Development of Railway Bridge Deflection Detection System Based on NI-cDAQ Inclinometer

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Abstract. Aiming at the limitation of the traditional deflection test method by the field application of railway bridge inspection, the paper develops a data acquisition and analysis system for bridge deflection inspection. The system is based on NI-cDAQ series acquisition equipment and the LabVIEW programming software development environment. Through the industrial Modbus bus protocol, it is possible to integrate the inclinometer, data acquisition equipment and other hardware acquisition equipment with the application software through the computer, and establish a complete set of practical instrument equipment and dynamic deflection detection process to achieve high speed, high precision and multi-channel acquisition Bridge deflection information. Combined with field tests for verification, the results show that the real-time collection and transmission of various parameters of the system can run for a long time under complex field conditions, with stable work and reliable data.

1. Introduction
With the rapid development of my country's railway transportation industry, bridge management and maintenance work is becoming more and more onerous. Due to the influence of factors such as climate, oxidation and construction, the strength and stiffness of bridges are increasingly reduced. This not only reduces the safety of bridge use, but also shortens it. The service life of the bridge[1], so the research on railway bridge inspection is of great significance. At present, viaducts are the main form of high-speed railway lines. As trains increase in speed, the dynamic interaction effect between high-speed trains and bridges becomes more obvious, so that the norms control the vertical deformation of bridge structure erection deflection and beam end corners and other vertical deformations more strictly [2]

Traditional deflection testing methods mainly include: cable displacement meter method, level or total station direct measurement method, camera method, laser method, radar interferometry, etc. On the one hand, the direct measurement method of cable displacement meter, level or total station will be restricted by the environment in the measurement process, and the measurement results are not satisfactory. On the other hand, such as camera method, laser method, radar interferometry, etc., the high cost and cost are not conducive to equipment maintenance and long-term use. Based on the combination of hardware acquisition results and the application of the software system, this paper establishes a bridge deflection detection and monitoring platform, and uses the inclination method[3-4] to analyse and process the detection content, which is beneficial to improve the real-time monitoring performance of the bridge.

The acquisition system is based on LabVIEW development environment, equipped with NI-cDAQ-9185 model acquisition board and inclinometer sensor to realize the bridge deflection field detection test. In addition, the system has high sampling accuracy and fast sampling rate, which is suitable for long-term monitoring in harsh environments. The man-machine interface is simple and the operation is simple, which greatly facilitates the use of on-site staff.
2. System Overall Scheme Design
This article chooses CompactDAQ as the hardware core platform design. In the CompactDAQ system, the chassis is connected to the PC via Ethernet, and one or more conditioning I/O modules can be inserted into the chassis to directly connect the sensor. According to requirements, multiple CompactDAQ chassis can be synchronized to build a distributed system. The CompactDAQ controller provides multiple models, which can run Windows systems or real-time operating systems to achieve independent operation[5], which makes the development work flexible.

The principle block diagram of the bridge deflection detection system equipment is shown in Figure 1, which is mainly composed of two parts, an embedded hardware platform and software acquisition. The hardware platform includes acquisition modules, high-performance embedded chassis, controllers and power supply units, etc., which provide stable and reliable hardware support for upper-layer acquisition applications. The data transmission adopts the industry standard Modbus bus protocol to ensure the reliability of data transmission and the easy expandability of the equipment. Carry on the corresponding configuration in LabVIEW, establish the shared variable and the register binding that Modbus stipulates, thus realize the free communication based on Modbus agreement[6]. The software acquisition part includes: communication module, signal analysis and processing, data storage management and Labview basic functions. Mainly realized functions: (1) Control the acquisition module to realize high-speed data acquisition; (2) Transform the physical quantity information of the different cross-section angles of the bridge obtained by the inclinometer test into analog quantities; (3) Perform data localization based on online data analysis and processing Operations such as storage and data transmission.

![Figure 1. Overall schematic diagram of system equipment](image)

3. System Hardware Scheme Design
3.1. Inclinometer
The inclinometer is mainly selected according to the range, accuracy, frequency range, resolution, zero drift and use environment. In this paper, considering the above factors, the QY-II inclinometer is selected in the system, and its performance indicators are shown in Table 1.

| Parameter                  | Index       |
|----------------------------|-------------|
| Range                      | 0.5°        |
| Accuracy                   | 0.02%       |
| Frequency                  | range 0~2Hz |
| Resolution                 | 0.00001°    |
| Zero temperature drift     | 30 minutes ≤ 0.2 seconds |
| Use environment            | Use environment -40~50°C; humidity≤85% |
3.2. Power Supply Unit

Since the power supply of the inclinometer sensor is DC 5V, the power supply of the acquisition device is 24V. Therefore, in the design process, the 220V voltage is converted by the power adapter and connected to the power supply module of the sensor. As the picture shows:

![Figure 2. Power supply unit structure diagram](image)

3.3. Data Acquisition Equipment

What the article chooses is the 9185 type acquisition card of NI's cDAQ series (Figure 3). This device provides close time synchronization with TSN, which can simplify and improve the scalability of synchronized and distributed systems. Its features and advantages include:

![Figure 3. NI-cDAQ-9185 data acquisition instrument](image)

![Figure 4. Acquisition module](image)

![Figure 5. Data acquisition card work flow chart](image)

The data acquisition process of this system can be simplified as shown in Figure 5: Because the physical quantities in nature are mostly analog quantities that continuously change in time and amplitude, and the information processing is mostly realized by digital computers, and the processing results are it is often necessary to "feed back" to the external physical system in the form of an analog quantity, so the problem of sampling and reconstruction processing is involved. Convert analog and digital quantities (analog to digital conversion) [7].

The scope of railway data collection is basically concentrated near the line, and the vertical range of the railway line can reach hundreds or even thousands of kilometers. This collection device uses the Ethernet interface to support long-distance wireless transmission and can adapt to the requirements of the railway bridge site. In addition, it is small in size, convenient to carry, easy to operate, and suitable for collection and test work on industrial sites.
4. System Software Scheme Design
The bridge deflection detection system is based on the LabVIEW development environment, which is the core of the NI design platform and an ideal choice for developing measurement or control systems. The LabVIEW development environment integrates all the tools required by engineers and scientists to quickly build various applications. It aims to help engineers and scientists solve problems, improve productivity, and continue to innovate[8]. It has the characteristics of simple operation and fast development speed.

![System software function diagram](Figure 6)

As shown in Figure 6, when the system software is running, it is necessary to set parameters first, and then perform subsequent operations based on the read data: data processing, local storage of data, online data analysis and processing, and data transmission. All software is developed based on the LabVIEW2017 platform, and the program is released and deployed through the network port.

![Structure diagram of bridge deflection detection system](Figure 7)

The software design part of the system is shown in Figure 7, which is mainly divided into five modules: parameter setting, data acquisition, data playback and storage, and signal analysis and processing. In the data playback function, a three-dimensional deflection waterfall chart has been innovatively added to facilitate users to view the data results of bridge deflection detection more clearly and intuitively. The overall design of the program is shown in Figure 8.
Figure 8. The overall framework design of the program

(1) Data collection
The whole collection process uses DAQmx API function to realize the function of continuously collecting data. The front panel of the system can not only observe the original waveforms transmitted from the sensor to the computer, but also the deflection waveforms and three-dimensional waterfalls after data processing, which greatly facilitates users to monitor the status of the entire bridge and local key locations.

(2) Data playback
Taking into account that after the data collection process is over, the software needs to have the function of viewing the collected data files to ensure that the collected data is correct and usable. This function includes: original waveform display, deflection waveform display and three-dimensional deflection waterfall chart display.

(3) Data storage
There are two types of data storage in the bridge deflection detection system: parameter files and processed bridge deflection data at special locations. The former is stored in txt mode; the real-time collected waveform file data of the latter is stored in LabVIEW’s unique file storage mode.

(4) Signal processing
The module calculates the post-processing function of the bridge deflection based on the original data of the inclinometer, and can realize the operation of converting the original data into the bridge deflection information.

5. Deployment Application Situation
The bridge deflection detection system based on the above principles has been successfully deployed to a railway bridge site. The working range of the railway line is basically concentrated near the line, and the distance can reach hundreds or even thousands of kilometers. The data collection adopts a distributed arrangement and uses the industrial Modbus. Bus protocol network transmission data. After accumulating many times of uninterrupted operation of real-time collection, the equipment runs stably, and the collection accuracy and speed fully meet the requirements. The test test verifies the accuracy and reliability of the bridge deflection detection system and provides important data support basis for bridge health monitoring.
6. In Conclusion
The paper designs a bridge deflection detection system based on the LabVIEW programming software on the inclinometer, data acquisition equipment, and the test system is highly adaptable, reliable and convenient. It can meet the requirements of bridge static or quasi-static deflection test.

7. References
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