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Design and Research of Railway Spring Bar Buckle Pressure Measurement System Based on LabVIEW

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Abstract: In order to quickly measure the size of clamping force of elastic strip fastener, accelerate the realization of automated non-destructive testing research and development process, and improve the detection efficiency, this paper designs a railway elastic strip fastener clamping force measurement system based on LabVIEW. This study designed a measurement device of clamping force of railway elastic strip fastener on the basis of LabVIEW. After completing one knocking and detection, it can automatically move to the next fastener for knocking and detection, which greatly saves manpower and time, has strong adaptability to the working environment, and has a high degree of automation. The aim of this study is to significantly improve the efficiency and automation level of railway spring bar buckle pressure detection. A railway spring bar buckle pressure measurement system was designed using LabVIEW, providing strong technical support for the safe operation of high-speed railways.

1. Introduction

With the rapid development of high-speed railway networks, track safety has become a key area of concern in railway system design, maintenance, and operation. Especially ω as a key component to ensure track stability, the accurate measurement of the clamping pressure of the type of elastic strip fastener is of great significance for preventing track failures and ensuring safe train operation. However, traditional measurement methods often rely on complex operational processes and manual intervention, resulting in low efficiency and susceptibility to subjective factors, making it difficult to meet the high efficiency and precision requirements of high-speed railway operation and maintenance.

In recent years, technological progress has provided new solutions for measuring the pressure of railway fasteners. Wang Limin et al. proposed a method by utilizing the correlation between structural stress and natural frequency ω. The hammering measurement method for the buckle pressure of the type of elastic strip fastener, which determines the buckle pressure by hammering the fastener and analyzing its vibration response, has shown good experimental results and application potential[1]. In addition, Yu Zheqi et al.'s research explored the applicability of laser measurement technology in high-speed railway buckle pressure detection, demonstrating the method of indirectly determining buckle pressure by accurately measuring the height difference of fasteners, which not only improves measurement accuracy but also simplifies the operation process[2-4].

Although these studies have made significant progress in improving the accuracy and efficiency of railway buckle pressure measurement[5], they still face challenges in achieving comprehensive automated non-destructive testing, reducing labor costs, and adapting to complex working environments[6]. The device was combined with COMSOL finite element simulation software for modal analysis, and the accuracy of the measurement method was verified through a combination of theory and experiment.

2. System Structure and Working Principles

2.1 The structure of BP neural network

The research and design scheme of the railway spring bar buckle pressure measurement system based on LabVIEW is mainly divided into three sections: the impact excitation section, the measurement section, and the automatic travel section, as shown in Fig.1.

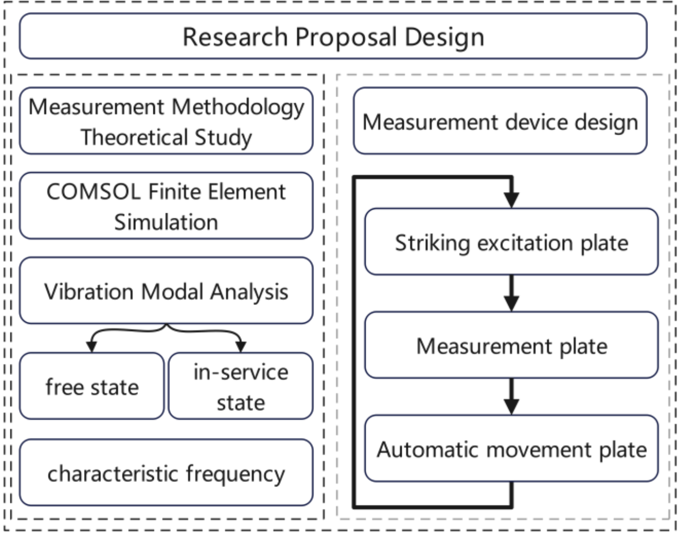

Figure 1: Design of rough research plan

The system sends signals through the NI-USB-6001 data acquisition card to move the entire device. After reaching the designated position, the acquisition card drives the tapping device to complete a single excitation[7]. The vibration sensor in the measurement plate detects the vibration signal and transmits it to the acquisition card for analysis and processing, obtaining the characteristic frequency of the spring bar. Measure a spring bar as a cycle, and the device will automatically move after it starts working. It will work continuously in cycles of "travel knock detection".

3. Hardware design of measurement system

The hardware design and implementation of the entire measurement system are divided into three sections, namely the impact excitation section, the measurement section, and the automatic travel section.

3.1 Design of striking vibration plates

The striking vibration plate is composed of a data acquisition card, an optical isolation device, an Hbridge, a motor, an infrared sensor, and an adjustable excitation striking device. The NI-USB-6001 data acquisition card sends a signal to the Hbridge, which drives the motor to work[8]. The motor drives the striking device and vibration sensor to descend through gear and rack meshing. The infrared sensor controls the descending height, and the adjustable excitation striking device works to complete a single independent striking. The design of the striking vibration plate is shown in Fig.2.

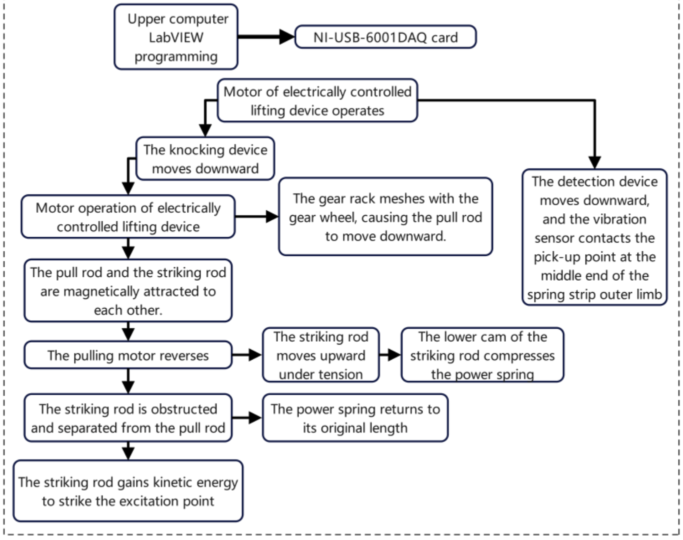

Figure 2: Hardware Design of Knocking Vibration Plate

The percussion excitation plate is centered around an adjustable excitation percussion device. Therefore, we have independently developed a highly automated percussion device, mainly used as a percussion device for measuring the pressure of the spring bar buckle using the percussion method. As shown in Fig.3.

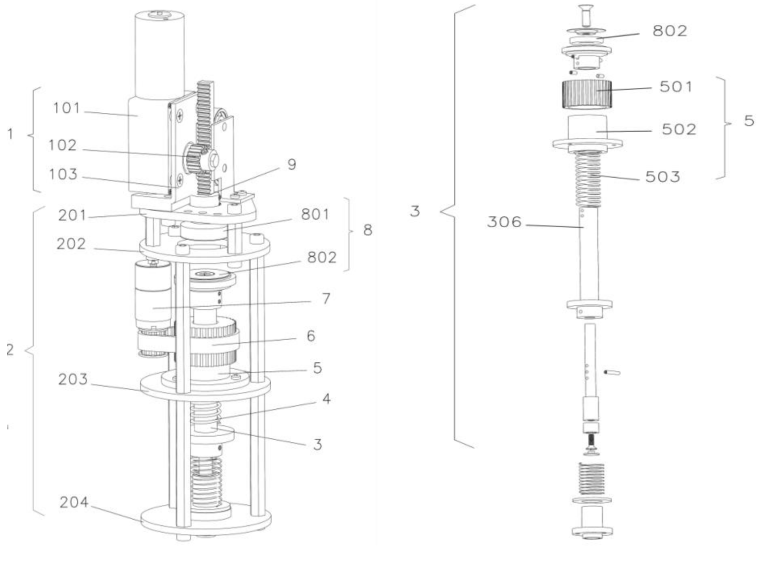

Figure 3: Overall schematic diagram of adjustable excitation tapping device (left) and structural diagram of tapping rod (right)

The movement of the traction rod 9 is controlled by the meshing of the traction motor 101 gear and rack in the traction section. The lower side of the traction rod 9 is equipped with a permanent magnet 8 on the upper side of the striking rod 3, while the second stage platform 202 can only allow the connecting traction rod 9 to pass through and cannot allow the striking rod 3 to pass through. The traction motor 101 controls the downward movement of the traction rod 9, which is connected to the striking rod 3 through a magnet and moves upward together. During the upward movement, the striking rod 3 compresses the power spring 4. After the traction rod 9 passes through the second platform 202 and the striking rod 3 is blocked and separated, the compressed power spring 4 will restore its original length and generate downward elastic force on the striking rod 3, thereby achieving the purpose of striking the railway spring bar.

Adjust the excitation size, and the elastic adjustment fixing threaded cylinder 502 in the elastic adjustment part 5 is fixed to the third stage platform 203 through screws. The elastic adjustment fixing threaded cylinder 502 is sleeved with a power spring 503, and the elastic adjustment fixing threaded cylinder 502 is threaded to the external elastic adjustment knob 501. The upper end of the power spring 503 is a flat surface that is tightly ground and pressed against the inside of the power adjustment knob 501; The elasticity adjustment knob 501 is similar to a bottle cap with a small opening at the upper end, and can be adjusted by tapping the barrel 306. The elastic adjustment knob 501 can be connected to the elastic adjustment motor 7 through the transmission belt 6[9-10]. When the elastic adjustment motor 7 rotates, it causes the elastic adjustment knob 501 to rotate. The elastic adjustment knob 501 is threaded to the elastic adjustment fixed threaded cylinder 502. The rotation of the elastic adjustment knob 501 can cause the elastic adjustment knob 501 to move up and down relative to the elastic adjustment fixed threaded cylinder 502, thereby changing the working length of the power spring 503, and then changing the compression amount of the power spring 503, changing the elastic potential energy, and changing the kinetic energy of the striking rod and the excitation size when the traction rod and the striking rod separate[11].

3.2 Design of measurement section

Automated LabVIEW simplifies programming steps through graphical programming and is more compatible with NI-USB-6001 data acquisition cards. Considering the compatibility between LabVIEW and NI-USB-6001 data acquisition card, this study mainly utilizes NI-USB-6001 data acquisition card and vibration sensor for data acquisition. The design principle of the measurement section is shown in Fig.4.

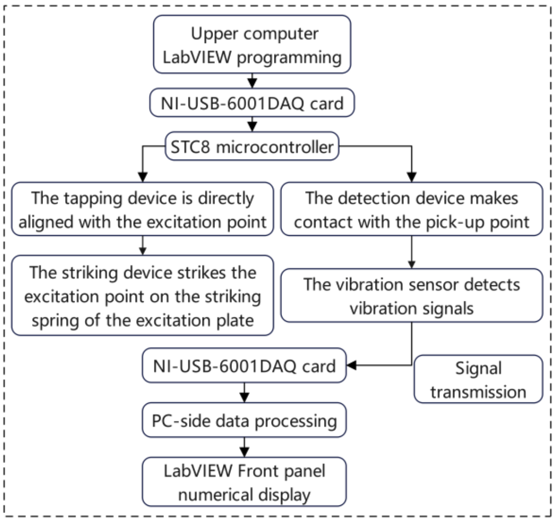

Figure 4: Hardware Design of Measurement Block

3.3 Design of Automatic Travel Block

The automatic travel plate is composed of several infrared distance sensors, travel wheels, etc. The design principle of the automatic moving plate is shown in Fig.5.

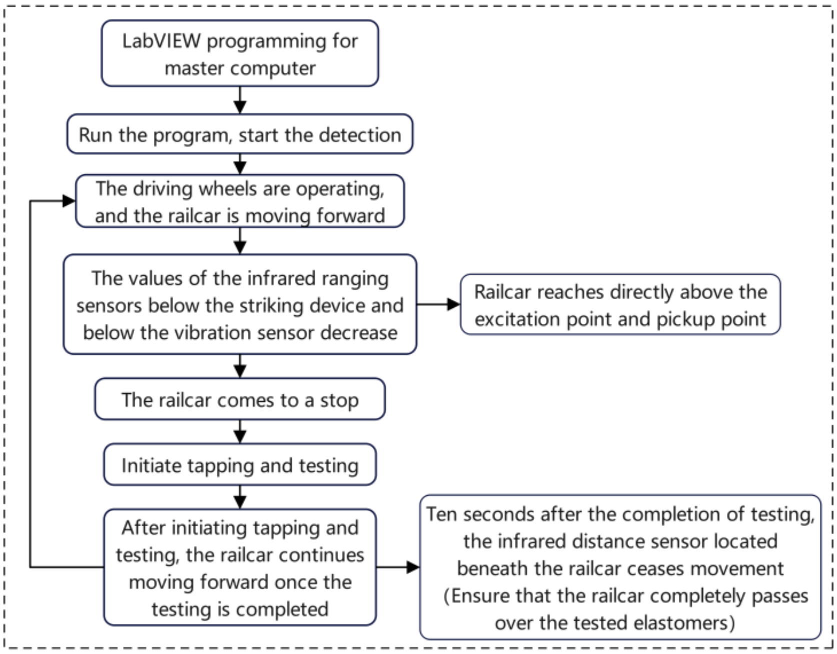

Figure 5: Hardware Design of Automatic Travel Block

4. System Software Design and Programming

LabVIEW simplifies programming steps through graphical programming and is more compatible with NI-USB-6001 data acquisition cards. The specific workflow diagram of the measuring device is shown in Fig.6.

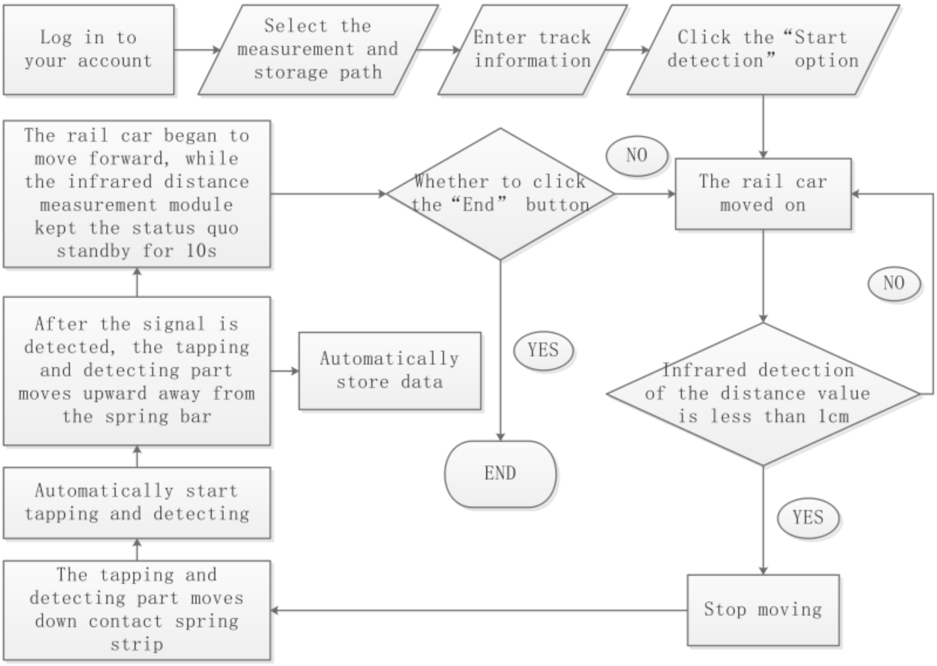

Figure 6: Schematic diagram of the specific working process of the device

The workflow diagram can be used for subsequent software design and implementation.

Write programs using LabVIEW programming software. The program diagram for exporting information from the rear panel during program runtime is shown in Fig.7, and the main program diagram is shown in Fig.8.

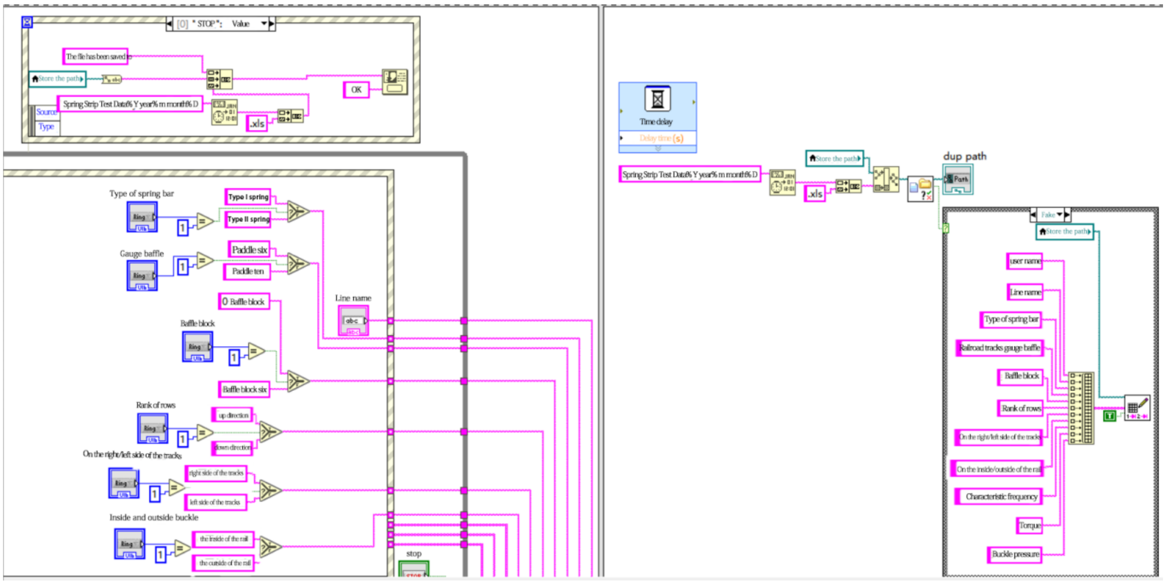

Figure 7: Information Export Program Block Diagram

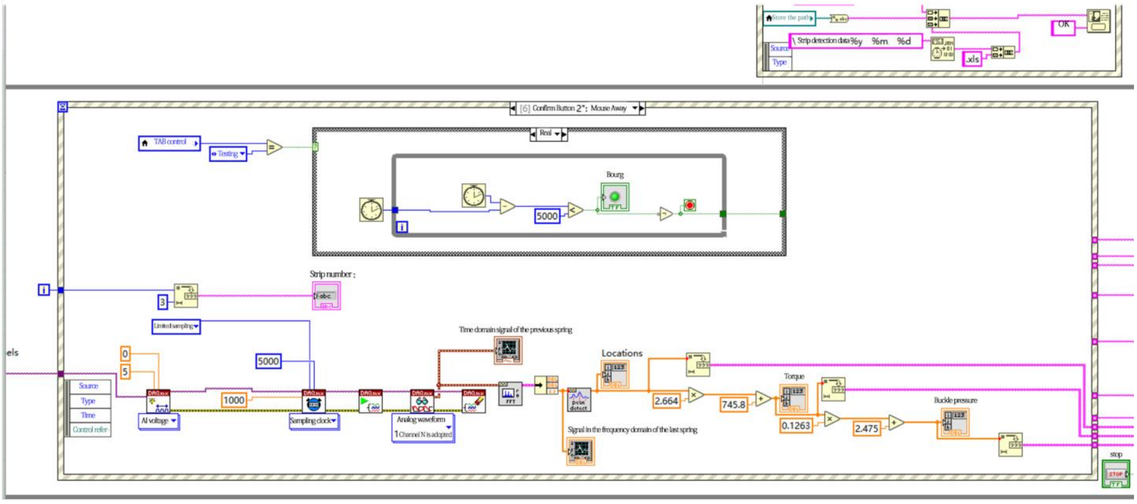

Figure 8: Main Program Block Diagram

5. Experimental Determination of Relationship Equation

5.1 Experimental conditions and environment

The experimental purpose is to find the relationship between the characteristic frequency, torque, and clamping force of the spring bar in service. The experimental equipment used is a torque wrench, a striking hammer, a railway spring bar fastening system, an electronic dynamometer, an accelerometer, and a NI-USB-6001 data acquisition card. The experimental plan is to determine the linear relationship between the buckle pressure, characteristic frequency, and bolt torque based on the results of finite element simulation. Apply a fixed torque of 112.3kN·m to the bolt on one side of the spring bar (No. 10 gauge baffle); Measure the characteristic frequency f and clamping force F on the other side under the change of bolt torque T (No. 6 gauge baffle). The experiment is shown in fig.9

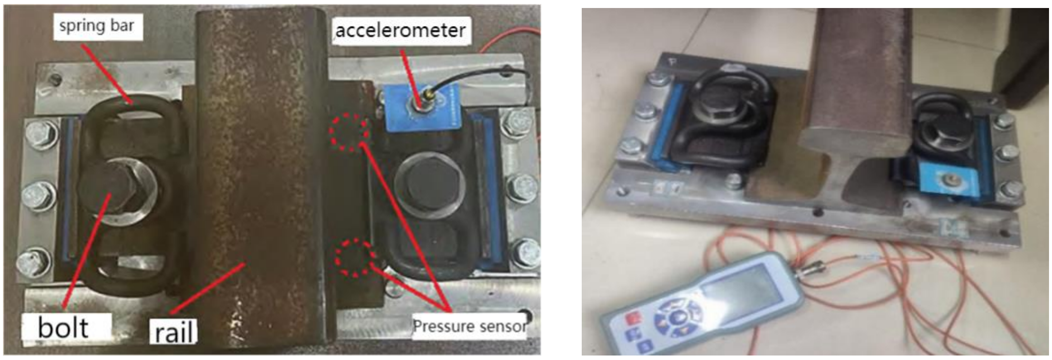

Figure 9: Experimental Site and Equipment

5.2 Data processing and analysis

Data processing and analysis are shown in Table 1.

Table 1: Record of experimental data on buckle pressure and torque

torque$T$(N·m)	Pressure sensor 1(kN)	Pressure sensor2(kN)	Buckle pressure$F$(kN)
65.8	4.712	1.325	6.037
70.1	4.989	1.466	6.455
77.8	5.294	1.864	7.158
80.3	5.625	2.222	7.847
88.6	6.081	2.648	8.729
102.4	6.833	3.340	10.173
110.0	7.385	3.865	11.25
119.1	7.835	4.277	12.112
125.6	8.616	5.015	13.631
132.8	9.155	5.555	14.71

Measure the torque using a torque wrench, and connect a data acquisition card to a sensor and a computer to record the characteristic frequency. The experimental data is shown in Table 2.

Table 2: Record of characteristic frequency and torque experimental data

torque$T$(N·m)	characteristic frequency$f$(Hz)
20.7	817.409
41.1	871.657
59.9	893.256
80.1	962.482
103.1	1025.751
121.5	1089.879

Using MATLAB to fit the data, the data analysis of characteristic frequency, torque, and torque shows that there is a roughly linear relationship between torque and torque, as well as between characteristic frequency and torque. There is a certain relationship between the three, and the formula for their relationship is:

$$F(T) = 0.1263T - 2.475 \tag{1}$$

$$f(T) = 2.664T + 745.8 \tag{2}$$

$$F(T) = 0.04741f - 32.883 \tag{3}$$

6. Conclusions

This article uses LabVIEW as the upper computer software development platform to design a highly automated railway spring bar buckle pressure measurement system. The lower computer of the railway spring bar buckle pressure measurement system uses vibration sensors to collect the vibration signal of the spring bar after excitation, and sends the data to the upper computer through the NI-USB-6001 data acquisition card. Utilize the powerful data processing capabilities of LabVIEW to store the detected bullet bar information and construct a database. This article presents a program idea for automated detection of spring bar buckle pressure based on the tapping method, which greatly reduces labor costs, especially for railway spring bar buckle pressure detection in harsh environmental road sections. The feasibility of the technology has been demonstrated through experiments.

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