Detection For Pavement Roller Compaction On Line Based On LABVIEW

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Abstract

Using the high performance data acquisition device, established the system hardware platform in the paper. Using the LabVIEW software development platform, combined with the corresponding driver, developed a set of data acquisition, testing, storage, analysis and display functions. The introduction of the correlation coefficient could display the degree of compaction in real time and be a timely reminder of the construction workers whether compaction meets the construction requirement. So it can effectively control the rolling times, consequently lessen the construction cost. The virtual test system has the advantages of simple operation, rapid, reliable operation and high precision.

Keywords: *Pavement roller; correlation coefficient；Compaction; LabVIEW; Detection on line*

1. Introduction

Now, the degree of compaction is the important indicator for quality control in filling construction. Its quality makes a significant influence on the roadbed and pavement. For this , to develop the degree of compaction is crucial for the road using performance and service life.

Water content, grain composition, composition of backfill soil sample, the thickness of rolled layer and the number of rolled passes are the key factors to compaction[1]. Therefore, how to control the number of rolled passes in a economic and efficient way is a key problem in the construction process. This paper proposes the detection system for pavement roller compaction on line based on LabVIEW, which can display the compaction in real time, consequently lessening the construction cost.

2. Theoretical analysis

2.1 "Vibratory roller-soil" Model

Vibratory compacting is a complex random process. So studying the mathematical model of the vibratory roller is necessary. Usually the "Vibratory roller-soil" Model can be simplified to a two degree of freedom system[2]. The model is shown in Fig.1.

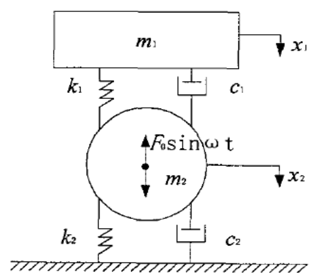

Fig.1 "Vibratory roller-soil" Mathematical Model

In order to make the mathematical model of vibratory roller coincide as closely as possible the reality and make the calculation simply and efficiently, the parameters and conditions of the model should be assumed before analyzing.

(1) The soil in fig.1 is the elastic body with certain stiffness. Its stiffness is k2, and its linear damping is c2.

(2) The quality of the rack, vibration wheel of the vibratory can be simplified to a focused quality mass, m1 for the rack and m2 for the wheel.

(3) Working at any moment, the vibrating wheels are kept in close contact with the ground.

The two degree of freedom model:

$$m_1a_1 + c_1v_1 + k_1x_1 - c_1v_2 - k_1x_2 = 0 \quad (1)$$

$$m_2 a_2 + (c_1 + c_2)v_1 + (k_1 + k_2)x_2 - c_1 v_1 - k_1 x_1 = F_0 \sin \omega t \quad (2)$$

$$F_0 = M_e \omega^2 \quad (3)$$

Solution of differential equations (1) and (2) can be obtained:

$$x_2 = F_0 \left[\frac{(A^2 + B^2)}{(C^2 + D^2)} \right]^{\frac{1}{2}} \quad (4)$$

Where:

$$A = k_1 \cdot m_1 \omega^2;$$

$$B = c_1 \omega;$$

$$C = m_2 m_1 \omega^4 - m_2 k_1 \omega^2 - c_1 c_2 \omega^2 + k_1 k_2 - m_1 k_1 \omega^2;$$

$$D = k_2 c_1 \omega + k_1 c_2 \omega - m_2 c_1 \omega^3 - m_1 c_1 \omega^3;$$

From the soil consolidation test:

$$S_i = H_0 \begin{bmatrix} H_0 & 1 \\ 1+e_0 & n \end{bmatrix} \quad (5)$$

Where:

S_i —Stability compression under levels of load;

H_0 —Initial height of the soil;

e_0 —Initial air space radio of the soil;

n —the compaction of the soil;

In fact S_i approximately equals to x_2.

Due to vibration harmonic excitation force, the vertical acceleration of the vibration wheel is followed:

$$X_2 = \omega^2 x_2 = \omega^2 H_0 \begin{bmatrix} H_0 & 1 \\ 1+e_0 & n \end{bmatrix} \quad (6)$$

From (6) it can be seen, without changing the vibration angular frequency of wheel, the compaction increases, so does the vertical acceleration of the wheel. There is a positive correlation between them.

2.2 The principle of the compaction measurement

Large construction practices show that when vibration roller is working, vibration acceleration and the compacted material compaction state have a close relationship. While ground material is soft elastic state, the vibration acceleration signal state is a regular sine wave. With the increase in the number of rolling times, the stiffness also increases. However, when the number of times increases to a certain degree, the vibration acceleration signal gets distortion and no longer shows the original sine regulation. When the vibration wheel acceleration increment is significantly reduced, or even zero, it indicates that vibratory roller in this particular condition has fully completed its compaction capacity. Therefore, with acquisition, analysis, processing of the vibration acceleration, we can easily get the state of the compaction.

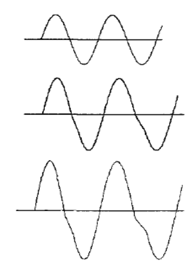

Fig.2 Vibration acceleration signal wave (Rolling times 1/6/12)

Compaction is usually measured through Radio Method by measuring acceleration. This method is also known as harmonic analysis method[3][4] ,which works by installing vibratory roller acceleration sensors and picking up the corresponding signal of the vibration excitation system through filters and Fourier transform. The radio of the fundamental and the harmonic wave can reflect the degree of compaction. Better the compaction, bigger the harmonic component, bigger the radio. Specifically the following formula:

$$\frac{\sum_{i-2}^{\infty} a_i}{a_i} \times 100\% = HVR$$

3. Main title System design

3.1 The composition of the detection device

The composition is shown in Fig.3.

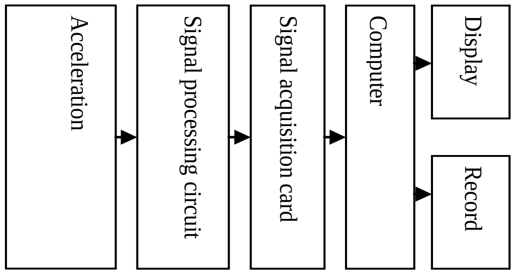

Fig.3 The composition of the detection device

3.2 Sensor selection

Parameters of the ICP acceleration sensor KD1010L is shown in Table 1. There is a core built ICP (Internal Circuit Package) circuit based on the conventional piezoelectric accelerometer. Its outputting and a constant-current source is a same line, namely it`s the superposition of an AC (vibration) signal and a DC level.

Tab.1 KD1010L Parameters

Voltage sensitivity / ()	10.72
Built-circuit voltage / V	15 ~ 24
Maximum transverse sensitivity /%	<5
Operating current / mA	2
Insulation Resistance /	100
Resonant frequency / KHz	25
Working temperature / °	-20 ~ 100
Frequency / KHz	0.5 ~ 6.0
Maximum measurable value / ()	500
Quality / g	37

3.3 Signal processing circuit

The vibration acceleration signal is weak, and the acceleration connecting cable is relatively long, resulting in greater resistance. So the collected signal processing is necessary. The circuit is for shaping the acceleration sensor signal, the input voltage protection, filtering and amplification[5].

3.4 Signal acquisition card

Signal acquisition card PC11711, which has 100KS/s sampling rate, 12-bit conversion accuracy, 16 signal-ended analog inputs, 16 digital inputs, including 1K sample FIFO buffer is suitable.

4 Software design

4.1 LabVIEW and Virtual Instrument

Electronic measuring instrument can be divided into four generations with a long development: analog instrument, digital instrument, intelligent instrument and virtual instrument.

Virtual Instrument (VI) is a product of modern instrument technology combined with computer technology. It`s an important part of the Computer Aided Test (CAT) technology. The computer hardware resources (such as microprocessors, memory and display) are combined to instrument hardware resources (such as A/D, D/A, I/O and signal processing, etc) through the software. Operator could accomplish the collection, analysis, judgment, display, storage and data generation of the test volume through a friendly graphical interface and the graphical programming language[6][7].

LabVIEW developed by National Instruments based on virtual instrument G language engineering platform is the powerful virtual instrument development platform with wide range of application. Using virtual instrument technology to build a test system is simple, short development cycle. Also it can reduce development cost, be easy of debugging, maintaining and upgrading. LabVIEW integrates a large number of graphic interface templates, a wealth of numerical analysis, digital signal processing, as well as hardware device driver functions[8].

4.2 Compaction correlation coefficient K and b

Definition $\alpha_{Kb} = K * HVR_n + b$

Where:

α_{Kb} --compaction;

K, b—compaction correlation coefficient;

HVR_n —the vibration acceleration harmonic radio after rolling;

With the increase in the rolled number, vibration acceleration harmonic radio HVR_n has a positive correlation with degree of compaction. The radio decreases relatively, the compaction value which measured by traditional sand cone method decreases accordingly. It is shown in Fig.4.

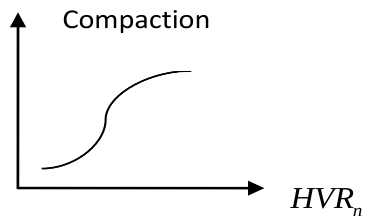

Fig.4 the positive correlation

The correlation coefficient K and b are not the same in different soil conditions. K and b can be obtained by a number of construction tests.

For example, when the compaction of bituminous pavement is required to achieve 95%, we can check the previous test manual and get the correlation coefficient K and b. When the compaction meets construction requirements, warning lights on the control panel alarm to alert construction personnel that the wok has reached the requirement. So it can efficiently control rolling times.

4.3 Block Diagram

4.3.1 Signal Acquisition

In order to achieve the virtual instrument function, LabVIEW must obtain the measured object`s data, which uses the data acquisition (DAQ) technology[9]. LabVIEW DAQ technology is the core technology. It collects signal from sensors and other physical device and converts them to digital signals.

4.3.2 Signal processing

(1) Spectral analysis

FFT is an efficient implementation of the discrete Fourier transform algorithm. The purpose of the discrete Fourier transform is to transform the signal from the time domain to frequency domain, which can process information in the frequency domain analysis[10].

(2) Filtering analysis (using a Butterworth filer)

The basic role of the filter is frequency selection, which allows the signal components in some areas and suppresses the other frequency component.

The digital filer can be classified to infinite impulse response digital filter and finite impulse response digital filter. Based on the performance comparison of these two filters, infinite impulse response digital filter is selected, for its low order and it is easy to accomplish. In addition to determining the center frequency, cut-off frequency, the band-pass frequency and the maximum attenuation , the band-stop frequency and the maximum attenuation are also considered seriously.

Therefore, Butterworth band pass filter parameters are followed: high cutoff frequency of 45Hz, the low cutoff frequency of 12.5Hz. Filter order is 4 bands.

4.4 Main panel design

The system software which uses modular design methods can be broadly divided into the following modules: data acquisition module, data storage/read module, data analysis module, the data display module, interface standardization, resulting in a module scalable process changes will not affect the other modules, thus increasing the flexibility of the system.

Software is written in LabVIEW. The main function are editing the input, parameter setting, data acquisition, vibration acceleration waveform display, spectrum analysis, real-time display degree of compaction, the test report generation, historical data query[11]. Main panel of software is shown in Fig.5.

Fig.5 the main panel of the software

5 Conclusion

The introduction of the correlation coefficient could display the degree of compaction in real time and be a timely reminder of the construction workers whether compaction meets the construction requirement. So it can effectively control the rolling times. The system can complete the real-time data collection, storage and retrieval. Though debugging the above hardware and software and analyzing the analog and digital signal, this system has a good and stable performance. The roller compaction detection system has high precision, anti-interference ability, as well as simple operation. The detection system platform is feasible. Not only can it saves development time, reduces system cost, its modular programming also can allow users to freely extend system functionality according to their needs.

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