

The design of mobile wheel set ultrasonic inspection system based on the phased array ultrasonic technology

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Abstract

A new automatic NDT system for the CRH (China Railway High-speed) wheel set is introduced in this paper, which can supply an efficient, high reliability and high quality service for the CRH wheel set. The mobile wheel set ultrasonic inspection system is based on the phased array ultrasonic technology which can realize the on-line automatic non-destructive testing of the wheel set.

Initially, the cause and typical defects as well as main defect area in the wheel are discussed. Then the design of phased array probe suites and distribution in the wheel tread surface and other part is given. The system can inspect all kinds of defects which cover the rim and disk area of wheel so that it can meet the demands of railway. Finally, the inspection ability of this system has been tested and verified by the reference wheel set with artificial and natural defects.

Through the phased array technology the key parameter of POD, the efficiency and accuracy for the wheel inspection can be improved and suitable for the areas difficult to access.

Keywords

Wheel sets in EMU, wheel rim and disk, phased array ultrasonic, mobile wheel inspection system, automatic ultrasound inspection, high-speed train

1 Introduction

Since 2007 the speed of CRH train in china has increased quickly and it is up to 350km/h in Wu-Guang PDL which is the fastest one in the world 2009. The high speed train needs more strict ways to keep the train safety than before. It's necessary to test the wheel-set in period times by NDT system in the way of maximum safety, efficiency and economy.

In this paper, it reports a mobile wheel-set inspection system named LU, which is based on the phased array ultrasonic technology and is applied to inspecting the wheel-set in stationary train on a maintenance line.

The LU system can scan the inspect scope of the wheel rim and disk area in the high sensitivity and POD at the same time with ability to evaluate the defects by software and image view for the inspection result as well. Due to adopting the phased array ultrasonic technology, the probe carrier of LU system has small size which can meet the different limiting boundary conditions of CRH trains.

2 The inspection principle^[2,3]

2.1 The typical defects in the wheel

Some typical cracks are often found on the tread of wheel, for example, Moire-like thermal cracking. The rolling contacts between the wheel and rail lead to those cracks, especially even to the spalling on the tread.

The appearance of spalling on the tread always causes the great vibration and shock in high speed train, which not only produces great uncomfortable noise, but also increases the wheel wear and damage, evermore generate the danger.

The defect occurs not only in the tread, but also near the holes which used to fix the brake disk in the wheel disk. It is necessary to check those areas at fixed periods. The figure 1 shows some typical CRH wheel in China railway and the red rectangular area references where the LU system can inspect.

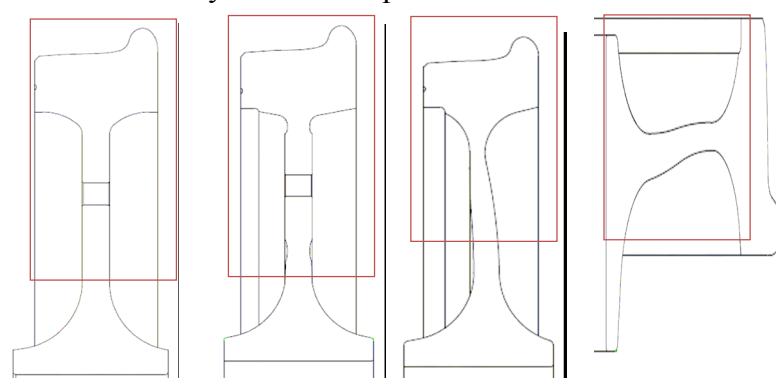


Figure 1 the typical CRH wheel

2.2 The principle of inspection wheel defect and CIVA simulation

In Figure 2, the probe carrier in LU system consists of two parts, one locates in the inner surface of wheel rim and the other locates the wheel tread. The probes marked yellow are phased array probes, the others are the straight beam probes.

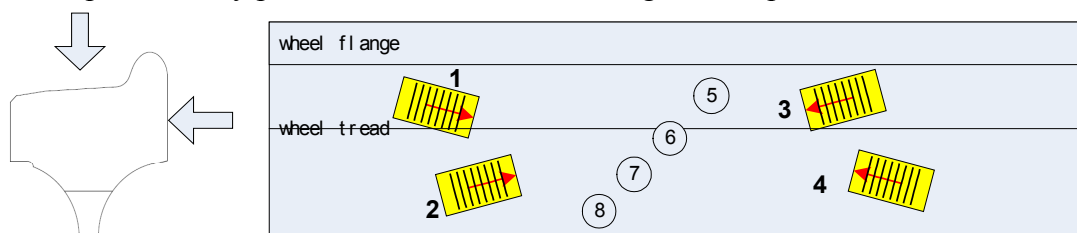


Figure 2 the scan area of wheel

2.2.1 The inspection of the wheel rim^[2]

The defects in the wheel rim can be tested by the probes from the tread side and the inner surface of rim. Several conventional TR probes are placed and covered on the whole surface of wheel tread. But it is difficult to test the defects in the chamfer and near surface of wheel tread by them. A special application of phased array probe with lateral scan can solve those problems, as shown in the figure 3.

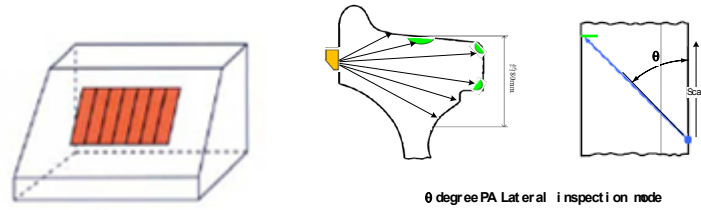


Figure 2, Principle of Phased array ultrasonic in inner side of rim

2.2.2 The inspection of wheel disk

The probe carrier on the tread has two kinds of probes: the TR probe and phased array probe. The function of the probe carrier is to inspect the wheel disk, especially the area of wheel plate holes. The TR probe generates the longitudinal wave and scans the axle orientation and circumferential orientation defect in the disk, but it can not obtain the defect below the holes. Comparatively, a pair of phased array probes is used in the Pitch-Catch mode for that area. The LU system, with the implementation of phased array probes with S-can, requires only one pair of probes each for the inner and outer wheel disc surface. In addition, the pulse-echo mode is used for the radial defect inspection in the wheel disk, as shown in figure 4.

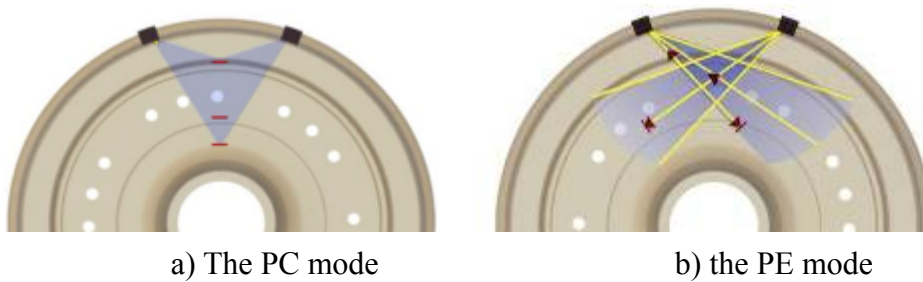


Figure 4 the inspection of wheel disk

2.3 CIVA simulation

The software CIVA is used to simulate the ultrasonic technique in the LU system. It optimizes the distribution of probes on the tread and inner surface of rim and coverage of the inspection areas in the wheel. In Figure 5, a module of CRH wheel is built in CIVA with some artificial defects near the plate hole, one pair of phased array probes are placed on the wheel tread.

It can be found a series of refracted shear waves to covering the different depth circumferential defect in the disk, and then the same configuration is applied in the phased array device to inspect the similar artificial defect in the practical wheel. The Figure 5-b shows the inspection results in TomoView, which are the same to the simulation results.

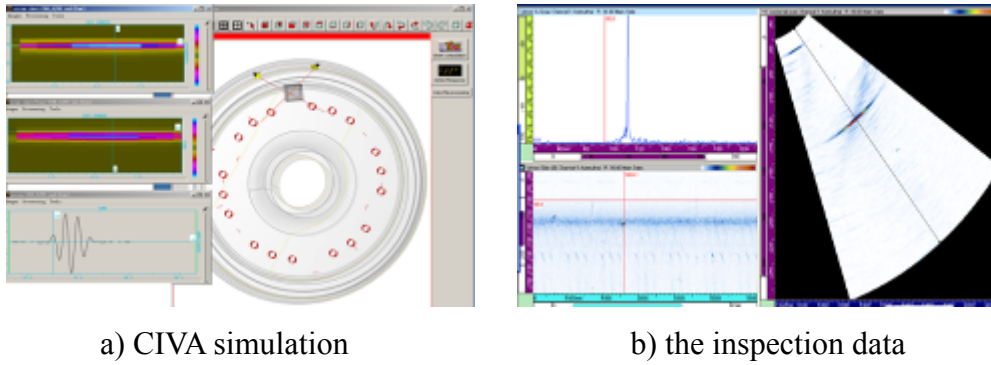


Figure 5 the simulation and experiment of wheel inspection

3 LU system

The LU system is designed to inspect the in-service wheel set in the bogie under the train on the maintenance line.

When the system works, it moves along the inspection line under the stationary train, automatic locates the actuary wheel set, then the wheel set lifting device in the inspection car is laterally expanded over the tracks with clamps being positioned on the tracks. After that, the wheel set is lifted a fixed height and can be rotated. The probes carrier move to the wheel and then inspection is performed during the rotation around one time. If there is any flaw in the wheel, the wheel should be inspected again and re-verified. After inspection wheel, the system works in the reverse procedure.

3.1 The technical specification

- Maximum axle weight : 30T
- The diameter of wheel: 750~1000mm
- Inspection time: 1 minute/wheel
- The typical probe: PA Linear probe and conventional probe
- The minimum defect in the rim: $\phi 1\text{mm}$ FBH

3.2 The system composition

The Figure 6 shows the composition of LU system, one is the inspection car which works along the maintenance line; the other is the master car. The operator can control the computer in the master car and send out the commands to inspection car. Then the inspection car can perform the whole inspection process automatically.

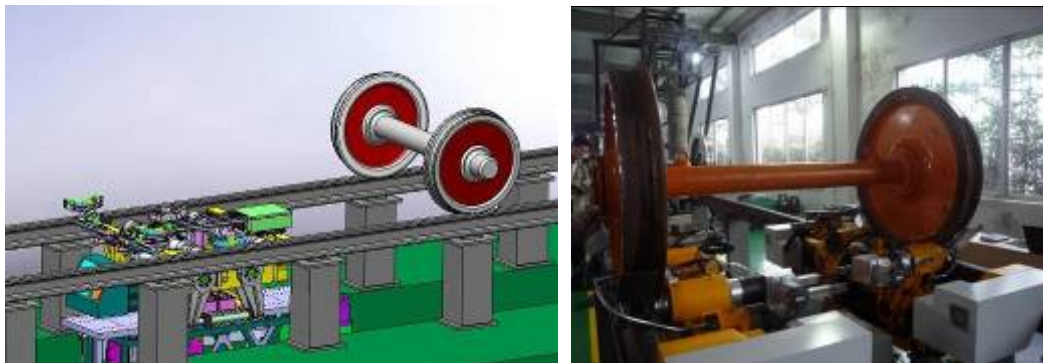


Figure 6, the LU system

3.3 The frame of system software

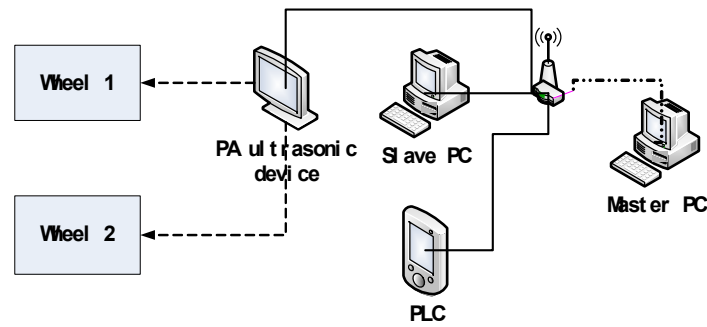


Figure 7, the frame of wheel inspection system

The software frame of LU wheel inspection system is described in the figure 7. Firstly, the operator uses the Master PC to control all functions of the PLC and Slave PC in wireless way, and then analyze inspection data, at last get the final report. The Slave PC connects to the Phased array device and gathers the inspection data.

3.4 Inspection data

The LU system has three analysis processes for different level user with different detail information. The first is a simple report, such as the final report of wheel inspection results and a list report of defects. the second one is 2-D wheel view, the user can get the position of defects in the wheel rim and disk easily through the view. the third one is with more detail information, such as the amplitude and position of the defect in the B-scan and A-scan. In the Figure 8, the different views for the defect in wheel are shown.

The image of echo wave from plate hole in wheel disk is in the fixed position, so it's easy and clear to identify the defect in that area through B-scan and 2-D wheel view. In the Figure 8-c, a wheel drawing shows the artificial defect in the practical wheel and the defect echo wave appease at the same position in the wheel view.

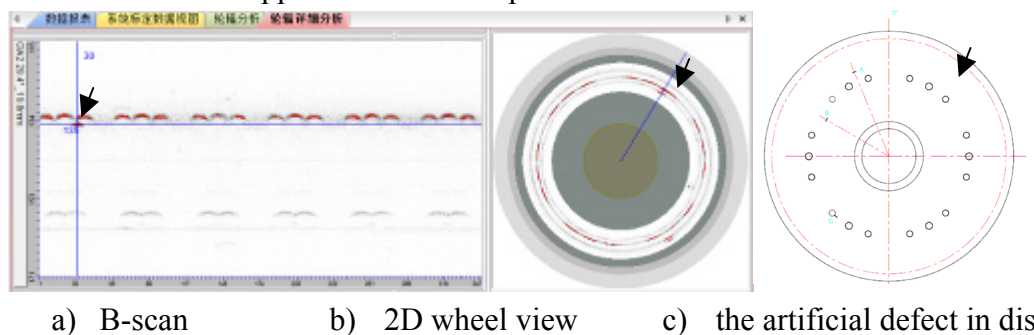


Figure 8 the inspection data analysis and view

4 Typical defects and inspection result

To verify the inspection ability and the compatibility of LU system, some reference CRH wheels with typical defects are machined. In those reference wheels, more than ten artificial defects with different size are distributed in the important area of wheel rim and disk. The result from the test shows that the LU system can inspect all defects in different type of wheel with the same probe carrier but using different

configuration.

The figure 10 shows an artificial defect A on the tread as the Moire-like thermal cracking and the result.

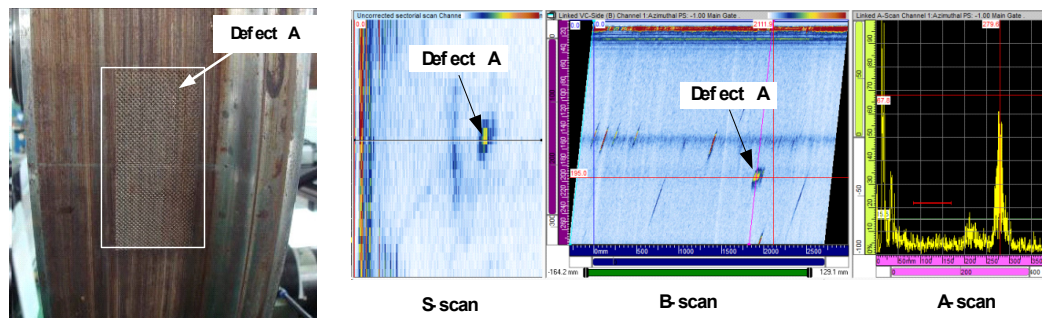


Figure 10 the artificial defect in the tread surface

The figure 11 shows a natural defect B with 20mm×30mm×3mm of the locomotive wheel on the tread area. It's difficult to detect from the tread surface because of the worse coupling status. But it can be inspected from the inner surface of the wheel rim by the PA probe. The inspection result is showed in the B-scan and S-scan in figure 11.

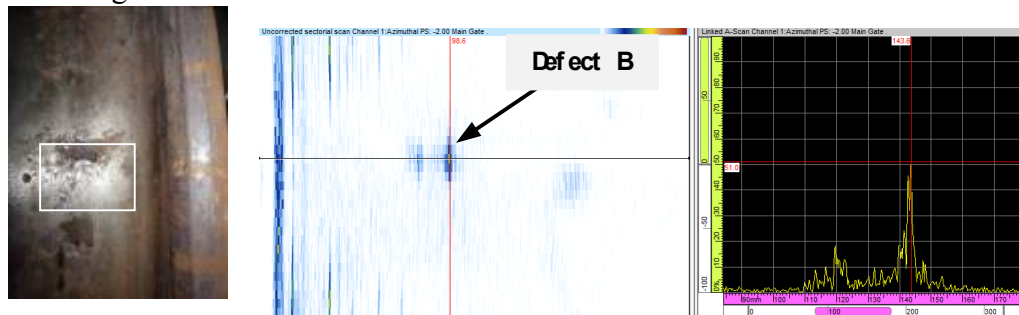


Figure 11, the natural defect in the tread surface and inspection data

5 Conclusion

The LU mobile wheel inspection system using the advanced phased array ultrasonic technique, has designed the compact probe carrier with small size to meet the different boundary limitation in CRH train. The system features have been realized through the CIVA simulation and testing in practical wheel set.

- 1) The LU system can inspect all kinds of defects in the wheel rim and disk area.
- 2) The LU system can realize the compatibility of using one type of probe carrier to meet the inspection demand of different CRH wheel set.
- 3) The LU system can work in high efficiency and reliability.

6 Reference

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