB-4716 powered by bus is produced, which has powerful functions on module of data acquisition and is suitable for USB interface.

The acceleration sensors are connected to channels (0–15) of the data acquisition system, in which the maximum sampling frequency can be achieved to 200 K S/s. For convenience, two kinds of fault types including gear wear and gear tooth breakages are researched under a no-load condition, while keeping motor speed 1000 rpm, and the sampling frequency is 5120 Hz.

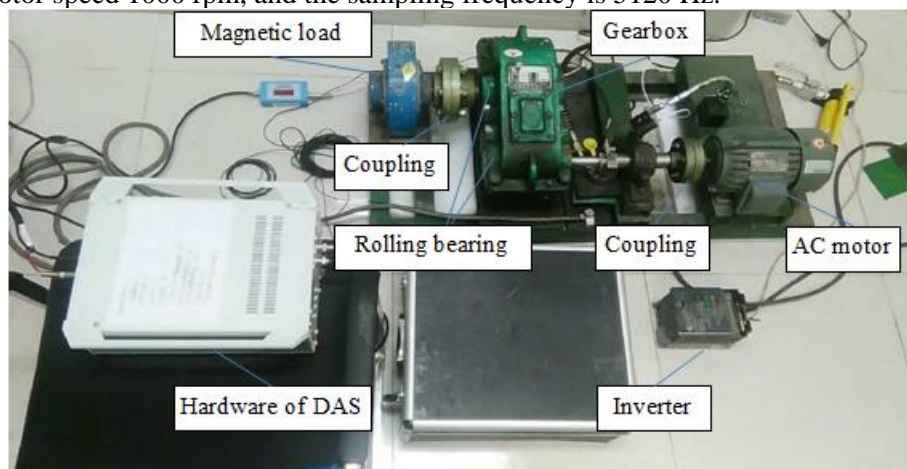


Figure 1. Structure of the test platform of gear transmission.

3. Data acquisition based on Labview

Labview is system engineering software designed for testing, measuring and controlling applications. It can access hardware and data information quickly. Labview provides graphical programming methods to help user visualize various aspects of applications. This visualization can help users easily integrate any supplier's measurement hardware, display complex logic, develop data analysis algorithms, and design a self-defined engineering user interface.

In this study, two programs are written based on polymorphic VIs which can be offered by Advantech DAS card to save and display the datum. The front panel and block diagram of the programs are shown in figures 2-5, respectively.

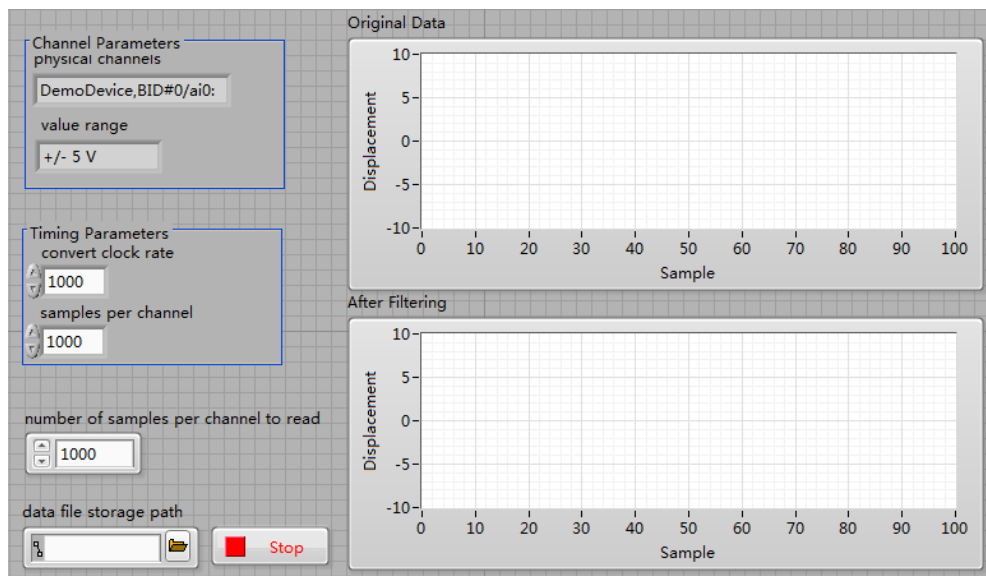


Figure 2. The front panel of the data acquisition program.

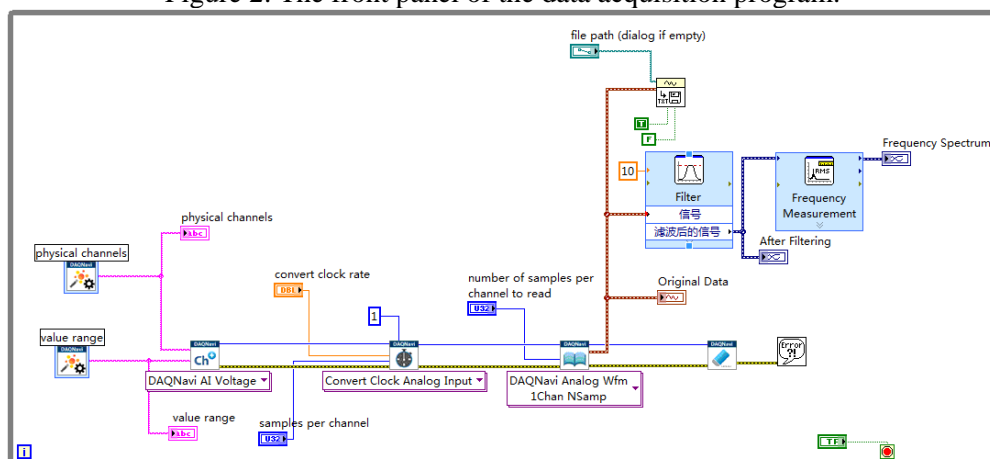


Figure 3. The block diagram of the data acquisition program.

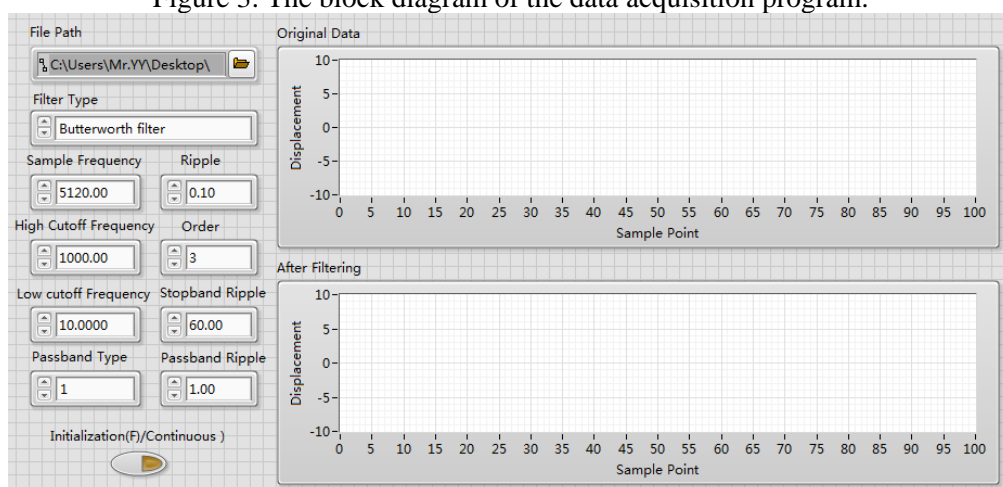


Figure 4. The front panel of the data display program.

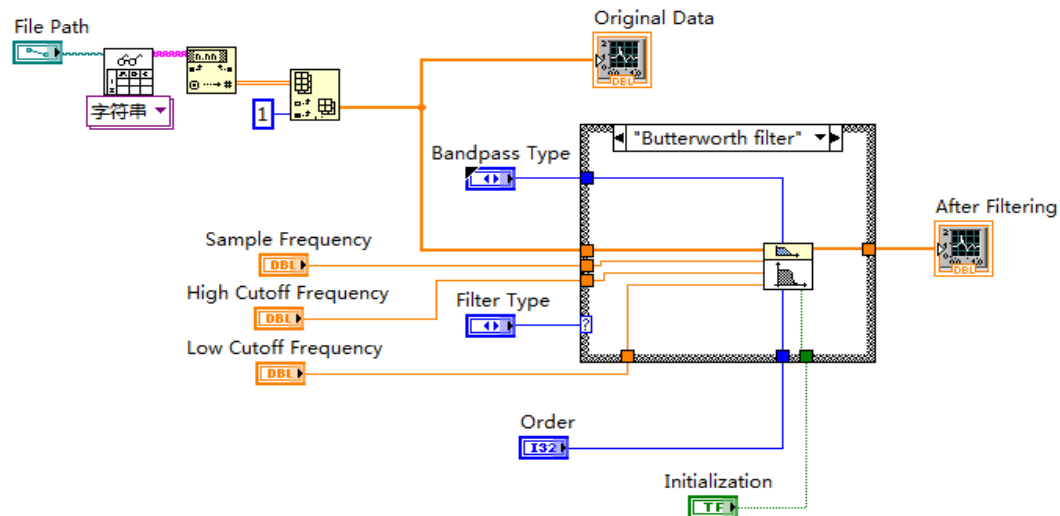
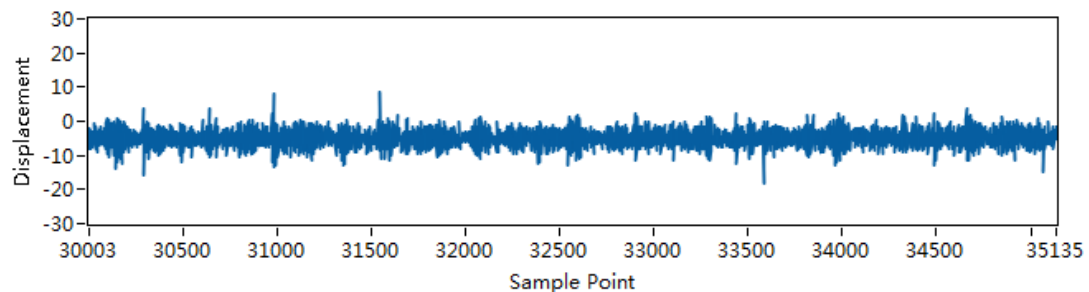
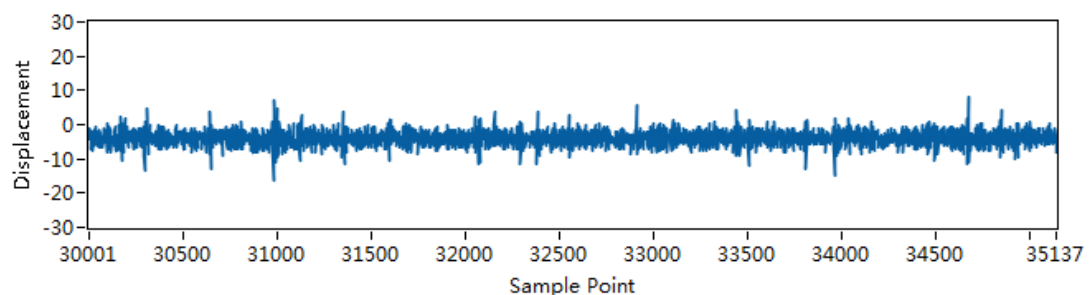


Figure 5. The block diagram of the data display program.

When the gearbox is operating with different states, the vibration signals will present different stationary characteristics. In the present work, the horizontal and vertical displacements are continuously acquired by accelerometers mounted on the outer case of the proposed gearbox. As mentioned above, the gearbox is operating under a no-load condition, while keeping motor speed 1000 rpm. All the vibration signals are processed through low-pass filters with cut-off frequency domain ranging from 100 Hz to 20 kHz. Figures 6-8 depict the sampled signals with three states, including gear health, gear wear and gear tooth breakage. Similarly, some vibration signals of gear transmission with and without faults for different speeds and loads can also be acquired.

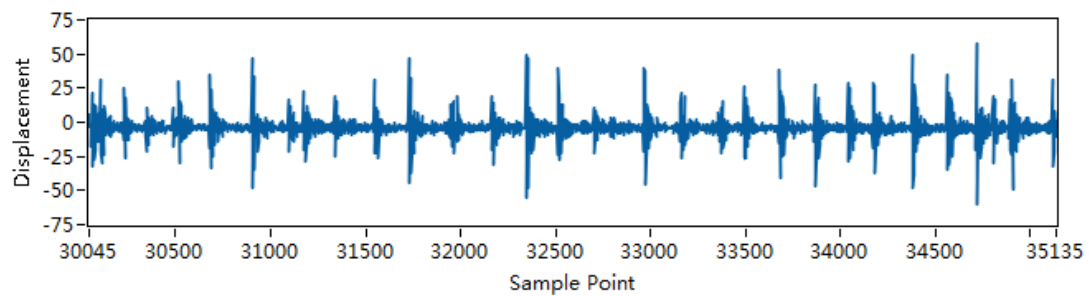


(a)

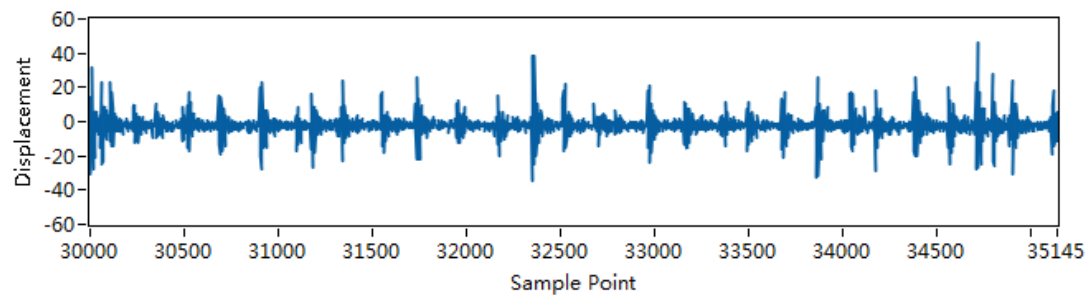


(b)

Figure 6. Sampled signals of the displacement with health gear. (a) Horizontal displacement. (b) Vertical displacement.

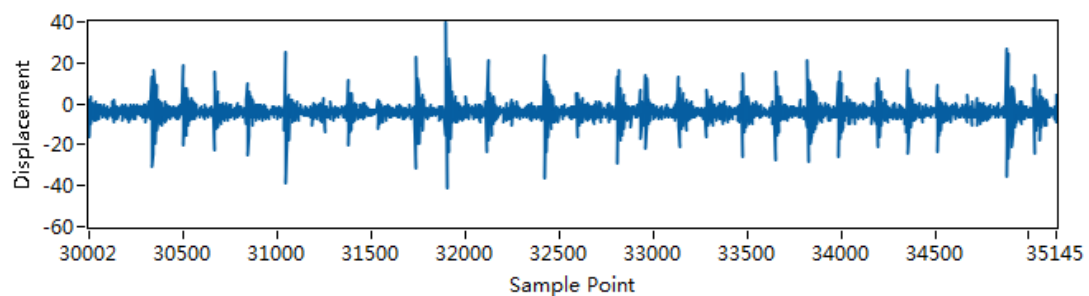


(a)

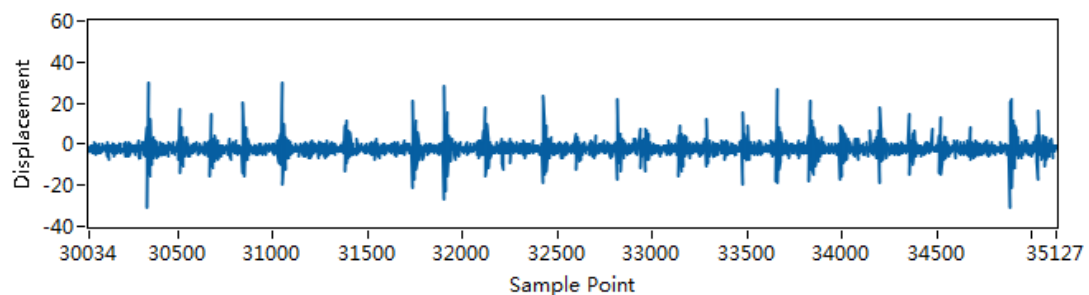


(b)

Figure 7. Sampled signals of the displacement with gear wear. (a) Horizontal displacement. (b) Vertical displacement.



(a)



(b)

Figure 8. Sampled signals of the displacement with gear tooth breakage. (a) Horizontal displacement. (b) Vertical displacement.

4. Conclusions

In order to study the influence of gearbox faults on gear vibration signal characteristics, a set of gear fault test-bed is developed to simulate vibration signals of the gear wear and gear tooth breakage. Based on the test platform, other simulation experiments such as gear surface pitting, bearing outer race nick, and bearing inner race nick, can also be carried out.

According to the simulated experimental datum, the characteristic database of gear faults signals in different conditions will be finally obtained. Therefore, the test platform will provide a good foundation of fault diagnosis for the typical gear system in the future research.

Acknowledgments

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