DYNAMIC WHEELSET DEFECT INSPECTION BY APPLYING ULTRASONIC TECHNOLOGY

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Abstracts. As one of the key components of the railway transportation, the condition of the railway wheelsets are essential, especially in the field of heavy-load and high-speed application. Normally, ultrasonic or magnetic particle testing is executed on the wheelsets detecting when the train is stopped for maintenance or after the wheelsets are disassembled from the train. A method for dynamic wheelsets defect inspection by applying ultrasonic technology is described in this paper. The defects in wheel rim and straight-shaped wheel disk can be detected when the train is passing by with a low speed of 5km/h typically. The inspection tracks are specially designed to make the tape line area of wheel tread be available for inspection. The ultrasonic probes are arrayed between the supporting track and the guiding track. The testing results show that Φ3mm side drill hole in wheel rim and wheel disk can be found out at the running speed of 3～10km/h. The system has been applied in Wuhan depot, China, which is used for Harmony Locomotive wheelsets defect inspection and about 200 wheelsets are inspected each day.

Key Words. Ultrasonic technology, Railway, Wheelset inspection, Dynamic testing

1. Introduction

Railway is one of the most important transportation in the world and its safety is paid much attention to. The Wheelset is one of the key components on train, and the failure of the wheelset may cause serious accident, especially in high-speed and heavy-load application. Some countries have had wheelset safety monitoring and inspecting system, such as Germany. German railway system (DB AG) has built an automatic safety guarantee system for wheelset with stationary wheelset ultrasonic testing system AURA [1, 2, 3] and mobile wheelset ultrasonic testing system UFPE [1, 4]. The automatic safety guarantee system for Chinese high-speed railway wheelset is consist of daily dynamic wheelset inspecting system, regular mobile wheelset inspecting system and

regular stationary wheelset inspecting system, as shown in table 1.

Table 1 Automatic safety guarantee system for Chinese high –speed railway wheelset

Order	Level	Periods	Inspection Items	Inspection system	Characteristic
1	Daily dynamic	Several days	Wheel tread	Dynamic wheelset inspecting system[5]	Wheelset is inspected when train is passing by.
2	Regular mobile	ab. 240,000 km	Wheel rim and disk	Mobile wheelset inspecting system	Train is stopped. Inspecting system moves to each wheelset.
3	Regular stationary	ab. 1.2 million km	Wheel rim and disk	Stationary wheelset inspecting system	Disassembled wheelset is inspected by stationary system.

For daily dynamic system, cracks on wheel tread can be inspected by EMAT (Electrical Magnetic Acoustic Testing) [5] now. However, the defects deep in wheel rim and wheel disk can not be tested with EMAT. With the help of the ultrasonic technology and inspecting system described in this paper, defects in wheel rim and wheel disk can be detected when the train is passing by with the speed of 3～10km/h. Chinese Harmony Locomotive and wheel are shown in Fig. 1.

Fig. 1. Chinese Harmony Locomotive and wheel

2. System inspecting principle

2.1 Specially designed Tracks

The tracks for dynamic wheelset defect inspection is specially designed and constructed in the field. First, monolithic bedding is needed to make the tracks stable and firm. Then, specially designed sleepers and tracks are installed on the monolithic bedding. The specially designed tracks are consisted of supporting tracks and guiding tracks, as showed in Fig. 2. The tracks are divided into three parts, guiding-in area tracks, inspection area tracks and guiding-out area tracks. The

guiding-in and guiding-out area tracks are used for the transition between inspection area tracks and normal tracks. The inspection area tracks are particularly designed for installing ultrasonic probe arrays.

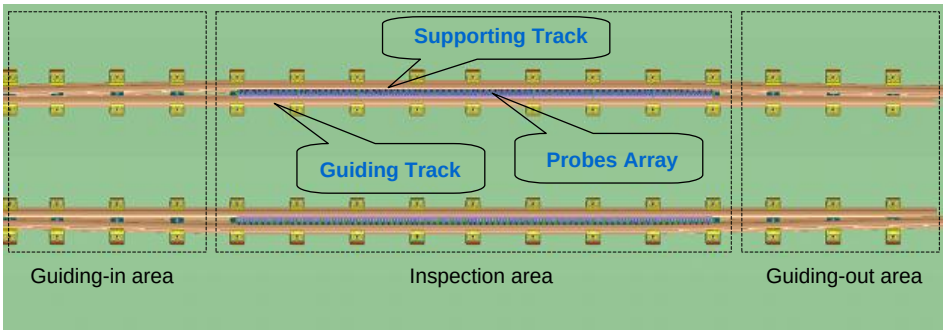

Fig. 2. Inspection field

Comparing with the normal rails, the rail head of inspection area are cut. For these inspecting rails, the contact area between rail and wheel tread is smaller than that on normal railway lines. When designing and installing the special inspection tracks, the area near wheel tread tape line need to be opened for ultrasonic inspection. The load of wheels is supported by the out side area of wheel tread. Because of this special designing and installing of the supporting tracks, the inner distance between two supporting tracks is wider than normal tracks. Guiding tracks are used to guide wheels going straightly and well supported on supporting tracks. By this way, the ultrasonic probe arrays are available to be installed for dynamic wheelset inspection.

The ultrasonic probe modules are arranged between supporting track and guiding track regularly, as shown in Fig. 3. The total length of the probe modules should be equal or longer than the maxim circumference of wheel which would be inspected to make sure that each wheel can be covered by ultrasonic signal with 360 degree. For each probe module, eight probes with different inspecting function are used. Each probe is supported by its spring to make sure that the probe can be well contacted with the passing wheels. The choice of the spring force is also important to keep the balance between contact condition and the lifetime of probe. If the spring force is too small, the probe can not adjust itself to fit the tread on time. Otherwise, the probe would be worn out quickly. The mechanical trigger devices are embedded in each module. Every transverse row of probes has one trigger device which is parallel to the probes. When the passing wheel is right on these probes, the correlative ultrasonic electronic channels connected to these probes will be fired by the trigger device. The ultrasonic signal are generated and transmitted into the wheel body by coupling water.

Each module has several small nozzles for supplying coupling water.

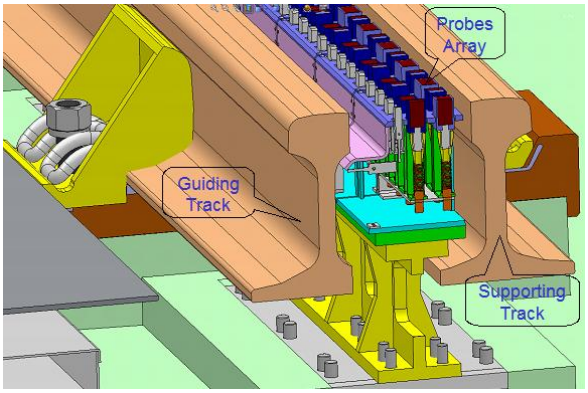

Fig. 3. Inspection tracks and probe array

2.2 Ultrasonic technology method

Using ultrasonic technology is the key part of the system, especially the parameter design of probes and the arrangement of the probes in each module. Considering the great number of the probes which are needed for the system, multiplexers are applied between the ultrasonic electronic channels and the probes to decrease the cost of the system. The probes arranged in the modules can make the system easy to operate and maintain. The probe type and arrangement should be well designed according to the wheel type, defect size and position which are concerned.

The probe arrangement in one module for Chinese Harmony locomotive is shown in Fig. 4.

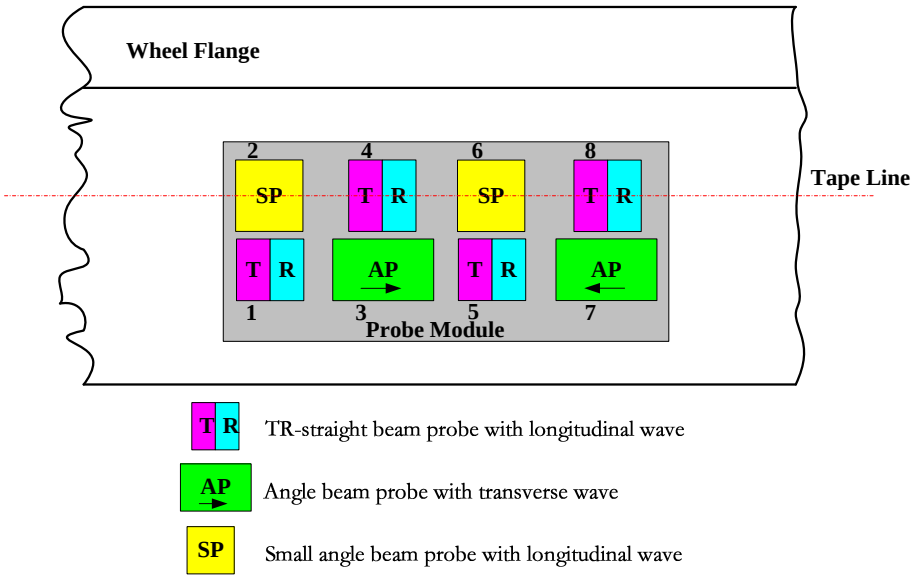

Fig. 4. The probe arrangement for each module

Three type of probes are used, TR-probe (TR straight beam probe with longitudinal wave),

AP-probe (Angle beam probe with transverse wave), SP-probe (Small angle beam probe with longitudinal wave), as shown in Fig. 4. Considering the size of the probes and their fixing brackets, the circumference of the wheel tread can not be covered continuously by ultrasonic signal. So, the risks of missing small defects do exist. However, with the help of the ultrasonic beam divergence angle and the circular shape of the wheel, the defect detecting ability of the system is well increased and the application requirements can be achieved. In conclusion, the arrangement of the probes is very important for application requirement, such as defect type and resolution.

1. Working principle of TR-probe

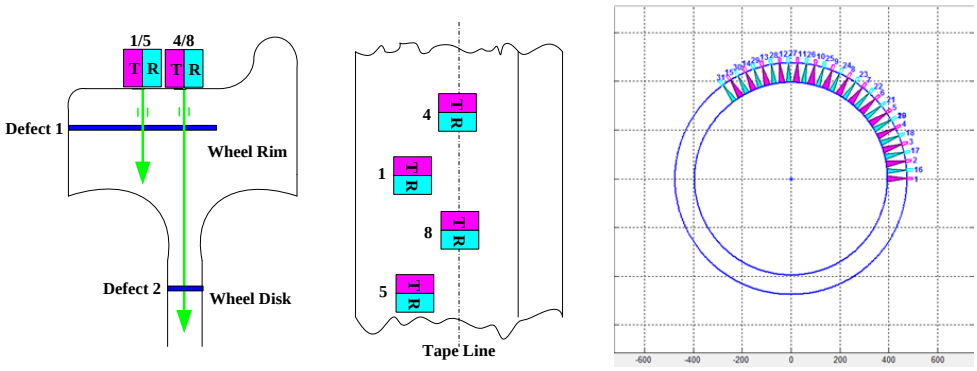

Fig. 5. Working principle of TR-probe

Four TR-probes are arranged on wheel tread area in one probe module. Probe No.4 and No.8 are located exactly on the tape line. Probe No.1 and No.5 are located on the outer part of tread. The circumferential defects with depth from 5mm to 200mm on wheel rim and wheel disk can be detected. Two separate crystals, transmitter crystal and receiver crystal, are used in this type of probes. The focus point of the TR-probes is at about 10mm depth below the wheel tread and small blind area can be achieved. TR-probes are especially good for the detection of the circumferential defects which are easy to happen under wheel tread. The ultrasonic signal from TR-probes located on the tape line can also go deep to the upper part of wheel disk for defect detecting. The arrangement and working principle of TR-probes are shown in Fig. 5.

2. Working principle of SP-probe

Two SP-probes No.2 and No.6 which are interlaced with TR-probes are located on the tape line. The circumferential defects with depth from 30mm to 400mm in wheel rim and wheel disk can be detected by using SP-probe. With a big single crystal, more energy can be generated to make the ultrasonic signal cover even to wheel hub. Because of the big blind area in near field, SP-probe is

mainly for the circumferential defects which are deep in wheel disk. The arrangement and working principle of SP-probes are shown in Fig. 6.

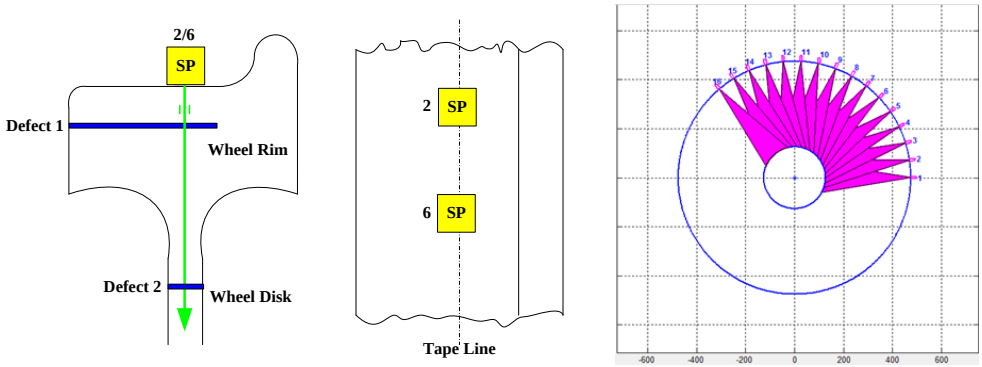

Fig. 6. Working principle of SP-probe

3. Working principle of AP-probe

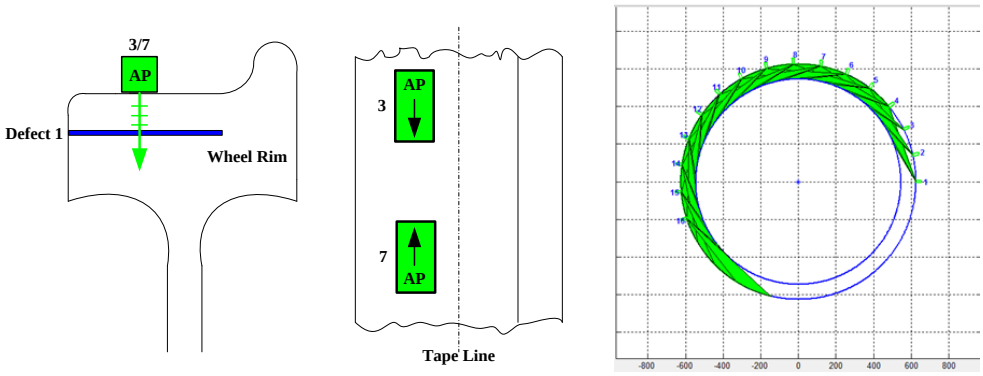

Fig. 7. Working principle of AP-probe

Two AP-probes No.3 and No.7 which are interlaced with TR-probes are located on the outer part of wheel tread. Radial defects with depth from 5mm to about 80mm in wheel rim can be found with AP-probes. The maxim inspection depth for AP-probe also depends on the diameter of the wheel. With a big single crystal, more energy can be generated to make ultrasonic signal cover the main parts of wheel rim. AP-probe is mainly for radial defects in wheel rim, cracks on tread or in the corner of the wheel rim, and some tread spalling. The beams of AP-probes No.3 and No.7 are used with clockwise and anti-clockwise directions to increase the defect detecting ability. The arrangement and working principle of AP-probes are shown in Fig. 7.

3. System composition

The whole system consists of three parts, inspection field, system control unit in the field and remote control terminal, as shown in Fig. 8.

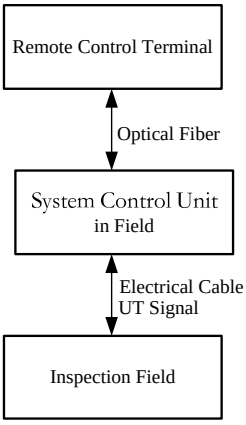

Fig. 8. System composition

Inspection field are the main part of the system. It is composed of specially designed tracks, ultrasonic probe modules, ultrasonic electronic units, trigger devices for ultrasonic signal, coupling water supplying system, wheel zero point marking device, system start and stop sensor and speed inspecting device, as shown in Fig. 9. With the help of different sensors and devices, all the inspection flow can be executed automatically.

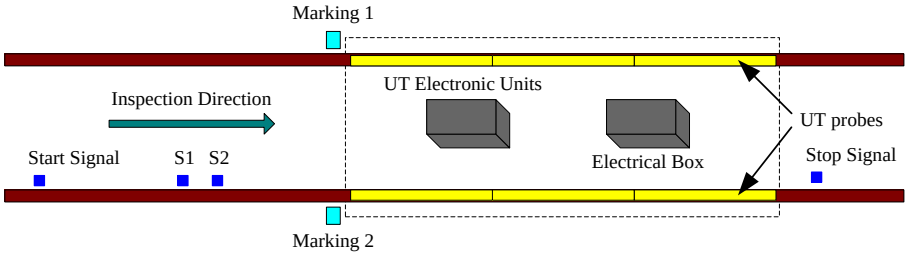

Fig. 9. Inspection field

System control unit is located on one side of the inspection field. Automatic control device, electrical control system and ultrasonic signal acquisition PC are included. All parts in inspection field can work in fully-automatic mode or manual mode. The ultrasonic testing data can be stored in acquisition PC and then transferred to remote control terminal by network.

The remote control terminal is located in data analyzing center. It is a powerful PC with data analyzing software, testing reporting, and data base. The inspection data is analyzed on the terminal PC by analyst. System status, defects on wheels and testing report are achieved here. The real-time system monitoring video in inspection field can also be transferred and displayed on terminal PC.

4. Testing results

A part of the system with probe modules in working position is shown in Fig. 10.

Fig. 10. Probe modules in working position

In case of dynamic inspection, the trigger position for ultrasonic testing should be very accurate. It means the best testing results are obtained when the wheel is exact on the probes. If the trigger is generated before or after the right position, the bad coupling and contacting condition between probe and wheel tread would cause inspection failure. The typical testing results of three types of probes are given as following.

1. The typical testing result for Φ3mm side drill hole with 40mm depth by using TR-probe is shown in Fig. 11. The B-scan of the ultrasonic data is shown on the left and one of the A-scan is shown on the right.

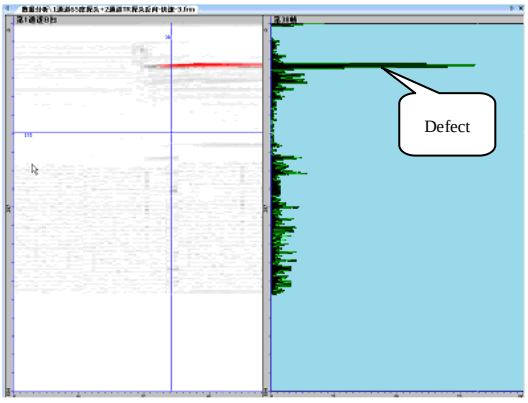

Fig. 11. TR-probe testing result

2. The typical testing result for Φ3mm side drill hole with 10mm and 30mm depth by using AP-probe is shown in Fig. 12. The B-scan of the ultrasonic data is shown on the left and one of the A-scan is shown on the right.

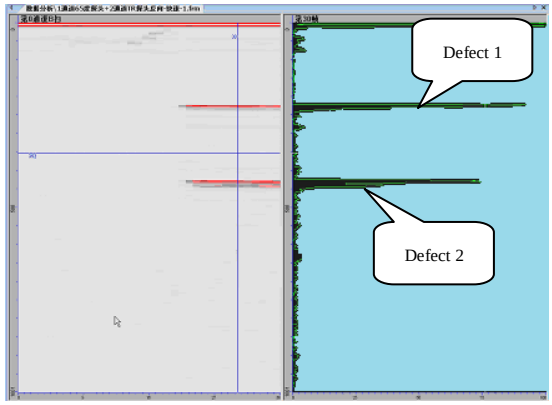

Fig. 12. AP-probe testing result

3. The typical testing result for Φ3mm side drill hole with 222mm depth on wheel disk by using SP-probe is shown in Fig. 13. The B-scan of the ultrasonic data is shown on the left and one of the A-scan is shown on the right. The back echo from wheel hub can be seen clearly.

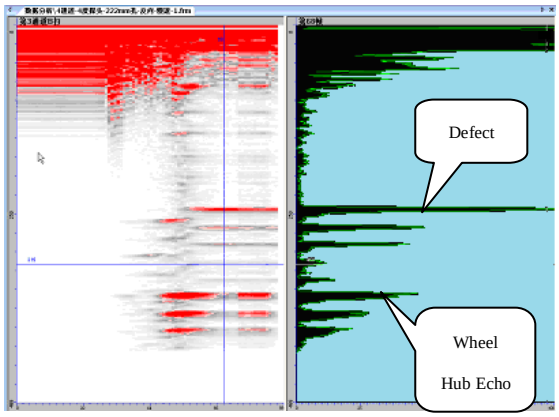

Fig. 13. SP-probe testing result

5. Summary

A dynamic wheelset defect inspection system by using ultrasonic technology is introduced in this paper. Fully-covered ultrasonic inspection is executed on wheel rim and wheel disk when train is passing by the inspection field. System layout and the key components are given, and the ultrasonic testing principle and the probe module designing for Chinese Harmony locomotive wheelset are described in detail. The typical dynamic testing results achieved by three types of probes are given at last.

At the moment, the system named ‘LD series dynamic wheelset defects detecting system’ based on this technology is applied in Wuhan depot, China for Harmony Locomotive. About 200 wheelsets are inspected each day by the system.

References

[1] B. Rockstroh, W. Kappes, F. Walte, et al., *Ultrasonic and Eddy-Current Inspection of Rail Wheels and Wheel Set Axles*, 17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

[2] Kappes, W., Rockstroh, B., Bähr, W., et al., *Application of new front-end electronics for non-destructive testing of railroad wheel sets*, Journal Reprints, Insight Vol. 49 No. 6, June 2007, P. 345 – 349

[3] B. Rockstroh, W. Kappes, F. Walte, J. Montnacher, R. Seitz, H. Hintze, R. Ettlich, *Automated Ultrasonic Testing of Railroad Wheel Sets, EI - Eisenbahningenieur*, 7/2001, Tetzlaff Verlag GmbH, Hamburg [journal]

[4] G Engl, R Meier, H Hintze and R Ettlich, *Advanced in on-train inspection of high-speed train wheels by the new generation of UFPE system*, Paper, European Conference on Nondestructive Testing, Berlin, 2006

[5] Hans-Juergen SALZBURGER, Li WANG, Xiaorong GAO, *In-Motion Ultrasonic Testing of the Tread of High-Speed Railway Wheels using the Inspection System AUROPA III*, 17thWCNDT, 25-28 Oct 2008, Shanghai, China