# ULTRASONIC TESTING OF RAILWAY AXLES WITH PHASED ARRAY TECHNIQUE EXPERIENCES DURING OPERATION

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**Abstract:** The increasing use of high-speed trains, resulting in higher stress to the material and serious accidents with human injuries in the past, lead to a demand for shorter inspection intervals, extended scope of inspection and more stringent test requirements to be applied to the critical components.
One component, which is inspected in regular intervals, is the axle of the railway wheel set. Critical areas for cracks are mainly the wheel and brake disc seats and the cross section transition areas.
The manual ultrasonic inspection of used axles by experienced personal is time consuming (since several sound beam angles have to be used to cover the complete test area), expensive, and of course, subjective. It represents a bottle neck in the inspection line.
One way to overcome this bottle neck is the automation of the test process and the use phased array probes.
GE Inspection Technologies, in co-operation with the German railways (DB) and the "Bundesanstalt für Materialprüfung" (BAM), developed a system to automate this inspection.
This system applies the phased array technique to detect transversal cracks in the most critical areas of the axle. The different angles of several conventional probes are replaced by steering the beam angle of one phased array probe accordingly.
Mechanical movement is substituted by software control
Meanwhile two of these automated systems have been delivered to the German Railways.
When taking these systems into operation, several problems came up, caused by the variety of the axles, coupling surface conditions and differences in the sound attenuation within the axle.
This lecture describes the technical concept and reports some practical experiences, problems and solutions in the commissioning phase of the automatic inspection lines.

In 2001 the first phased array systems have been supplied to the maintenance shops of the German Railways. These automated systems replaced manual or partly mechanized testing by conventional probes with all their constraints, like subjective test, time consumption, bad access to the coupling surfaces etc. An additional challenge was the batch size of the axles in a maintence shop, which is "1" and thus requires adaptation of the test system for each single axle.
The test task itself is the detection of radial cracks, mainly in the wheel and brake disk seats and their transition areas. The test can be performed with a total of 4 arrays, covering the critical test areas.
(Wheel and brake disc seats). Fig. 1 shows test areas and coupling positions.

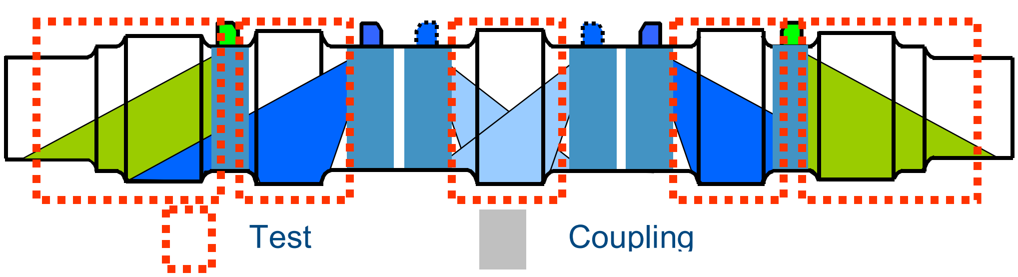


Fig. 1

The following block diagram (Fig. 2) shows the layout of the complete system.
Heart of the system is a 64 channel PA electronics called COMPAS. It drives the four array probes and performs the evaluation. The COMPAS is connected to a host computer, which controls the mechanics and synchronizes the complete test run-off.
This host is also the user interface (input of wheel set type, communication with plc, etc…) for normal operation.
An additional online terminal is used to monitor coupling and correct function of the UT system while acquiring data and for adjustment purposes.

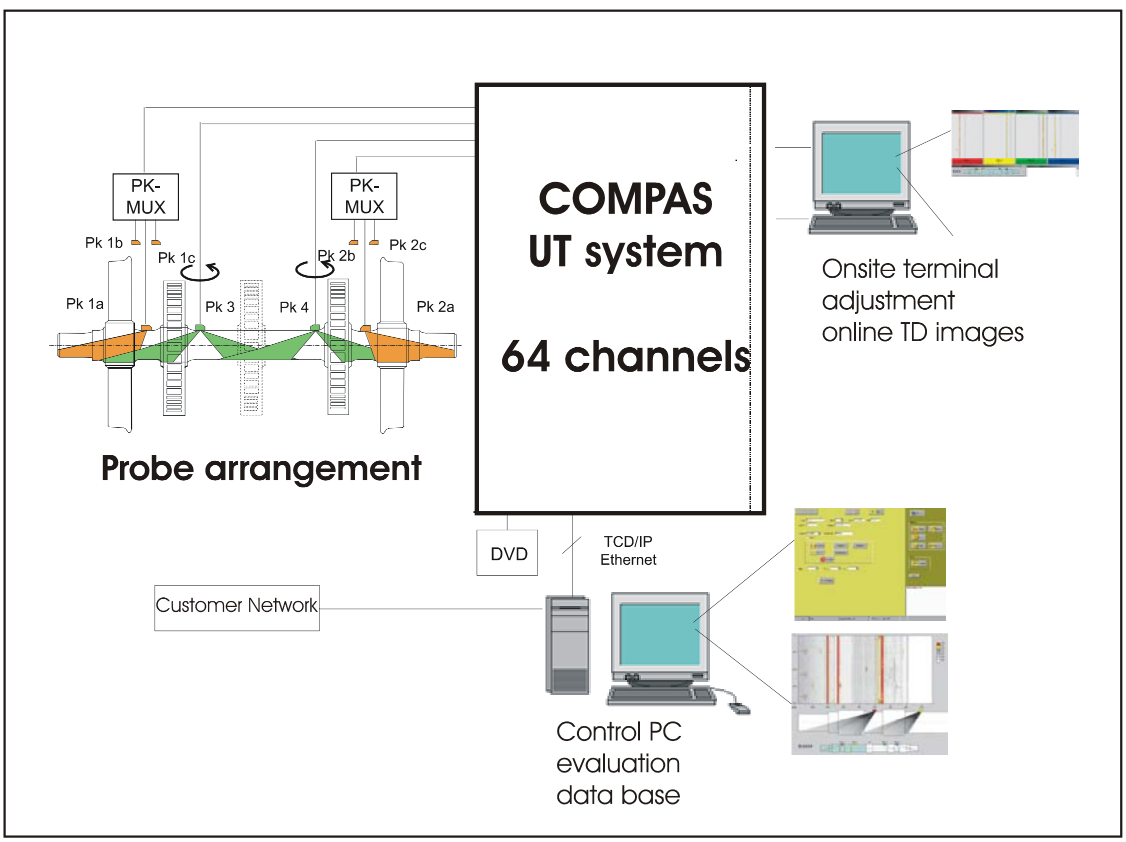



Fig. 2

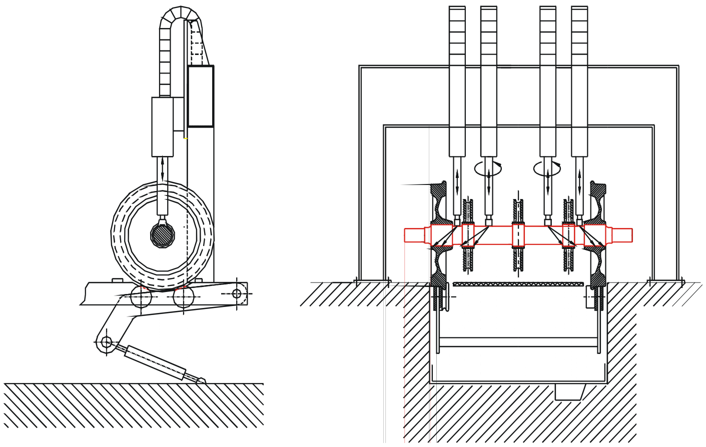


Fig. 3: test mechanism

The test mechanics consists of a roll stand with portal, which carries 4 independently controlled probe manipulators. The 2 inner manipulators can be turned by 180 degrees around their Z - axis, in order to test a 3rd brake disk seat in the middle.

Before the ultrasonic test can be applied, the coupling areas have to be cleaned in order to enable reliable and consistent coupling. A patented shot-blasting machine performs the cleaning process.
The wheelset is rolled into the test station, the manipulators are lowered down to the axle and first one prewetting rotation takes place. After that the measurement cycle starts, all probes beaming to the outer faces of the shaft. In case a third brake disk is mounted, the inner arrays are turned by 180 degrees and test this 3rd brake seat in an additional rotation.
The arrays couple at fixed positions and vary the beam angle between 25 and 75 degrees. So within one rotation of the axle, the complete test area is covered and all measurement data is acquired.

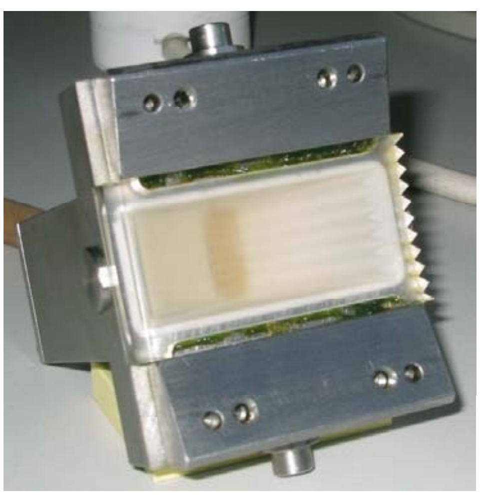


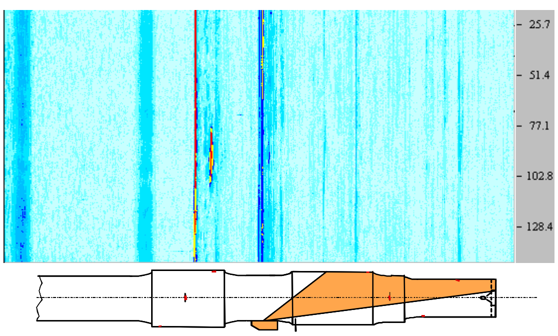
Fig. 4: Phased Array probe

Phased Array probe W60B3GM14

- Array 20 mm x 22 mm Composite material
- 14 elements
- 2.7 MHz

- Wear soles (exchangeable)
- Pre-adjustment of angle by Perspex wedge
- Controllable angle 25° - 75°

The consistent coupling of the probes has turned out as the most critical issue of this test.
The coupling area of a phased array probe is much bigger than that of a conventional probe (here 55 mm in axial direction). On the other hand, the access to the coupling surfaces of the axle, especially between wheel and brake disk seat, is very limited. In some cases the surface is additonally limited by radii in axial direction. These conditions required changes in the original probe design (mechanical guiding on the axle), material and form of the wear sole and also in the coupling water gap and guiding. Since there is no time to change wear soles, a special probe holder ("revolver type") has been designed. This probeholder carries 3 identical probes with different formed wear soles. These are switched according to the wheel set type under test.
During the test run-off the digitised A-scan data and the corresponding beam angles are stored on the hard disk. Simultaneously an online TD image for each probe is shown on the onsite monitor in order to control coupling and correct function of the system.
When all data is captured, the classification of the tested axle is performed by the operator through visual justification of the test data presentation, provided by the COMPAS system.
The COMPAS internal PC software reconstructs the evaluation image, a special version of a TD image out of the stored raw data.




In general, the TD image is a projection of the colour-coded amplitude on to the developed view of the axle (C-scan) - the x-axis represents the sound path, the y-axis the circumferential position (0 - 360 degrees).
Every circumferential angle position delivers one TD image line.

To support the operator, a scaled sketch of the tested axle type is faded in under the developed view, in order to enable an easy discrimination between real defects and indications caused by the geometry of the axle.

Indications caused by geometry produce a straight line over the entire circumference of 360°. Real defects normally occur only over a certain section of the circumference. The graphics is reduced to the important data, e.g. the colour palette is reduced to red, yellow and a greyscale, in order to simplify a fast visual rating.
Main advantage of this kind of result presentation is the simple discrimination of real defects and indications caused by the geometry.

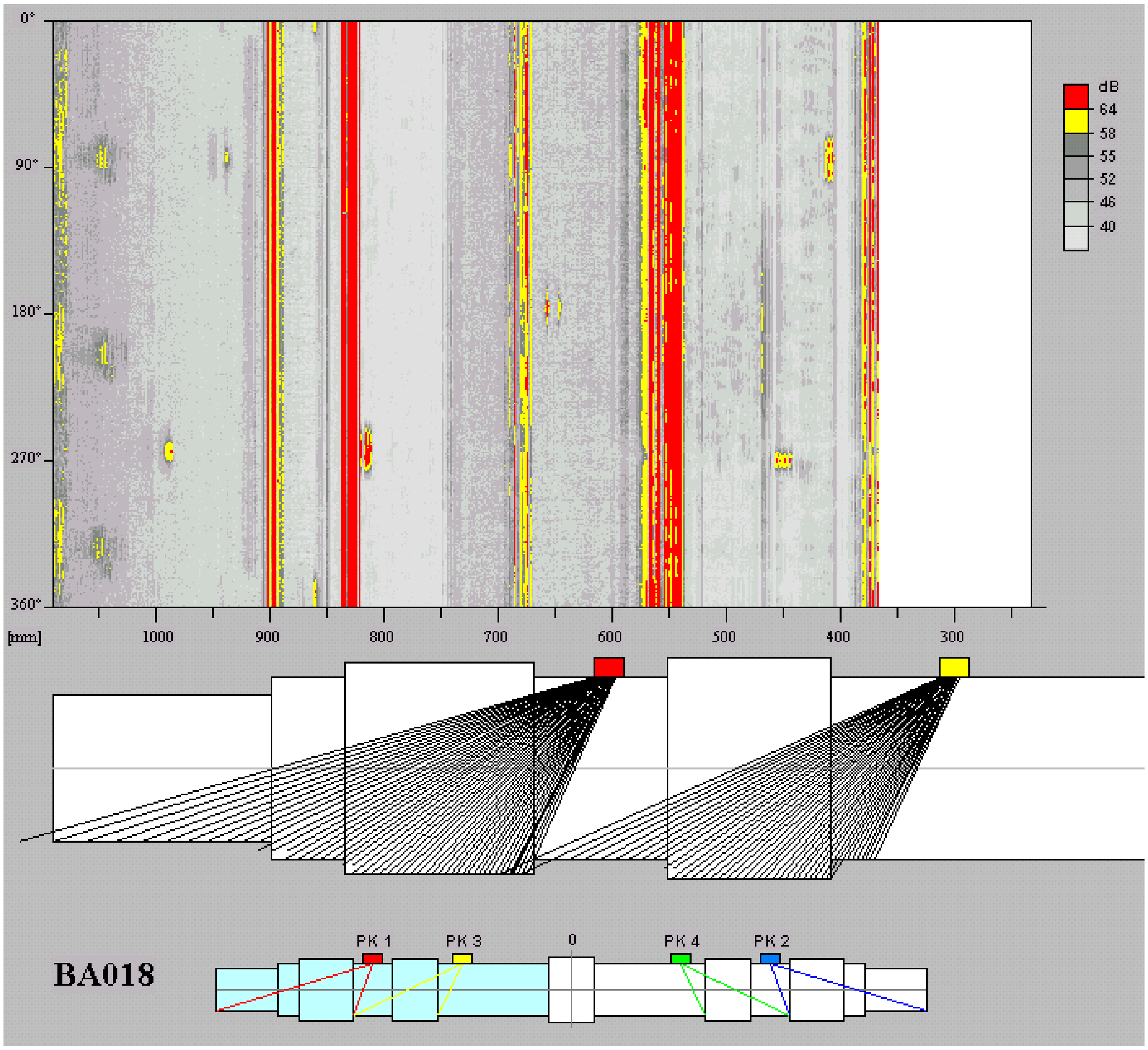


Fig. 5: Evaluation image

It is also possible to identify the axial position of the defect easily.
The operator compares the image with the image of a defect-free axle and decides about the classification (GO/NO GO).
All test data are collected in a database for further reference and used for creating a history file of the wheel set.
The ultrasonic system is calibrated using an axle with artificial defects on a regular base (beginning and end of each shift) or in case some components have been changed. The artificial defects are transversal saw cuts in the critical areas (2 mm depth).

**Conclusions:** The application of phased array technique and the automation of the inspection offer significant advantages for the maintenance shop:

- Shorter test times per axle through mechanised inspection,
- Shorter change over time when changing the axle type, since mechanical adjustment is substituted by software control of the probe angle. This is of great importance, since the batch size in the maintenance shop is "1", that means, it can be necessary to change test parameters for each axle.
- Comprehensive documentation possibilities of the test results, archiving of test data.
- If required, storage of raw data is possible.

Meanwhile two of these systems are in operation at the German Railways, in 2004 a 3rd one has been sold to an outsourced mainrtenance shop of the German Railways. The first one, taken into operation at the end of 2001 has tested more than 80.000 wheel sets so far, out of 16 different types.
Target for the future will be the development of software tools, which automatically evaluate the TD images and generate the sorting signal, without human operator influence.


Fig. 6: Total view of installation

**References:** ECHO 39, 2003
Operation manual COMPAS, 2003