New Ultrasound Testing Systems for the Production Testing of Rail Wheels

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Abstract. Previous standards for the manufacturing inspection of railroad wheels using ultrasound, such as UIC 812, have been replaced by new standards, for example EN 13262 and RD32.144-2000, both requiring ultrasonic testing in immersion technique.
These new standards require the development of an ultrasonic technique for 100% coverage of the wheel rim and wheel hub, and in special cases for both straight and curved wheel disks.
In order to encompass a large variety of railroad wheel designs, inspection and handling techniques should be capable of dealing with wheel diameters ranging from 600 mm to 1300 mm (23" to 51") at testing cycles from 1 to 4 minutes per wheel.
The current requirement for the minimum detectable flaw size is DSR 1 mm (disc shape reflector, DSR, 1 mm diameter) for high-speed train wheels rims and DSR 2mm for all other wheel rims. The minimum detectable flaw size for all other wheel areas (hub and disk areas) is DSR 3 mm.
To meet all these criteria, the Rail Wheel Inspection (RWI) System was developed by IZFP and their partners. The system consists of an ultrasonic testing sub-system, immersion tank and transportation/handling sub-systems. Test cycles of 1 minute per wheel require two immersion tanks and two transportation/handling sub-systems. The ultrasonic sub-system features modular computer-aided 6 to 16-channel UT electronics (PCUS 11) to employ 6 to 16 ultrasonic transducers (the precise number is determined by the testing procedure).
This presentation paper offers descriptions of, and results from three of these systems that have been integrated into manufacturing processes at German and Russian wheel manufacturers, and provides details on the following topics:
Wheel rim inspection, single-tank immersion technique, 4 minutes inspection cycle per wheel (Bochum, Germany)
Wheel rim, hub and disc inspection, single-tank immersion technique, 2 minutes inspection cycle per wheel (Ilsenburg, Germany)
Wheel rim, hub and disc inspection, dual-tank immersion technique, 1 minute inspection cycle per wheel (Nishny-Tagil, Russia)

Introduction

Rail wheels are exposed to great dynamic loads in the transportation of goods and passengers. High-speed rail traffic and the transportation of cost-intensive and hazardous goods call for high quality in rail wheels as an important prerequisite for safe, trouble-free running.

Heavily loaded wheels, (e.g. ICE train wheels) must conform to the requirements of European standard EN 13 262. Ultrasonic testing is being used for the inspection.

1. Automatic wheel testing unit for the Bochumer Verein Verkehrstechnik GmbH

An automatic wheel-testing unit for BVV, the *Bochumer Verein Verkehrstechnik GmbH*, was projected, constructed and commissioned.

The aim was to fulfil the following functions:

- ultrasonic detection of minute internal defects in accordance with EN 13 262
- observance of a 10 mm dead zone corresponding to the surface quality of the wheel
- cycle times of four minutes (between removal and return of the wheel to the production line)
- two minutes testing-time per wheel
- option for the testing of the wheel disc and wheel hub

Wheel diameter:	690-1350 mm
Weight:	max. 900 kg
Defect detection threshold:	1 mm DSR

On the basis of the AURA testing-systems developed by the Fraunhofer IZFP Saarbrücken for rail wheel sets, the automatic ultrasound system RWI (Rail Wheel Inspection) for the testing of individual single wheels was developed and put in operation using test wheels and test wheel tyres. [1 / 2 / 3]

Unlike the AURA testing-units for wheel sets, which work with contact search units and running water as a couplant, the RWI system employs the immersion technique. Figure 1 gives a general view of the ultrasonic RWI system at BVV. The basic RWI testing-system is designed for the ultrasonic vertical-beam testing of wheel tyres and solid wheels without the need for mechanical retooling, and requires between five and twelve pulse-echo probes.

Optionally, the disc, the hub and the flange can be tested on solid wheels, and it is also possible to carry out angle-beam testing from the inner rim face. The entire testing-system, with all options, requires some 13 pulse-echo probes. For the correlation of indications which originate in the area of stamp-marking on the outer wheel rim face, a broad-angle beam transducer is used in angle-beam testing.

For complete coverage of the test area, the wheel or wheel tyre is revolved several times, and the probes are repositioned across the axis after each revolution.

Fig. 1: the BVV ultrasonic wheel testing system

An option in RWI is the retrofitting of a probe system carrier for the testing of the hub and the wheel disc.

The system allows:

- short testing-time per wheel
- automatic wheel handling
- easy operation of systems due to user-friendly software module
- maintenance and repair-friendly thanks to integrated function checks and remote diagnostics via ISDN for UT and control electronics
- immediate documentation of test results
- facility for post-analysis of A, B, C and TD scans
- simple compilation of quality-assured documentation on wheel test results
- CAD visualisation of test functions and monitoring sensors
- verifiability and documentation of the operability of the system in accordance with standards

2. Ultrasonic wheel testing unit for the wheel set factory Ilsenburg

Incorporating the experience gained from BVV, another wheel testing system was designed, constructed and deployed on continuous duty for RAFIL, the wheel set factory in Ilsenburg.

The aim was to fulfil the following requirements:

- testing sensitivity corresponding to DSR 1 mm
- 10 mm dead zone beneath scanning zone
- automated testing procedures
- cycle time approx. 2 min. (without testing of discs and hubs)
- no mechanical retooling necessary to cope with differences in wheel diameter
- automatic evaluation of test data
- complete documentation and backup of test results

The Fraunhofer IZFP PCUS 11F circuit board was used for ultrasonic testing. 14-UT-channel electronics with 2 reserve channels were also used. As a backup to trouble-free

continuous duty, remote diagnostics and remote maintenance were possible via ISDN for the UT PC and control electronics.

Figure 2 offers a general view of the ultrasonic inspection tank with its gripper.

Fig. 2: General view of the RAFIL RWI testing system

3. Ultrasonic wheel testing system for the Metal Combine Nishny-Tagil (NTMK)

During the reorganisation of the wheel rolling-mill in the Metal Combine Nishny-Tagil (NTMK), the manufacturing inspection of railway wheels was modernised by adaptation to an automated ultrasonic wheel testing system [4 / 5].
The new ultrasonic wheel testing system for the NTMK needed to fulfil the following requirements:

- testing sensitivity corresponding to DSR 1 mm
- 13 ultrasonic sensors per inspection tank, 16-channel UT electronics
- approx. 5 mm dead zone beneath scanning zone and corresponding to the surface quality of the wheel
- testing areas: wheel flange, wheel rim, disc, hub and stamp recognition
- automated testing by means of two immersion tanks
- cycle time: 1 minute per wheel (without disc testing)
- disc testing on every tenth wheel
- no mechanical retooling necessary for diameters to be tested
- automatic evaluation via C-scan image
- complete documentation and storage of test result data
- data analysis with HF data input
- 4 A-scans on the on-line monitor
- remote diagnostics for the UT and control electronics via the Internet

On account of the high production output of one wheel per minute, 22 hours per day and the high testing-speed (approx. 750 mm/sec) associated with it, it was necessary to develop, build and test new, fast 16-channel UT electronics (PCUS 11F) and a two-tank testing system (two inspection tanks and two special cranes, including the sophisticated control electronics). However, some major tasks also needed to be fulfilled on the hardware side, in particular for the complex control, evaluation and documentation software. Under the project management of the Fraunhofer IZFP in Saarbrücken, those working jointly on the wheel-testing system included the Fraunhofer TEG in Stuttgart, *Spezialkrane Frömberg*, Arxes GmbH Berlin and a group of Russian engineers. The high defect detection sensitivity of DSR 1 mm on the wheels to be tested, which had not yet been turned off on the lathe, and the heavy demands made by continuous duty, 22 hours per day in a 7-day working-week, posed some serious challenges here.

The following testing-norms were to be met by the RWI system:

- RD 32.144-2000
- EN 13 262
- UIC 812-3V
- AAR M 107-84
- ISO 5948
- DB-TL 918 272
- AFNOR 09-340
- AFNOR ND-FOII-142
- DIN/EN 473 and GOST 30489

Figure 3 is a depiction of the ultrasonic two-tank inspection system. It comprises 2 inspection electronics systems (each with 16 channels), 2 inspection tanks, one craneway and 2 robots for the transfer of the wheel into and out of the inspection tank and a measuring-bar for the geometric control of wheel diameter.

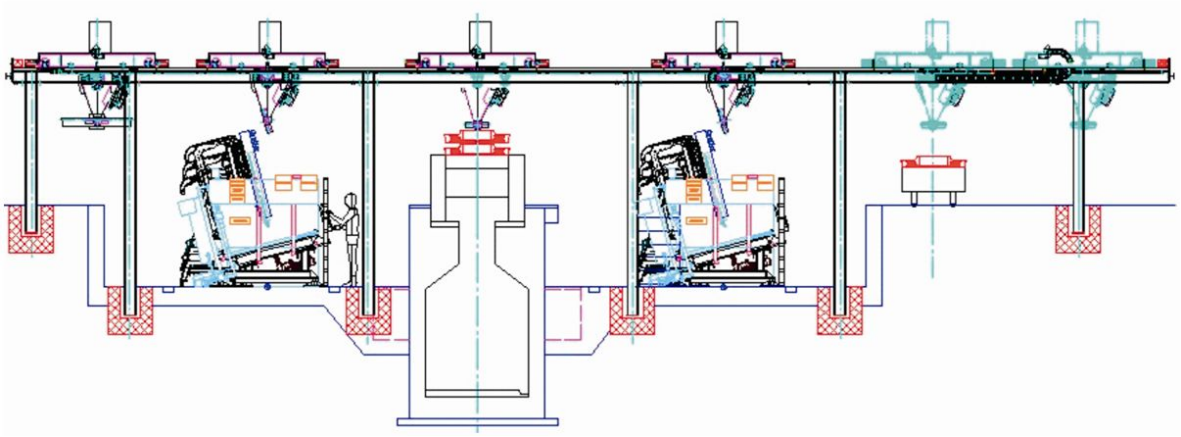

Fig. 3: ultrasonic two-tank testing system

Figure 4 is a 3-D depiction of the immersion tank.

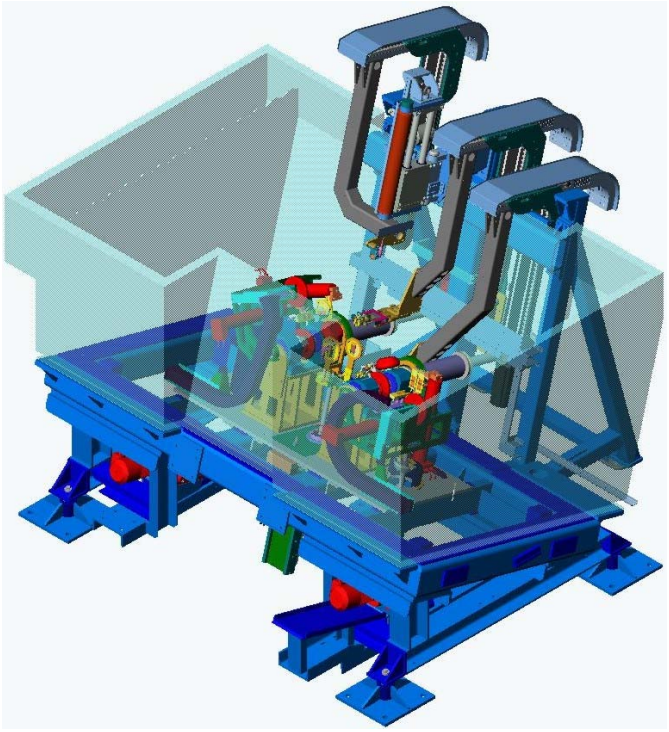

Fig. 4: immersion tank

Figure 5 shows submerged mechanisms in the inspection tank.

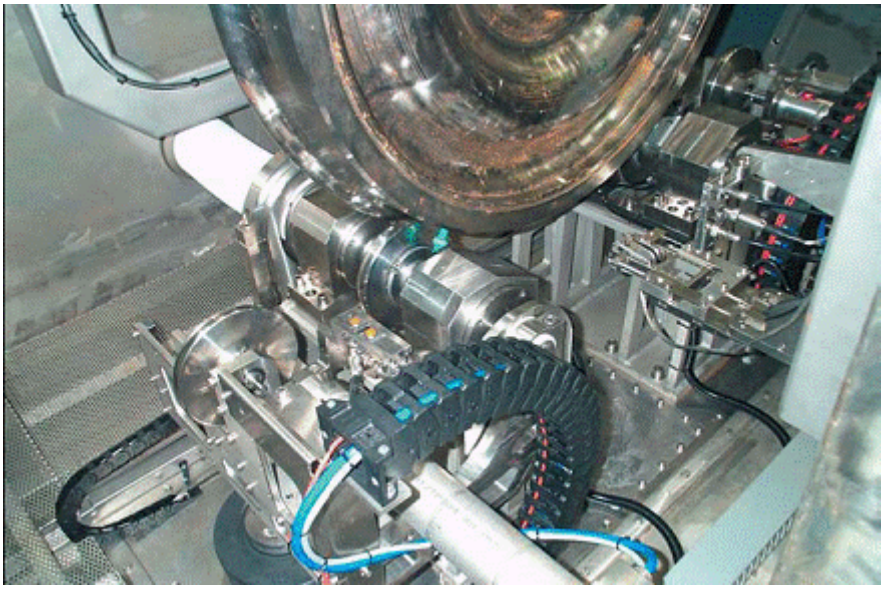

Fig. 5: submerged mechanisms in the inspection tank

Figure 6 is an overview of the system as a whole.

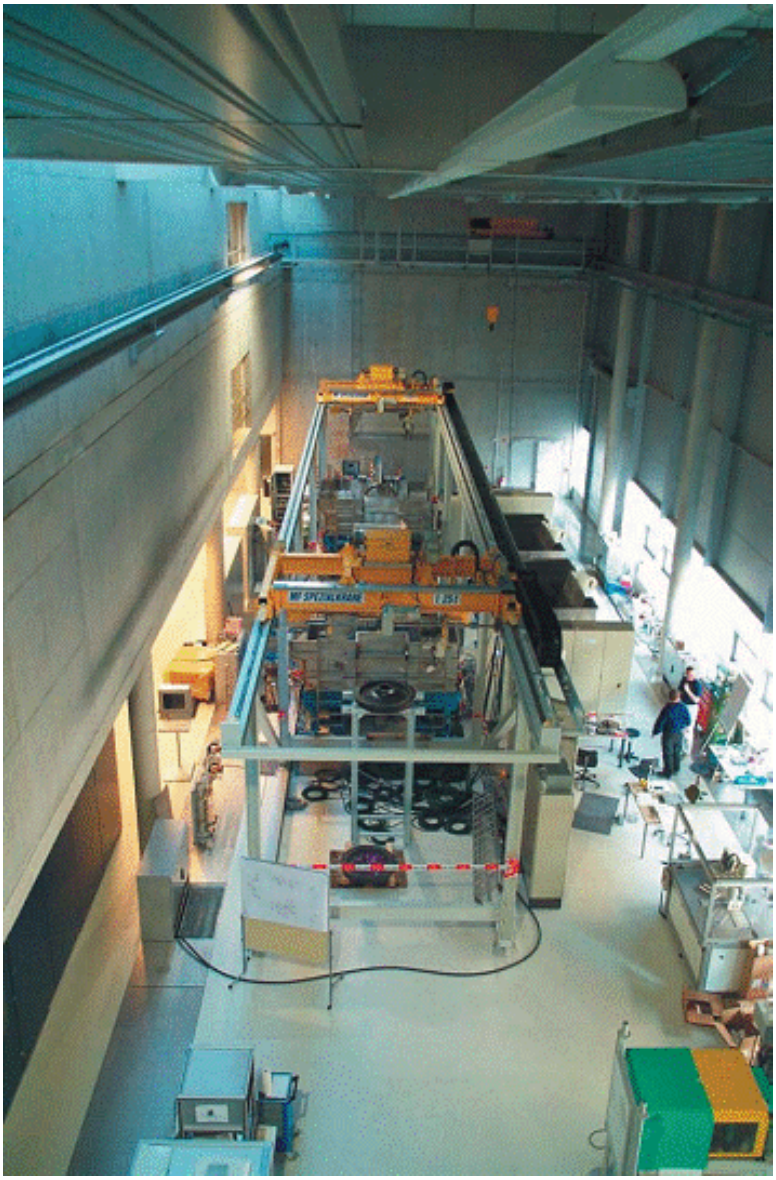

Fig. 6: the system as a whole

Having undergone final acceptance by the customer, the first ultrasonic wheel testing system at the NTMK was deployed on continuous duty and was able to be released from guarantee on February 24th 2006. A second ultrasonic wheel testing system is to follow. During the guarantee period, the Russian and German colleagues involved worked together in a very professional manner. Indeed, good cooperation was the only way in which the high demands posed by continuous duty at 22 hours per day could possibly be met.

Figure 7 shows the RWI-System installed in the Metal Combine Nishny-Tagil (NTMK).

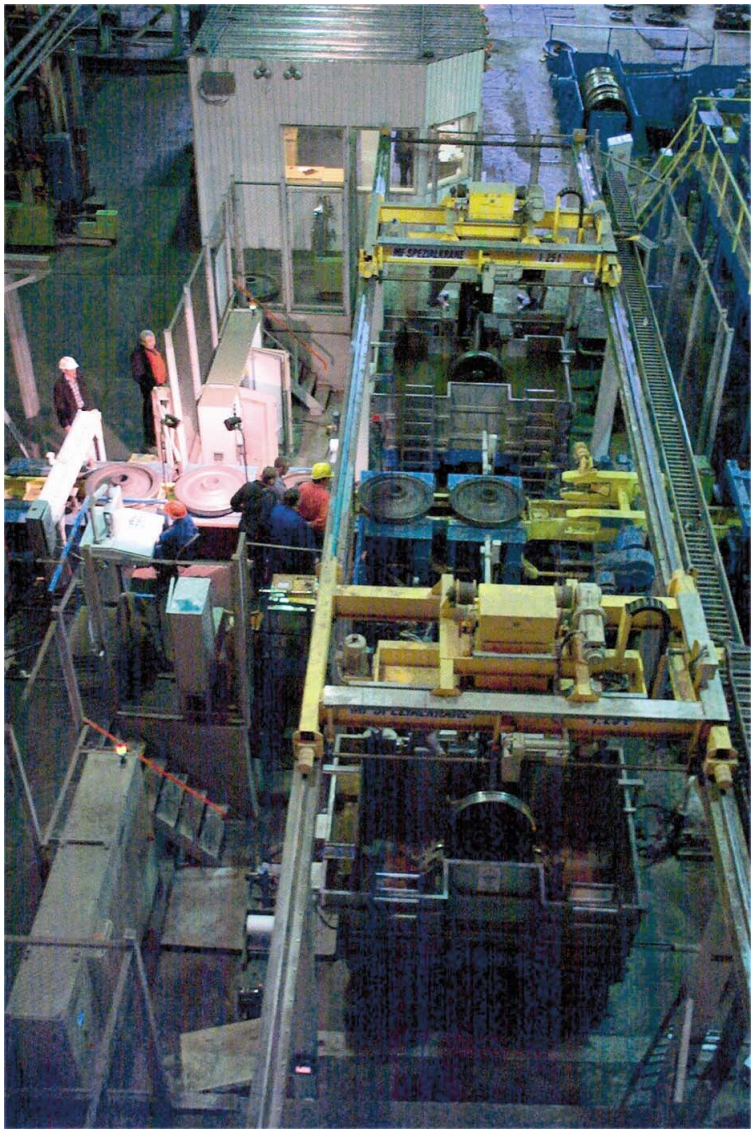

Fig. 7: NTMK ultrasonic wheel testing system

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