



RAWIS: The Next Generation of Automated Inspection Systems for Railway Wheels

Andreas KNAM¹, Thomas SCHWENDER², Wolfgang KAPPES²,
Rolf BAUMGARTEN³

¹ ROSEN Technology & Research Center GmbH, Stutensee, Germany

² Fraunhofer-Institut für Zerstörungsfreie Prüfverfahren IZFP, Saarbrücken, Germany

³ ROSEN Germany GmbH, Stutensee, Germany

Contact e-mail: aknam@rosen-group.com

Abstract. Railway wheels are exposed to great dynamic stress. For this reason, they need to be subjected to non-destructive inspection during the manufacturing process with the aim of detecting material flaws that may have been caused during manufacture.

In accordance with the current state of technology, the inspection is carried out using automated inspection systems.

The challenge was to design a system which guarantees a sensitivity of FBH 1 mm, a dead zone of 5 mm beneath the test surfaces and a cycle time between 60 to 90 seconds.

This makes high demands on the ultrasonic inspection technology. To reduce the mechanical outlay, allow optimum coverage of the prescribed inspection areas and enable flexible configuration of the inspection technology with regard to the wide range of different wheel geometries, phased array probes are used for the inspection of the wheel rim and wheel hub, whilst squirter probes guided by robots are used for the inspection of the disks.

In order to be able to cover the prescribed inspection areas when the beam is being directed into the rim axially and radially and into the hub from both sides for all the wheel types at the manufacturer's works, phased array probes designed specially for this inspection problem, with 64 and 128 elements (linear arrays), have been developed. In the case of the hub in particular, the challenge consisted in finding a suitable configuration of the phased array probes, in order to cater at the same time to both the small dead zone and the large inspection area of up to 300 mm within a single test cycle. It was also necessary to develop a suitable probe carrier which would make constant coupling possible through a water gap in spite of the large active aperture of the probes.

In wheel requalification, examination of the disk is also required. Here the challenge involves recording the geometry, which may be complex, and then carrying out the inspection. In particular contoured wheel disks make it more difficult to determine the contour data and carry out the ultrasonic inspection, and call for solutions that are sophisticated in terms of the inspection technology they use. This paper aims to provide an introduction to robot-aided contour recording and ultrasonic inspection using squirter probes.



The reference flaws in the wheel disk are provided from both sides of the web.

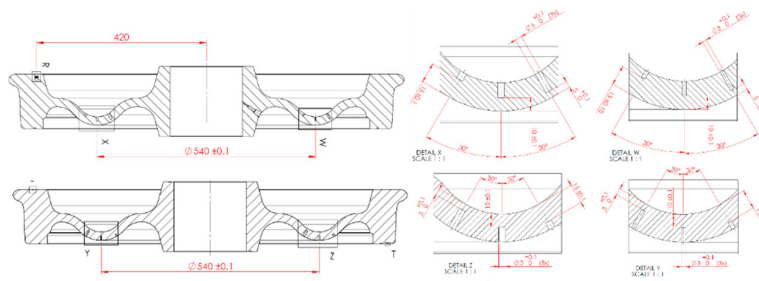


Fig. 3. Reference flaws in the wheel disk

The railway wheel inspection system should be designed to inspect the wheels with a dead zone of less than or equal to 5 mm.

Common types of wheels are inspected within a max. of 90 secs. for the rim and the hub and of 15 mins. for the web.

3 Machine and Inspection Set-up

3.1 Machine set-up

The RAWIS inspection system is part of the client's manufacturing and inspection line. The RAWIS is normally loaded by an automated handling system. The gripper of the handling system sets the wheel to be inspected with an inclination of approx. 10° to the perpendicular from above onto the driving rollers of the RAWIS. A supporting axle, which is adjustable in height, keeps the wheel to be inspected in a stable position during the inspection.

While the wheel to be inspected is loaded into the system, all axes of the RAWIS are moved into the parking position.

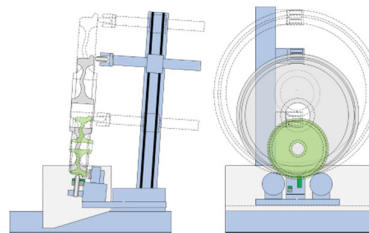


Fig. 4. Set-up of the RAWIS system with different wheel diameters

All data with a relevance for the inspection task are transmitted to the RAWIS inspection system via an interface from the MES - Manufacturing Execution System. In order to optimize and facilitate the access to the inspection mechanics and the probes and thus the ease of maintenance of the RAWIS inspection system, different set-ups have been conceived for the coupling for the wheel rim, wheel hub and wheel disk inspection.

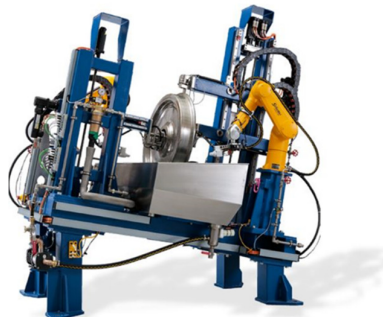


Fig. 5. Overview of the automated RAWIS wheel inspection system

3.2 Inspection set-up

3.2.1 Wheel rim inspection

The wheel rim is inspected by linear arrays using the immersion technique.

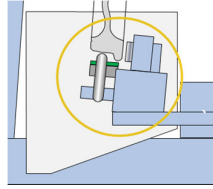


Fig. 6. Probe arrangement for the rim inspection

3.2.2 Wheel hub inspection

The wheel hub is inspected by linear arrays with water gap coupling from both the inside and the outside of the wheel.

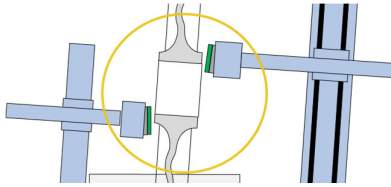


Fig. 7. Probe arrangement for the hub inspection

3.2.3 Wheel web inspection

The web of the wheel disk is inspected by two pulse echo probes with water jet coupling. One squirter each, including the probe, is installed on a multi-axle robot for the inspection. The robots are installed on the inside and the outside of the wheel and position the squirters in parallel with the contour of the wheel disk. The contour of the wheel disk is automatically recorded by a laser sensor before the inspection and transmitted to the robot control.

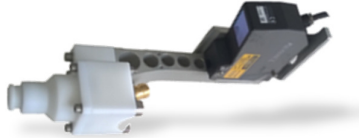


Fig. 8. Squirter with a laser sensor

The robots then position the squirters so that they are always in a perpendicular position to the web. The delay is kept constant.

The wheel rotates in the inspection system for the inspection of the web, while the squirters inspect a circular orbit. When the wheel has been rotated by 360 degrees, the squirters reposition themselves and the next circular orbit is inspected. When the web has been completely inspected, the circular orbits are put together in an overall image and evaluated by the inspection software.

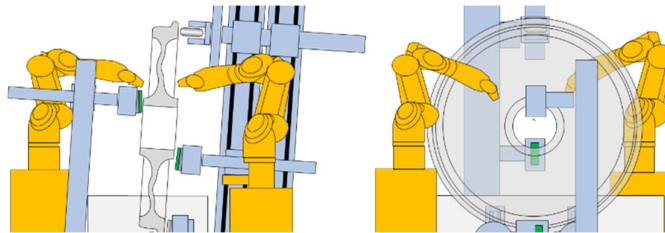


Fig. 9. Robots for the wheel web inspection

4. Inspection Technique

4.1 Inspection technique for the wheel rim inspection

Using the immersion technique the wheel rim is inspected in compliance with the inspection standard ISO 5948 in a radial and an axial direction by two linear array probes with 128 elements each. The inspection is carried out by one active element group consisting of 16 elements in each direction, which is moved on along the linear array by a multiplexer in cycles of a programmable length of one or more elements (see Figure 10).



Fig. 10. Electronic scanning along the linear array

Each element of the active element group can be individually actuated by the corresponding electronic circuit to generate the sound field. The sound field can be pivoted or focused by an appropriate setting of the delay time of the individual elements for transmitting and receiving. A combination of both is also possible. The probe does not have to be moved mechanically to scan the area to be inspected, if this method of electronic generation of sonic beams and scanning along the linear array is applied. This permits an inspection of the wheel rim in a single cycle.

In order to reduce the dead zone underneath the scanning surface to less than or equal to 5 mm, an additional linear scan, focused into the scanning areas directly underneath the scanning surface can be carried out in addition to the inspection with the unfocused sound field (see Figure 11).

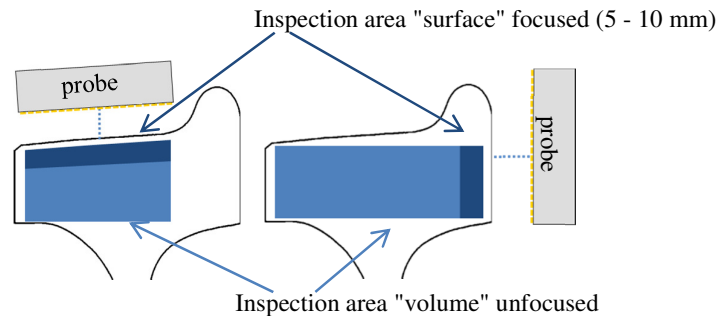


Fig. 11. Diminution of the dead zone by beam focusing

Due to the complex geometry of the profile of the tread of the wheel, the delay times for each active element group have to be set so that the irradiation of the ultrasonic beam into the wheel rim is exactly radial. This makes it possible to minimize sensitivity differences caused by the position and resulting in an inhomogeneous evaluation of the tread inspection.

As there is such a wide range of different tread profiles, a pre-inspection is carried out before every inspection to reduce the set-up work. The tread profile is scanned by ultrasound for this pre-inspection. The delay times required for the radial beam scanning are computed from this profile. The effect of the tread profile on the scanning angles and the sound field geometry is shown in Figure 12 by means of simulated data, computed by CIVA.



Fig. 12. Effect of the tread profile on radial wheel rim inspection, without consideration of the tread profile

(left) and with consideration of the tread profile (right)

4.2 New inspection set-up for wheel hub inspection

In compliance with the EN 13262 standard, the wheel hub is inspected from both sides of the hub by means of axial beam scanning. Linear array probes consisting of 64 elements and working with a frequency of 5 MHz are utilized for the inspection, which makes it possible to inspect hubs with a width of up to 100 mm. The probe aperture can be adjusted without requiring any additional mechanical set-up to the wheel type specific hub widths and other geometric features (e.g. bayonet) by flexibly selecting and deselecting element groups. In addition, the sound fields can be pivoted or focused by setting the delay times appropriately as described in chapter 4.1.

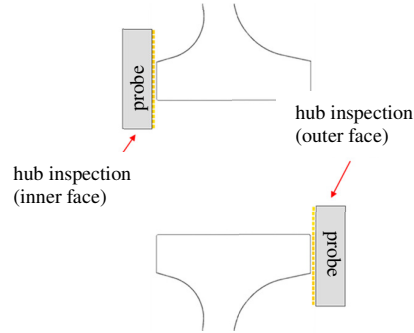


Fig. 13. Hub inspection with linear phased array probes

The design of the probes were determined with the aid of the CIVA simulation software. A hollow cylinder was provided with 3 mm flat-bottom holes in an axial direction, corresponding with the position of the adjustment reflectors given in the EN 13262 standard. The central and the outer areas were provided with bores of the same depths in a radial direction, i.e. in the movement direction of the element group (see Figure 14).

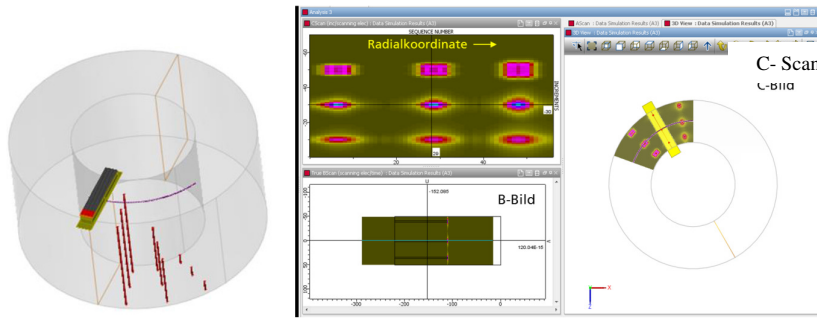


Fig. 14. CIVA- Simulation scenario and simulation results

4.3 Ultrasonic squirter technique for web inspection

The web inspection described in chapter 3.2.3 is another challenge for the inspection technique. Wheels with a contoured web affect the sound field depending on the position, as convex inspection areas alternate with concave and flat inspection areas, which results in varying inspection sensitivities depending on the radial position (see Figure 15).

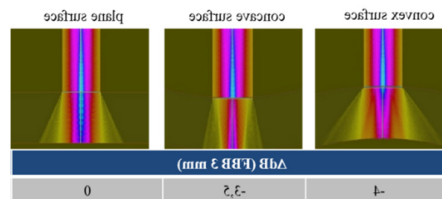


Fig. 15. Beam profile and sensitivity for FBH 3 mm in different disk geometries

The web is inspected on concentric tracks. The web zone to be inspected is then divided into subsegments, depending on the geometry of the contour. The AURAWIS software makes it possible to adjust the inspection parameters per track as well as to adjust the distances between the inspection tracks per segment. In this way any variations in the inspection sensitivity caused by geometry can be compensated.

5. Evaluation Software

The AURAWIS software was developed for the inspection of railway wheels during the manufacturing process. The software works in conjunction with the ETHUS phased array ultrasonic inspection electronics and the ROCO communication software controlling the overriding processes of the inspection system. AURAWIS serves to set up the inspection parameters, to record data, to present results on-line, to evaluate the data and to document the inspection. In addition to the functions of the standard modules, the surfaces can be automatically corrected and the inspection results can be automatically presented and evaluated in C-Scans and side views. A re-inspection can be carried out after a first inspection in order to determine features exactly. Another possibility is an analysis run, in the course of which only a defined inspection zone is selected and inspected. The data of such an analysis run are recorded as TD data, which makes it possible to evaluate in more detail.

Zones, which cannot be inspected, can be parameterized during set-up. As a result, for example, any indications depending on the geometry are ignored in the inspection report. An additional option is to define number and distance criteria for a basic inspection program in order to facilitate the evaluation for the inspection personnel.

There are several modes for the AURAWIS inspection software in conjunction with the ROCO communication software, so the operator can for example choose between a partly automated and a fully automated inspection mode.

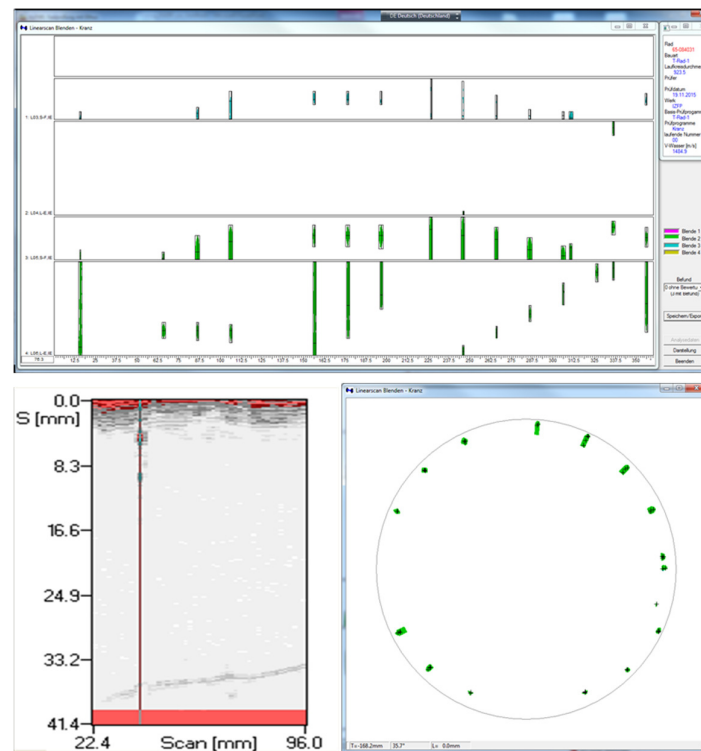


Fig. 16. AURAWIS software, representation of the inspection results

6. Conclusion

RAWIS is a standardized automated ultrasonic inspection system for the inspection of railway wheels in the manufacturing process, inspecting a wide range of products independent of batch sizes and without any loss of productivity. The simulation software CIVA was used, before the commissioning of the system, to design the optimum probes for the inspection tasks and to define parameters for the basic inspection programs such as focal laws, wheel geometry dependent compensation curves as well as inspection tracks adjusted to the wheels to be inspected. This results in an increased performance of the inspection system and a reduced time span required for commissioning at the clients' premises. The application of an advanced inspection software with automated evaluation procedures reduces the pseudo reject rate and the time required for the inspection of inspected items featuring indications. In addition, the software facilitates the evaluation of inspected items with any findings for the inspector and the inspection supervisor.

References

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- [2] DIN EN 13262 Bahnanwendungen – Radsätze und Drehgestelle / European Committee for Standardization
- [3] Ultraschallprüfung an Neurädern mit Linear-Arrays am Radkranz und neuem Konzept für die Naben- und Stegprüfung / Thomas SCHWENDER, Werner BÄHR, Wolfgang KAPPES, Andreas KNAM, Wolfgang SCHÄFER