MOBILE INSPECTIONS OF RAILWAY WHEELS WITH UFPE AND ITS LIGHT VERSION

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ABSTRACT

Curved tracks, different stresses of load, wear and fatigue are potential challenges to cause a failure while the railway operates. Non-destructive testing with ultrasonic systems is a preventive method to inspect the wheels while they are mounted to the train. To bring down the cost of dismantling during maintenance and improve the service performance it is useful to place a mobile test rig underneath the train, between or beside the rail. With UFPE (underfloor testing equipment) and UFPE-light, currently Deutsche Bahn AG uses mechanized systems for driving- and carrying wheels with phased-array technology and standard probes to prevent a defect while the railway is operating.

In 2000, the Deutsche Bahn AG started the ultrasonic testing for wheels in mounted position. This conventional method includes a V-transmission with standard probes. These probe holders had an enormous dimension and it turned out to be very difficult to get it between the wheel housing, wheel and rail. To achieve a higher availability of trains and lower test time, wheels had to be tested by special mechanized test equipment. After introduction of a new maintenance concept for ICE trains in 2004, new UFPE were ordered and UFPE-Light, an innovative light version of UFPE from DB Systemtechnik GmbH, was supplied to the market. With this new version the testing procedure was simplified and the testing time for one wheelset could be reduced to 10 min. Several economic and security reasons suggest the need for the inspection of high speed trains and carriage wagons. The advantages of novel (non-destructive) technology compared to traditional maintenance are as follows:

- Reducing the time of testing and maintenance
- Obtaining reproducible testing results
- Automated electronic documentation of results
- Adaptable to new wheel parameters
- Accessibility of wheels without dismantling of components
- Consistent sensitivity over all wheel sets by using an adjusting device

Today, ten years later, the checks are mainly done at night to prevent an additional immobilization time. In the meantime, while everything is done on and inside the train, wheelsets are tested simultaneously. Only qualified inspectors in ultrasonic testing are admitted by DB Systemtechnik GmbH to the instruments and applications. The system sensitivities are set to any category of wheels and due to the training of employees, small cracks, damage in the material and even production-related failures have been detected in the past.

Keywords: ultrasonic testing (UT), railway, wheel-inspection, underfloor test equipment (UFPE), Phased-Array,

2. INTRODUCTION

Railway wheels are commonly classified as carrying and driving wheels. Intercity Express (ICE) trains are tested at near-service conditions with underfloor testing equipment (UFPE) and UFPE-light. The difference between those two is the amount of inspection. Wheels with mounting holes for the engine or disk brakes need to get a bigger scope of testing which is provided by UFPE. Thus, the wheel disks are added to the ultrasonic software in order to fulfill these especially adapted NDT standards. The UFPE-Light takes over the testing of two dimensional flaws underneath the tread in the wheel rim.
Block-braked wheels, mainly used in freight transportation, exhibit different load and stress conditions than disk-braked wheels, which are primarily installed in high-speed trains. In contrast to high-speed trains, the heat-affected zone on the tread of freight wagon wheels got a potential cracking fissuration, which is tested in dismounted condition. Those wheels are also tested at DB AG but the topic of automatic wheel test in dismounted condition RPS is not considered here. The scope of testing between RPS and UFPE is equal. Due to occasional fatal events wheels used for passenger trains are under increased observation. Railway wheels must be examined periodically. The length of the test interval depends on the level of the dynamic load or the exact usage of the vehicle. The likelihood of a failure should be reduced as far as possible. Therefore, the tolerance must be low enough to prevent a flaw from spreading to a level where it would be a serious danger. With endurance and crack propagation tests it is possible to specify the ideal ultrasonic technical inspection interval. The test equipment for the mounted wheelsets in Germany is certified every year by DB Systemtechnik GmbH.

2.1 UFPE

The underfloor testing equipment (UFPE) provides a test at DB maintenance facilities to inspect wheelsets with ultrasonic in installed condition. Particularly in the field of high-speed trains, every wheel has to be checked. Besides the wheel flanges, especially the disk is in the focus of the test. The wheel disks possess several and different types of designs and differ in their transversal sections. Incorrect signals and wave mode changes of different reflection angles in the curved cross section are problematic to test from the tread. Because of the ultrasonic shadow from the tread, the wheel hub cannot be completely tested in mounted position. This cannot be avoided since coupling of the ultrasonic waves needs to be done without hand test at the time of maintenance. However, typically no cracks are generated in this section.

A special feature is the V-transmission which is used to detect failures underneath the boreholes in the wheel disk, in any kind of orientation. For this method the probes must have a defined gap apart from each other. Reference Reflectors with different dimensions and depth simulate the scope of possible error occurrences.

For straight wheel disks, loss compensation has to be posed to compare the flaw dimension with the real indicated reference defects in different depths. The sensitivity of signals has to be varied in different gates to get the same signals heights. In the critical depth for potential crack incidence, like tangential-axial and axial-radial flaws in the rim and disk, reference holes and saw cuts are impleaded in a reference wheelset.
Transversal and longitudinal ultrasonic waves are coupled into the wheel using different probes. The software has to calculate the change of wave speed and intromission angles to get the difference between special ultrasonic characteristics, like the grazing incidence, back-wall echos and discontinuity echo. The first UFPE generation was developed in cooperation between DB, BAM (German department of material research), IZFP and TEG and is currently in use at several DB facilities. Probes with diverse angles of refraction in different coupling sections and insonification back- and forward provides a 100% test of the wheel flange and disk.

A premise for the second UFPE generation was a significantly lower overall size of the test unit in order to simplify its problematic placement between wheel and wheel housing. This was achieved by using phased array technology. Now, DB Systemtechnik and intelligeNDT System & Services Erlangen has developed the second generations of UFPE. The lifting and turning devices and trigger mechanism for the probe system are the main parts of this device. The steering mechanism of Siemens Simatic S7 is moving the probes to the coupling point on the tread. With eight phased array probes (2 and 3 MHz), which are able to slew horizontally and vertically, the scope of testing has been preserved despite inferior coupling surface. The main item is the 112-channel phased array ultrasonic device Saphir plus, produced by iNDT. It allows the evaluation of Test data offline. To test all different types of wheels at DB, 88 cycles had to be written and checked under service conditions. In additions to the probes mentioned above, conventional probes are used with constant beam angles. [1]

The vertical probes are using pulse echo and transceiver techniques. One probe is covering a large section of the wheel’s disk. This section is further expanded with the help of phased array technological to transmit or receive the sound from the other probe. Figure 2 and 3 show the sections which are tested on the wheel. Besides the coupling from the tread, UFPE is using the flange backside to initiate the sound. The flange backside provides a vertical coupling surface for testing the flange dome (Figure 3 “yellow triangle”) and vertical intromission of sound to the outer surface of the wheel. (Figure 3 “red triangle”) Within 30 minutes a wheelset can be tested. This includes the pre and post feed motions and the test cycle. The control system of UFPE 2 is, beside the new Phased array technology, a completely novel invention. Every train has different wheel housings and thus altered free space around the wheel. With an Automatic driveway program from variable positions underneath the trains, the probe-holders make a static drive to the wheel. Coupling with water is for ecological reasons the state of the technology.
Meanwhile, the third generation is out to tender. DB Systemtechnik GmbH accompanies the procedure of purchasing of technical equipment with special knowledge in Non-destructive testing. Figure 4 shows a Tomography Data analysis scan of a driving wheel with 18 boreholes, nine reference flaws in the disk and four in the rim. To get reproducible results, a reference wheelset has to be build. The wheelset consists of two different wheel disks and an axle. The sensitivity of the wheels varies especially in the sections of the boreholes. DB Systemtechnik inserts boreholes and saw cuts in relation to potential cracks. Every probe has to detect the synthetic flaws to check and recheck the probe. This comes to pass pre and post the vehicle test.

### 2.2 UFPE-LIGHT

In comparison UFPE, wheels, which are tested with UFPE-light, the scope of test reduced down to the wheel rim, but the wheels are still mounted on trains. The UFPE-Light is a special version of the previously considered UFPE to provide a test of the high deposition section of the wheel rim (Figure 6). The rig is equipped with two probe holders, Ultrasonic test equipment and a specific reference standard wheel, charged by a reference drilled hole to get reproducible results. A mobile workshop carries an additional 50 liters water pack to test four wheelsets without refilling (Figure 5).
This device identifies two-dimensional Material separations below the surface. At this point, errors occur due to an existing biaxial state of stress. Compressive and shear stresses occur due to the weight of the train having an impact on the track and, in addition, introducing torsional forces into the wheel. These stresses reach their maximum at 5 to 25 mm below the tread and expand 30 to 40 mm further along the tread induced by the sinusoidal run between wheel and rail (Figure 6). Under these prerequisites, which repeats every 360° by contact with the rail at one point, small defects or material inclusions (sulfides, manganese, etc.) increase a potential issue. The sizing technique, which enables an estimate of the size of a discontinuity, is an acceptance level of maintenance with a disk shape reflector (DSR) with 4 mm added by 6 decibel (DIN 27201-7). In comparison to the manual test of one wheel rim within 60 minutes, testing with UFPE-Light reduces the time to 10 minutes for each wheelset with a reproducible result. More difficult than dissolution of the tread, is the abscission of the flange.

The Scan displays the depth and the exception reporting of the result. Transmitter and receiver probes have their focal zone 14 mm underneath the surface. Wear plates with a defined water delay path prevent an early wear of the probe contact area. The Ultrasonic system provides the evaluation software with an A-Scan and a bar graph of each probe trace for a simply analyzable acquisition (Figure 7/8). The measurement of the peak is foundation of the bar graph. While the wheel is turning with a continuous speed and the peak is above the reporting level, it shows the operator a reflection of the flaw. The trace of the probe is turning red. After calculate time to circumference the result is evaluable by the user.

The expanded time-base sweep reproduces the discontinuity and gives it out in the exact depth. Afterwards, flaws underneath the surface of the wheel can be purged with a wheel lathe. Re-profiling of the wheels brings down the cost of dismantling the whole wheelset. The wear notch is the limit of trimming wheels. The reflectivity of voluminous reflectors depends on the direction of the error. Typically, two-dimensional defect are parallel disposed to the tread.

Figure 6: wheel rim sectional representation

Figure 7: evaluation by A-Scan presentation

Figure 8: analysis by bar graph (check)
3. A VIEW INTO THE FUTURE OF WHEEL TESTING

In future, UFPE-Light will be able to test the flange dome additionally with fixed probes and a static beam angle. With a straight beam, a probe will send the signal straight through the rim to the outside face of the rim. As evaluation, it would be possible to make a check for coupling control or a back wall echo drop for defects in vertical direction to the tread or sinkholes, which were already detected in the past. An additional probe holder with light material (Aluminum, steel with weight reducing holes, etc.) could be coupling probes from the flange backside. This means an extra moveable part to handle for the operators. The tightrope walks between easy to handle and tough enough against the railway conditions, will be a challenge.

The third UFPE generation will replace bit by bit the old machines in the plants, which are already in use since 2000 and equipped with phased array technology since 2004. The oldest rigs in Frankfurt will be replaced in 2015. Afterwards it will be a period of four month trail operation until the acceptance from DB AG concluding the process of the new UFPE generation. Thus all DB plants are well prepared for the future. All main mainenances plants are organized and equipped with new technology of ultrasonics. With new options to set up and adjust the software for wheels, the possibility to react in a minimum of time to new bought railway vehicles or wheel constructions is given.

4. CONCLUSION

Deutsche Bahn AG is testing all ICE wheelsets with UFPE, RPS and UFPE-Light. Nominal was it almost 13.000 tested wheelsets in 2013. Ten UFPE-Lights und seven UFPE in seven plants spread across Germany, carry out the high-speed train testing every day and night. DB Systemtechnik GmbH has also worked as consultant for the first wheel test device in Sankt Petersburg (Russian Federation) in 2013. In average there are 10 qualified operators (DIN EN ISO 9712 UT1) and one overhead (UT2) in each plant. The people, who are driving the rigs, have to work with it every three month in order to keep their admission and thus to avoid another training lesson. In addition, the overheads and inspectors get an update and a field report of knowhow to identify potential deficiencies from DB Systemtechnik GmbH. Shrinking holes and flaws with highly jointed surfaces were found in the past with the wheel testing rigs.

DB Systemtechnik provides technical specifications and inspection instructions for new developed ultrasonic test rigs. An engineering approval and permission with certificates will be permitted after the operating test of the rig is passed. Especially UFPE-Lights inspection instruction includes a user manual, besides the characteristically regularity links. The usage of the rig is shown step by step added by the evaluation of indications.

New technologies of Ultrasonic testing (Phased-array), revised feed motion and experience, still make the railway service in Germany safer and in economic aspects superior to previous generations. In Summary, the UFPE technology is since about 13 years an established device of NDT in the railway industry.

References