Research on Vibratory Roller On-line Monitoring System based on LabVLEW

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Abstract. To improve the quality and efficiency of road roller, Vibratory Roller online monitoring test system of machinery based on LabVIEW is designed. The integrated structure and function of the system are introduced briefly, and the discussion of LabVIEW software design is focused on. The compaction is corresponding to the specific GPS position, and be displayed in graphic. The practice demonstrates that the system is reliable and real time, which provides a reference for the compaction and improves the efficiency of compaction.

Introduction

The using lifetime of pavement and the comfort of driving are directly related to the asphalt pavement paving quality. The degree of compaction road is the important key of Pavement Acceptance. Rollers construction is the last step of paving the asphalt pavement. During the prescriptive temperature range, the asphalt of pavers is rolled by road roller timely to reach the technical target of road paving. Finally, the rolling results should be Sampled and analysed to detect whether meet the technical requirements.

The traditional pave compaction detection has two defects: The lag of detection method. The limitation of detection point. The detection method is to detect and sample the result after road paving; in this way cannot the compaction result be given. Detection point is the simply random data samples, but it can't ensure the construction quality of all sections. How to reduce the rolling times of roller and prevent "under compaction" and "over compaction" under the premise of construction quality assurance is the difficult problem that construction companies need to be resolved.

This design uses the Labview to explore a vibratory roller-line monitoring system. By online continuous detecting the compaction of the pressing material and rollers performance parameters, and displaying visually the road construction quality parameters, this allows the operator to monitor the indicators real-time, and to provide the scientific and reliable basis for reasonably safe use of equipment and compaction effect on the determination.

Principle of compaction detection

Any vibratory roller is equipped with the vibration exciter. The exciter is consisting of the vibrating shaft and a set of eccentric blocks installed vibrating shaft. When the vibratory roller is working, the vibration of vibration wheel is forced vibration that caused by the centrifugal force produced by the high-speed rotation of exciting vibration equipment droved by hydraulic motor [1]. The eccentric blocks of vibration exciter are rotated on the basis of sinusoidal discipline, and mathematical expressions are as follows:

$$F=F_o \sin \omega t \tag{1}$$

$$F_o=mr\omega^2 \tag{2}$$

Where F_O is Eccentric force generated by eccentric block; M is eccentric block mass; R is Eccentric Moment of eccentric block; Ω is angular velocity of eccentric block.

In the construction machinery, the vibratory roller belongs to a kind of relatively bad working conditions. During the working process, it can lead into the random frequency noise that caused by

vibration motor, engine vibration or the bump between the vibration shaft and the bearing chock. Thus, the collected acceleration signal of vibration wheel is mixed up with some sinusoidal periodic signals of high-frequency noise in generally.

When the vibratory roller is rolling operation, the excitation signal amplitude of vibration wheel and the degree of compaction of pressed material is linear correlation [2]. When it is rolling relatively soft elastic pavement, the acceleration signal of vibratory wheel is a regular sine wave state, and with the increasing of rolling times, the excitation signal amplitude of vibration wheel is also increased. When it is compacted to a certain extent, the increment of vibration amplitude reduces significantly, even to zero, and this shows the description compaction work is completed. The continuation of compaction will result in excessive pavement compaction, the vibratory wheel will generate "bounce vibration", a phenomenon, and the compaction of pressed material will go down. According to the characteristics of above vibratory signal, the direct analysis of changes of processing excitation vibratory signal amplitude is taken to determine the degree of compaction. Thereby, the compaction of pavement can be measured indirectly.

Hardware Structure

Hardware section provides running platform for developed monitoring software, the system consists of sensors, signal conditioning, data acquisition cards, computers, monitors and printers etc., the overall structure of the system diagram is shown in Figure 1.

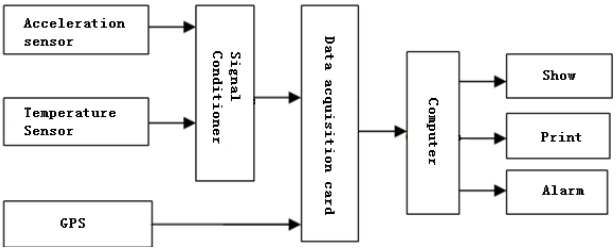

Figure 1 the overall structure of system

Design of Software System

This system is to solve the problems of the detection of pavement quality, condition monitoring of roller and control management. Detection parameters are in two parts: the first is the real-time monitoring of roller’s own state, which is mainly to provide the basis for future maintenance, and the signals can be drawn from the original systems of roller; the other is the detection of compaction information, which is mainly to monitor the construction quality, and the parameters of construction quality can be measured by various types of sensors. This system uses LabVIEW 2013 platform, and the software of system need for data collection, storage, analysis, display and other functions.

Software Architecture

For the high-speed data acquisition system of dynamic testing, sometimes a computer's memory can not store large amounts of collected data, or at the same time it conducts the signal acquisition, it also analyse data, save data, once the speed of reading data and analytical processing mismatch, it easily leads to duplication or loss of reading data. In order to prevent this from happening, the entire programming is based on LabVIEW producer / consumer loop mode structure.

As figure 2, this mode allows the program design to be more quick, simple and efficient; it puts the plurality parallel loops into two categories: the one is to product date continuously (producer), the other one is to process data continuously (consumer), and they pass data through the queue mode between the cycles.

When the data acquisition is too quick and the data cannot be processed, data will be temporarily stored in the buffer. In figure 3, when consumers have the ability to deal with them, the data will be transferred to analyse, storing and other treatment form the buffer as a principle: First Input First

Output, FIFO. This will avoid competition caused by high speed data acquisition, repeated analysis or data loss.

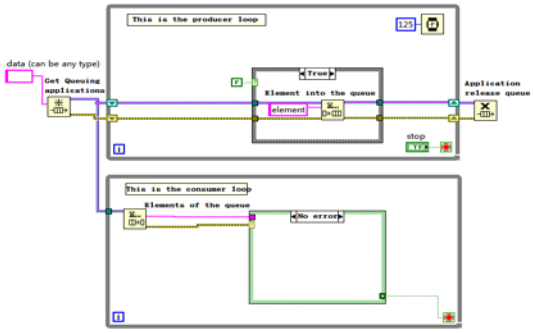

Figure 2 using a production / consumer design pattern of queue

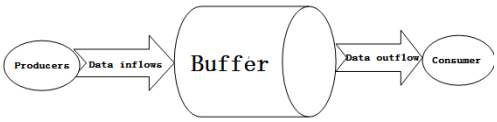

Figure 3 principle of production consumer model

Design of Data Acquisition Module

Data acquisition device (DAQ) is an instrument to obtain and convert the physical signals (Such as voltage, current, acceleration, and temperature) to digital format and to store the data into computer. According to the method in the test and measurement between the instrument and LabVIEW and the structural characteristics of system, this system take the API function of LabVIEW to create data collection procedures in the producer cycle, creating DAQ applications scilicet.

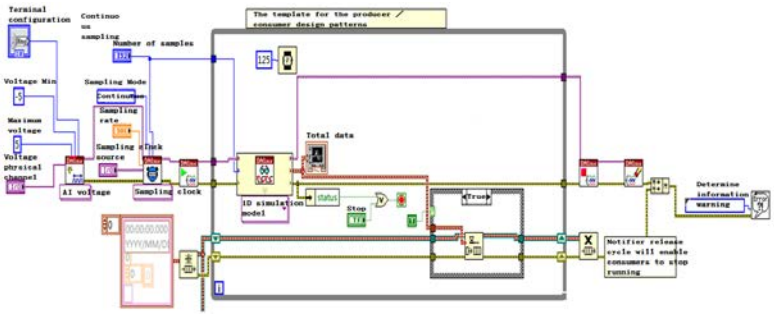

Figure 4 Data Acquisition

Firstly, It need to create a virtual channel and physical channel DAQ tasks based DAQ, and assign the input signal range (maximum and minimum) and the signal measurement; and then it need to set the sampling clock, and set the sampling mode on the sampling clock node for continuous sampling, and continuously sample via the input control to set the buffer size and the sampling rate of per channel; then add DAQmx Start Task node to start the task, here is mainly configured trigger mode and trigger source; in addition, also need to use the DAQmx Read node to read the data from the continuous acquisition DAQ devices; finally add the DAQmx Clear Task node in the production cycle , but for the clean-up task [3]. Then the acquisition block diagram of the design is completed, shown in Figure 4.

Design of Data Analysis Module

DAQ hardware is only converting the input signal into a digital signal that the computer can recognize, system testing task essentially is completed by analysis software installed in the computer. Data analysis is to convert the collected raw data into meaningful information through curve fitting, statistical analysis, frequency response or other processing methods, and then the data is displayed in graphs, charts or other visual forms.

In this system, the degree of compaction road is the most important monitoring parameters; it can take two kinds of ways to build relationships with the acceleration signal and degree of compaction. One is to determine the degree of compaction through direct analysis of acceleration signal

amplitude variation of vibration wheel during compaction; another is to determine the degree of compaction via characteristic value obtained by the spectrum analysis of the vibration signal. According to the analysis comparison, it shows the first method, amplitude method, to achieve simply and use less parameter; and the harmonic ratio method is more complex, generally it requires the use of digital signal processing technology. The system analysis module uses the amplitude variation of acceleration signal to determine the degree of compaction.

GPS Module Design

When asphalt pavement construction is ongoing, via the GPS positioning system, acceleration sensors and temperature sensors and other equipment, it make the operating position of rollers and compaction information (such as vehicle speed, rolled several times, compaction, asphalt temperature and other parameters) correspond, in order to locate the accurate geographical position and take remedial measures while the “under compaction” and “over compaction” appearing.

GPS (Global Positioning System) that is the abbreviation for Global Positioning System, it uses global navigation satellites and ground stations to provide continuous weather, high-precision, real-time three-dimensional coordinates (latitude, longitude, altitude), three-dimensional velocity and position information, anywhere on the Earth's surface can be used for positioning and navigation[4]. Simply by receiving satellite signals spread from the GPS receiver when in use, and through software processing it will be able to get real-time accurate position of roller, velocity, time and other information. And the locations that the receiver is located can receive the satellite signals (Generally cannot be received within the building and metal shielding device), and that is also to say GPS location information can be received.

The GPS receiver positioning information is usually a string ASCII characters output data stream containing position information. This article uses LabVIEW to develop GPS data acquisition and processing program, and completes the design of visualization software for Reading, analysis and calculation, displays of the GPS location data. GPS program divided four modules: Serial communications module, its main function is to collect positioning GPS receiver output data; Control module, it mainly determines whether the GPS data is valid and responses to a user action. Data processing module, it Mainly analyse GPS data of NMEA-0183 protocol, and is to read real-time three-dimensional coordinates (Latitude L, longitude B, altitude H), speed, time and other information from ASCII characters in the stream containing location information; Display module, it is to display the processed GPS positioning information.

GPS positioning achievements belong to WGS-84 geodetic coordinates (B, L, H), in order to facilitate the calculation, it has to convert geodetic coordinates to earth space Cartesian coordinates (x, y, z). The same points on the ground are completely equivalent in the two coordinate systems, they are Interchangeable [5]. The following is the conversion formula:

$$\begin{cases} x=(N+H)\cos B\cos L \\ y=(N+H)\cos B\sin L \\ z=[N(1-e^2)+H]\sin B \end{cases}$$

In the formula: N is the curvature radius of prime vertical of the ellipsoid; e is the first eccentricity of ellipsoid. If a and b respectively represents long radius and short radius of ellipsoid, and there is a formula:

$$e^2=(a^2-b^2)/a^2,\ N=a/(1-e^2\sin^2 B)^{\frac{1}{2}}$$

Relative to the entire earth, the range of motion of roller is small; the construction road can be approximated as in a plane, after obtaining the effective position information, according to the current point position relative to the starting point, the trajectory of roller can be monitored [6].

System Calibration Module

In engineering applications, LabVIEW is often used to measure physical quantities, and then there is some problem of amount of transformation, that is to convert the capacity value to the physical magnitude that has practical significance.

This system is mainly to consider the degree of compaction and asphalt pavement temperature. For the temperature calibration, LabVIEW has some functions which are devoted to converting.

They are located in "Function" | “Mathematics” | “value” | “Zoom” drop-down list. Seen by the selection of temperature sensor, here, "Convert Thermocouple Reading function" can be selected; it can convert the voltage value read from the thermocouple to temperature values in Celsius. Program is shown in Fig 5.

The experience of a large number of engineering practices has shown that within a certain range, acceleration of vibration wheel and the degree of compaction are approximately linear relationship, and the data of asked functional relationship between them has to be obtained from the current test.[7] When paving test section, firstly measure the compaction of every asphalt pavement rolling by using the sand replacement method, and then establish correspondence between the detected acceleration signals corresponding to each pass, table 1 show the data of measured values in the field test segment.

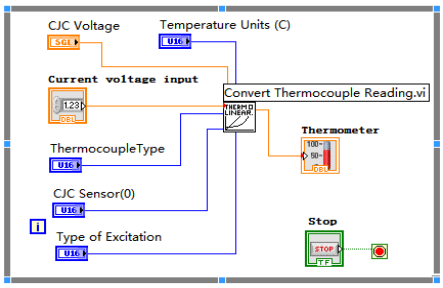

Figure 5 Temperature Calibration Program

Table 1 asphalt pavement acceleration values at different degree of compaction

Compaction passes	After paving	1	2	3	4
Peak of acceleration /g		16.77	21.46	28.06	28.19
Compaction values	84.7%	88.4%	91.2%	95.6%	98.4%

According to the construction process of asphalt pavement, just four times vibratory roller compacted, so the amount of data to be fit is not very large. Therefore, this system uses Excel software to fit the data both easy and accurate, and the obtained results are the same to the results obtained by MATLAB programming. Figure 6 is the fitting curve between the measured compaction and acceleration.

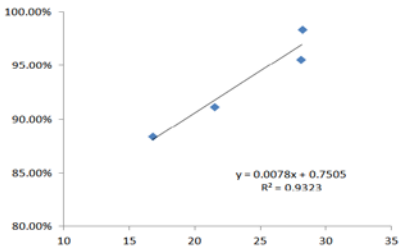

Figure 6 correlations between peak acceleration and compaction degree

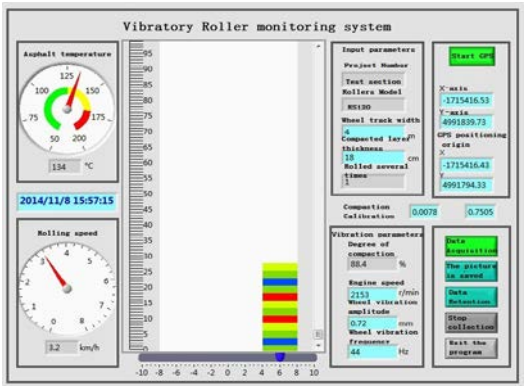

Figure 7 Monitoring System Interface

Then the calibration factor is entered into the monitoring system written in LabVIEW program, and the acceleration value can be measured in terms of the degree of compaction, and it also can real-time monitor and show the value of compaction.

After the integration and debugging of hardware and software, the system that is after successful commissioning will be installed on Shaanxi built machinery SRD120 vibratory compactor to conduct the site construction test. The running interface of vibratory roller online monitoring system is shown in Figure 7.

Conclusion

In this paper, an online monitoring system of vibratory roller based on LabVIEW is designed, and the overall structure is given. The hardware and software subsystems of system are detailed, the principle of monitoring of system is described, and GPS technology is taken to make the compaction position and information correspond. This system can monitor in real time the compacted state of road surface, and it can make the driver work by speculation and experience. It can reduce the phenomenon, lack of compaction and over compaction, caused by human factors, and it can essentially guide the construction workers, and is also benefit for ensuring the construction quality to enhance the efficiency of compaction.

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