Design of multifunctional railway track inspection vehicle

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Abstract. With the continuous construction of railway network, it is more and more important to maintain the operating state of railway track. Meanwhile, due to the rising departure density, the time available for maintenance is shortened, and the contradiction between operation and maintenance is becoming increasingly acute. In order to improve the efficiency of track maintenance, this paper proposes a multi-functional railway track comprehensive test platform, which can effectively integrate the existing track maintenance equipment, improve the maintenance kilometers per unit time, and puts forward a set of matching internet data management system, which has important practical value for improving the modernization of track operation.

1. Introduction
For the rapid development of economy, the roles of railway and rail transit is becoming more and more prominent. Trains, subways and high-speed railways are not only our popular means of transportation, but also our key national infrastructure projects. Railway transportation has maintained a rapid and stable growth trend.

With the development of railway, the tasks and difficulties of railway maintenance and inspection in China are also increased. Due to the large volume of railway transportation, once an accident occurs, it will produce devastating results and immeasurable losses. [1]This requires our railway maintenance department to timely and accurately check the damage and defects in the track to ensure the safety and reliability of track operation. The rapid development of railway construction requires a lot of maintenance works, especially the high speed and large load trains require higher pavement flatness. The defects and manufacturing errors of the track materials and parts, as well as the initial errors caused by the site construction, and the spatial position of the track changes under the influence of the train and environmental conditions, all of these factors cause the pavement lower flatness. This change compares to the initial state and design of the track line. The lower flatness of the pavement will aggravate the wear between train wheels and track, damage track parts and shorten track service life. Low track flatness is an important factor leading to vehicle vibration, which directly affects the comfort of the train, causes traffic safety problems, and increases the track maintenance cost. [2]

In order to ensure that the track is in good condition and the train can run safely, it is necessary to check, adjust and maintain the track status regularly. So far, the commonly used track line detection methods are track inspection vehicle, light measuring trolley and manual detection. [3]The rail inspection vehicle has high detection efficiency, but its high equipment cost and hard to transfer limit its promotion. The cost of manual detection is low, but the detection items and detection efficiency are limited. Therefore, using light measuring trolley to detect track line is the most popular measuring
method at present. However, most rail inspection instruments on the market are hand pushed. Generally, every 25km ~ 50km is divided into a work area. The detection method is mainly the manually pushing single rail unpowered ultrasonic flaw detector. The detection speed is about 3km / h, and the double rail detection speed is 1.5km/h. It needs 8 to 15 technicians to maintain every kilometer, and it takes nearly 14 hours to complete the 25km detection. The amount of track maintenance work and the required operation time are very huge. At the same time, according to the statistics of the railway department, the non-traffic time of high-speed railway is ≤ 6 hours / day, and that of ordinary railway is ≤ 2 hours / day. All road network inspection work needs to be completed within time, which puts forward high requirements for the mobility of maintenance personnel and equipment.

Therefore, the development of a fully automatic track comprehensive inspection vehicle with complete inspection items, high inspection efficiency and portability will provide great convenience for track maintenance and railway construction. It has strong practical significance and popularization value for the efficiency, stability and completeness of track condition detection.

2. Overview of multifunctional track inspection vehicle
In order to improve track detection efficiency and reduce manual detection intensity, a portable multifunctional railway track comprehensive detection vehicle with complete measurement functions is developed in this paper. The detection platform is improved on the basis of traditional hand push detection trolley to realize full-automatic measurement. Based on the Internet technology as the control core, it integrates four functions: track ultrasonic detection function, machine vision track detection function, track power line inspection function and detection data cloud upload, processing and analysis function. [4] In the hardware part, the four-wheel electric wheel hub power platform is selected, the nondestructive testing equipment with specially customized high-speed and high-distance ultrasonic probe and high-speed industrial linear array camera are integrated, which can realize safety detection under high-speed operation, and record and transmit images and sensor data in real time. At the same time, the mechanical structure of the platform adopts the design concept of modularization and lightweight. After actual test, the platform can be installed and debugged quickly within 10 minutes, which greatly saves time and labor cost, reduces the operation and maintenance cost of maintenance, greatly improves the detection speed and accuracy, and improves the intelligent level of track detection.

3. Structural design of multifunctional railway track inspection vehicle
For the promotion of the designed products, it is necessary to comprehensively consider the needs of rapid transportation and convenient installation and commissioning of the platform under different scenarios, divide the needs of the test vehicle, and design and manufacture it by module. The test vehicle can be divided into base power structure module, test equipment installation and work module and data cloud processing module according to its function.

3.1. Base power structure module
The base plate and beam frames is shown in Figure 1.

![Figure 1 The base plate and beam frames](image)

The base of the track inspection vehicle includes the bottom plate and left and right beam frames. The bottom plate and beam frame are made of structural steel by welding, and detachably connected
beam frames are set along the left and right sides of the bottom plate. The left and right sides of the upper end face of the bottom plate are provided with overlapping edges extending outward. The first beam frame is located below the overlapping edges, wheels are installed at the front and rear of the two first beam frames, and ultrasonic flaw detectors are installed between the two wheels on the two first beam frames.

At the same time, a control seat needs to be installed on the bottom plate, a detachable front seat is symmetrically arranged on the left and right sides of the front end of the upper end face of the bottom plate, the left and right sides of the bottom of the front seat are provided with a front and rear extended first longitudinal chair beam, and a left and right extended transverse chair beam is arranged between the two first longitudinal chair beams. The base plate is provided with a limit groove for the first longitudinal chair beam of the front seat inside the base plate, and the seat installation structure is shown in the figure2.

According to the working requirements, the design speed of the detection vehicle is 20km/h, which can move forward and backward stably on the track, maintain constant speed cruise, and ensure rapid installation and commissioning in a short time. Therefore, the power system of the detection platform adopts the design of electric 4WD hub drive. When the trolley is running on the track, it needs to stop in time when damage information or unexpected [5] conditions are detected, which requires our flaw detection to stop in time. In order to ensure the stability and reliability of the braking of the flaw detection trolley, the system designs two independent braking schemes: foot brake, miniature mechanical braking and electromagnetic braking. The electronic automatic holding brake reducer is connected with the brake. After power failure, the wheels will automatically hold the brake. Under the remote-control command, the electrical control will issue the command to slow down the reducer to stop the vehicle. After stopping, the wheels will automatically hold the brake and lock. [6]

In order to meet the characteristics of the control system and improve the requirements of system integration, FPGA is used as the control core, and brushless DC motor is used as the power output source. As a digital device, FPGA can be used to control DC motor. FPGA has parallel operation circuit. Multiple control objects can be added to a control core to drive independently, and the speed regulation accuracy and control function of the system can be improved.
3.2. Installation and working module of testing equipment

The detection equipment installation and work module is equipped with three modules, including track ultrasonic detection module, track visual detection system and power line inspection module. The integrated installation of multiple equipment previously required greatly improves the efficiency of track detection. [7]

The ultrasonic flaw detection instrument is installed on the two first beam frames and between the two wheels. The ultrasonic flaw detection instrument adopts the double track rail flaw detector. The flaw detection system can detect all kinds of defects on the track during operation, including cracks on the head and waist track and all kinds of cracks on the welded joint. The probe of the flaw detection system contains 18 channels, which can effectively reduce the damage to the probe during operation while ensuring accurate detection of the track. At the same time, the flaw detection system is equipped with calculation and processing module, and the high reliability industrial control computer and highlight monitor are used to ensure that the system can maintain the stable and reliable operation of the flaw detection system even in the harsh field working environment. The flaw detection real-time imaging collects data, which is convenient for the inspectors to monitor and judge the track damage state. The flaw detection vehicle transmits the ultrasonic signal to the tested rail through the transducer, and the reflected signal of the flaw detection rail is received by the ultrasonic transducer, transmitted to the upper computer through the signal processing circuit and then transmitted to the upper computer through ethernet to realize the analysis and storage of flaw detection data. When there is damage information, the flaw detection vehicle needs to spray marks on the steel rail in time.

The current track video images were obtained by a vehicle camera mounted on the head of the platform, and an exotic intrusion detection system model was established combined with the track edge extraction algorithm. The track visual monitoring system can monitor the exotic intrusion, and discriminates the exotic into the safe and danger categories. The safe category includes static small obstacles, moving obstacles quickly across the track. And the danger category includes static large obstacles, movement obstacles affecting the train through. For the latter ones, the system will alarm or warn in time. [8]

The power line inspection system is different from the artificial paper medium recording method commonly used in the domestic power industry. The inspection system based on GPS and GIS infinite Internet is developed. The on-board power inspection system is composed of equipment terminal and management center cloud server. The GPS module receiver is used to collect the location data of the transmission line fault point and upload it to the cloud server database to complete the record of the fault transmission lines. The GPS location module is the GU620 module made in China. The product has a high positioning accuracy (tolerance can reach to 2-5m), The static drift is small and has high positioning accuracy, which is especially suitable for inspection in strong electromagnetic environment and field environment.

3.3. Data cloud processing module

In the communication module with data processing function, data transmission and storage are implemented based on the Internet of things technology are selected, and data transmission is realized through the external communication interface integrated by embedded terminals, such as GPRS module, ethernet interface, etc. Rail maintenance time, geographical location and detection parameters will be stored on the cloud server for operators to trace and postprocessing the data.

In order to realize the data management and maintenance, a set of maintenance data information management system was developed according to the current standard ----provisional technical conditions of dual-track ultrasonic detector, through the evaluation, prediction and economic and technical analysis, maintenance plan, and the track operation status and maintenance performance, improve the accuracy and reliability of the inspection project, and can realize the dynamic monitoring of track quality.
4. Conclusion
Based on the investigation of the development status of track detection equipment at home and abroad, this paper proposes a new multi-functional comprehensive track detection vehicle, which greatly improves the efficiency compared with the hand-propelled track detection equipment widely used at this stage. The multifunctional track inspection vehicle can realize various functions such as ultrasonic flaw detection, track visual inspection and electric power inspection. The modular installation mode is adopted for the inspection vehicle, which is convenient for transportation and installation, greatly improves the efficiency of track inspection, and has a good application prospect.

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