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Online detection system for wheel-set size of rail vehicle based on 2D laser displacement sensors

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ABSTRACT

The real-time detection of wheel-set size, the most significant technical parameter during vehicle operation, has important implications for ensuring the safety of wheel running. Based on laser ranging, an online detection system of the wheel size installed below the track is developed. Eight two-dimensional (2D) laser displacement sensors are applied to detect the wheel-set size including wheel flange and tread profile. A digital I/O card is utilized to generate synchronous signals which guarantee simultaneous working of all sensors. Least square based curve fitting and pick-up algorithm of tread feature-points are used to process the measured data and calculate the flange width, flange height and wheel diameter. The experimental results show that the online detection system of wheel-set size can realize the non-contact, dynamic and real-time measurement of wheel-set parameters. When train running speed is under 5 km/h and sampling frequency is 30 Hz, the detection accuracy of flange width and height is ±0.2 mm and the detection accuracy of wheel diameter is ±0.5 mm, which can meet the requirements of maintenance operation.

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1. Introduction

With the rapid development of urban rail traffic, the issues of train safety are becoming more and more prominent. Train wheels are the most important components among the traveling system which ensure the running and steering of the train on the rail and bear all the static and dynamic load from the vehicle [1]. The interactions between wheel and rail wear down the wheels gradually, which cause the undermining of wheel size and affect the safety and operation quality of the train. Therefore, real-time detecting wheel size is of great significance to ensure the safety of urban railway transit [2].

The wheel size detection method can be roughly divided into the contact and non-contact measurement. At present, artificial calipers, the representative tool of contact measurement, is still an effective method for wheel size measurement because of the advantage of simple operation. The calipers have the problem of high labor intensity and low accuracy. With the development of computer information technology, non-contact measurement is more widely applied. The early non-contact method to detect wheel-set size is based on Charge-coupled Device (CCD) image processing technology. However, the structure of the system is too complex, and the system is too sensitive to harsh environment with vibration and light [1–4]. Along with the development of sensor technology, the laser sensor has been widely used in non-contact detection systems, especially in China [5–8]. In laser sensor based detection system, the technical difficulties are how to process the measured data after obtaining the tread profile and flange, and then how to calculate the geometric parameters including flange width, flange height and wheel diameter.

This paper provides a new online wheel-set size detection system which is installed below both sides of the rail. The system based on the principle of laser ranging obtains the tread profile and flange by using high precision 2D laser sensors. Feature point extraction, curve fitting, and best tread contour extraction algorithm are applied to accurately calculate the flange height, flange width and wheel diameter.

2. The principle of wheel-size detection system

The wheel size online detection system depends on laser scan method, which consists of eight high precision 2D laser sensors installed below the track to acquire both sides of the train wheel

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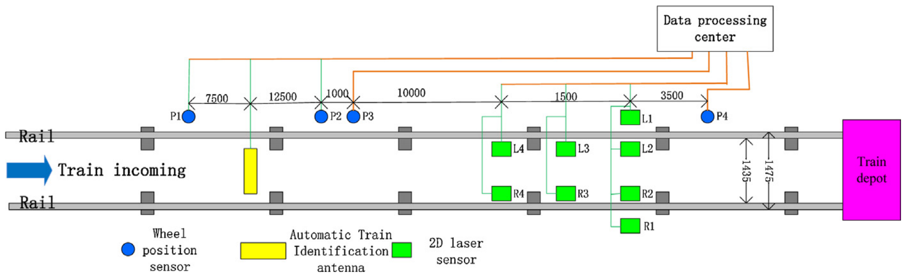
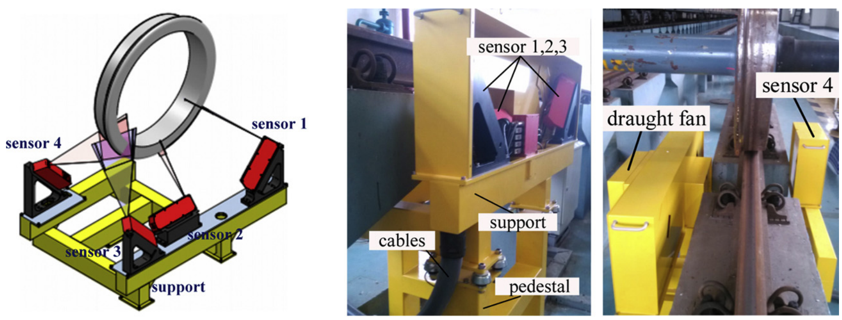


Fig. 1. Schematic diagram of sensors installation.



(a) (b) (c)

Fig. 2. Laser sensor installation diagram.

profile. The sampled signal is analyzed in data processing center, and finally the condition of each wheel is decided.

The layout of all sensors is shown in Fig. 1. Along the rail, the equipments are wheel position sensor, automatic train identification antenna and 2D laser sensor respectively. Four wheel position sensor are installed beside the outside of the rail, where the first one is used to detect the arriving moment of the first wheel axis of a train, and hence, to trigger subsequent hardware facilities; the second and the third are used to calculate the speed of each wheel, and then, to decide the scan duration of laser sensors; the last one is used to detect the leaving moment of the laser wheel axis of a train, and hence, to close the subsequent hardware facilities. The automatic train identification antenna is used to identity the incoming train. The eight laser sensors are divided into two groups and each group of four sensors are installed on a mechanical support.

As the laser sensors cooperate with each other to complete the measurement for the wheel-set size including wheel diameter and tread profile, the installation of the laser sensors is a core of this system. The 2D laser sensor, which is based on laser triangulation measurement principle, is made up of laser diode and a CCD linear sensor element. The emitted laser forms a laser belt on the wheel tread and the laser is reflected to the CCD linear inductive components with a certain angle. The integrated circuit of the sensor processes the optical displacement data to obtain the tread and flange profile coordinates. The installation position of one group sensors is shown in Fig. 2(a) and the other group mirrored. Sensor 1, 2 and 3 are located inside the track, and sensor 4 is located outside the track. The horizontal (x axis) measurement range of sensor 1, 3 and 4 is 177–273 mm and the vertical (y axis) measurement range is 330–510 mm. The horizontal (x axis) measurement range of sensor 2 is 45–60 mm and the vertical (y axis) measurement range is 260–340 mm. The x axial and y axial resolution of all sensors is 50 μm. The bracket support of sensor 4 is designed to have adjustment function in three freedom degrees in order to guarantee the laser surfaces of sensor 3 and 4 are on the same plane. The actual installation detection system is shown in Fig. 2(b and c). Except the facilities mentioned above, the wheel size detection system also consists of mechanical support, mechanical pedestal, cables and draught fan etc.

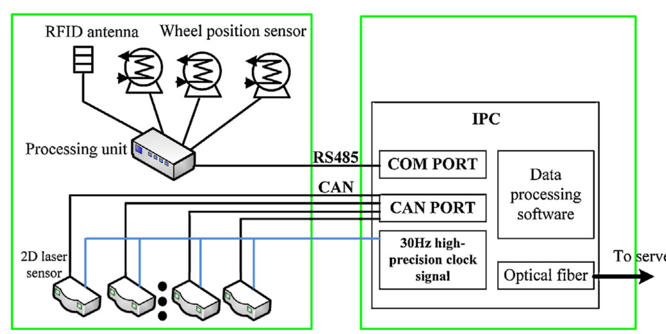


Fig. 3. Hardware schematics.

The hardware schematics are shown in Fig. 3, include wheel position sensor, train identification antenna, 2D laser sensors, industrial personal computer (IPC), data acquisition card and processing software. The signal from wheel position sensor and train identification antenna are preprocessed in a processing unit and then transmitted to IPC through RS485 port. A digital I/O card (PCI1730U) is utilized to produce 30 Hz square signal in order to ensure all sensors to complete the task of acquiring the wheel profile synchronously. The sensors begin to collect the data on the decline of the square wave signal, and then transmit the data to the IPC through CAN port for the subsequent process includes data segmentation, calculation and display. The data acquisition card are PCI 846 and PCI 841, which extend COM port and CAN port respectively.

3. The laser sensor calibration

During the detection process, the coordinate of original output point from four 2D laser sensor is based on each sensor itself. The output points of the sensor 3 and 4 should be converted to a unified tread reference coordinate to calculate the flange width and flange

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