



# Ultrasonic and Magnetic Particle Testing of New Railway Wheels

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**Abstract.** Several testing procedures for new railway wheels are a mandatory part of the production process. These include an ultrasonic and a magnetic particle inspection. The Schuler Group currently provides an entire production line for the Turkish company KARDEMIR. KARL DEUTSCH was appointed to implement the ultrasonic and magnetic particle systems. The production and also the testing line was designed to achieve a high throughput with a total cycle time of approx. 90 s per wheel.

The magnetic particle testing system uses a trapezoidal coil, which is pneumatically moved between safety position and test position. The loading of the testing system is accomplished by means of a carriage, which linearly moves between the loading position and the testing position. The wheel is oriented in a vertical manner. After moving the wheel into the test position and lowering the magnetization coil, the test is carried out within one full rotation of the wheel. Up to three operators perform the visual inspection under UV light. Therefore, the accessibility of the wheel from three sides and the operational safety for the staff must both be ensured.

The ultrasonic inspection is carried out in almost vertical position. The wheel is inserted from above into a water filled tank where only the wheel flange is immersed. Two phased array probes, each with 128 elements, are mounted in the 6 o'clock position below the wheel. They are used to inspect the wheel flange from two sides (running surface/rim and rim). The wheel hub is tested from both sides with two 64-element phased array probes using the water gap coupling technique. Naturally, the hub probes must be adjustable in height in order to test wheels of varying diameters. Phased array testing allows to quickly inspect the wheels within one rotation.

KARL DEUTSCH is shareholder of the French M2M company which provided three modules for the phased array test electronics. In total, 384 parallel test channels are used. Therefore, several shots can be produced simultaneously and the shot sequences can be flexibly arranged. The slightly curved running surface requires a careful adjustment of the delay laws of the phased array probes. Also, the test mechanics must ensure a smooth rotation of the wheel in order to achieve a high test sensitivity.

## Introduction

The Turkish company Karabük Iron & Steel Industry and Trade Inc. (KARDEMIR) currently expands its railway activities. A new production line for railway wheels with an investment volume of more than 90 million Euro is currently implemented by the company SCHULER. For the press manufacturer SCHULER, which was founded 174 years ago, it is the largest

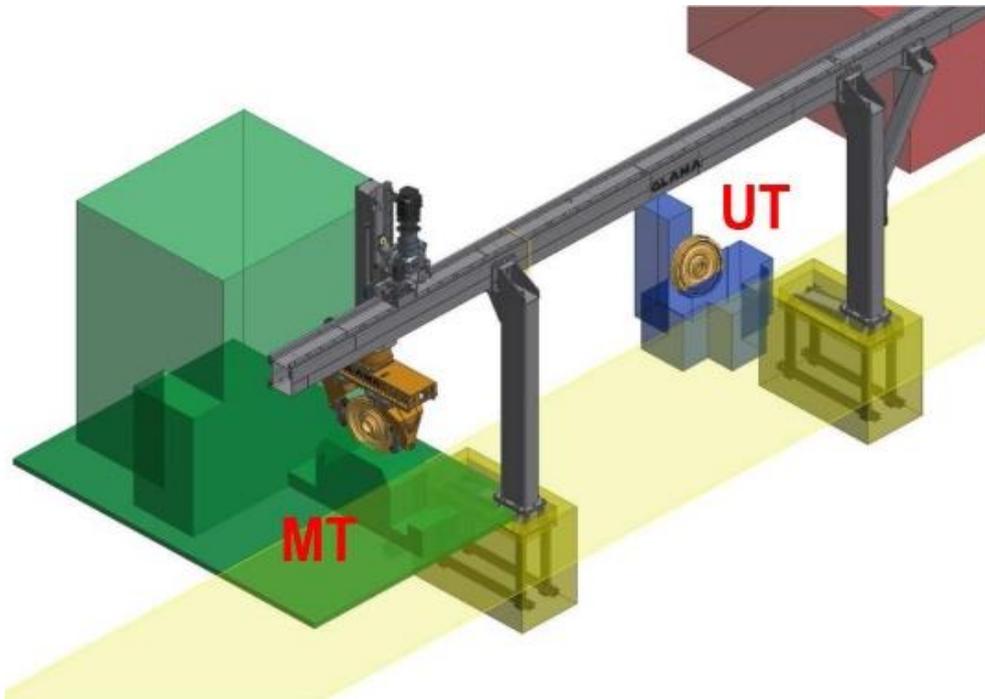


contract in the company history. The production line is designated to produce 200,000 wheels per year with an average weight per wheel of 500 kg.

KARDEMIR is the oldest steel manufacturer in Turkey with an annual capacity of 3 million tons. The company is based in the city of Karabük, which is approximately 200 km North of Ankara. It employs approximately 4000 people, generates an annual turnover of 660 million Euro and operates the most modern integrated steel mill in Turkey. KARDEMIR already produces rails and railway switches for high-speed railway tracks. The Turkish government strongly pushes the extension of the existing high-speed connections. Until 2023, the network size is supposed to be doubled to reach a total length of 25,000 kilometers. Besides the forming press for the railway wheels, SCHULER also supplies the heat treatment line and the entire equipment for the mechanical machining of the wheels. Also the testing line of the manufactured wheels is within the scope of supply.

### 1. Transportation Concept of the Testing Line

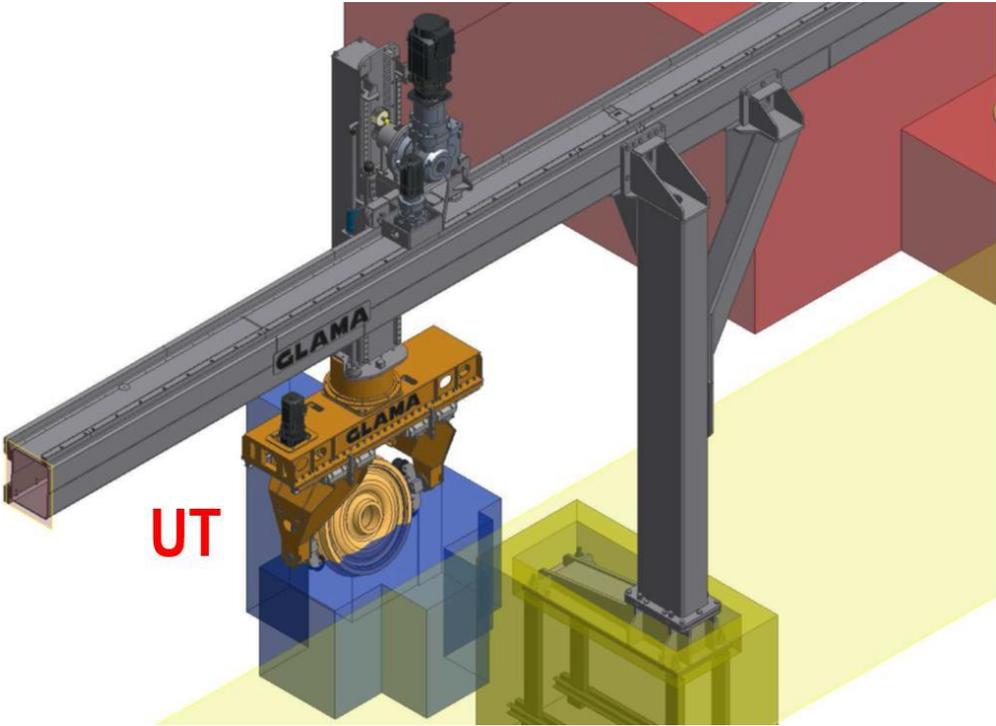
The manufactured wheels are fed into the testing line which comprises several machines. After washing, the wheels are optically tested with lasers and the geometrical data are recorded. Afterwards, the wheels are tested with ultrasound and magnetic particles. A wheel balancing system and a marking system are the final steps within the testing line. The transportation system is provided by the company GLAMA Maschinenbau GmbH from the town of Gladbeck, Germany. Five loading cranes move along a linear portal for feeding and unloading the wheels between the respective machines within the specified cycle time of 2 minutes.



**Figure 1.** Transportation mechanics using a linear portal by the company GLAMA

The cranes are capable of vertical and horizontal movements. The wheels can also be tilted and turned by the cranes. The magnetic particle testing system is loaded with a wheel in vertical position. The ultrasonic testing system is loaded with a wheel which is first in vertical position and afterwards slightly tilted. Oblique support rollers then smoothly turn the wheel.

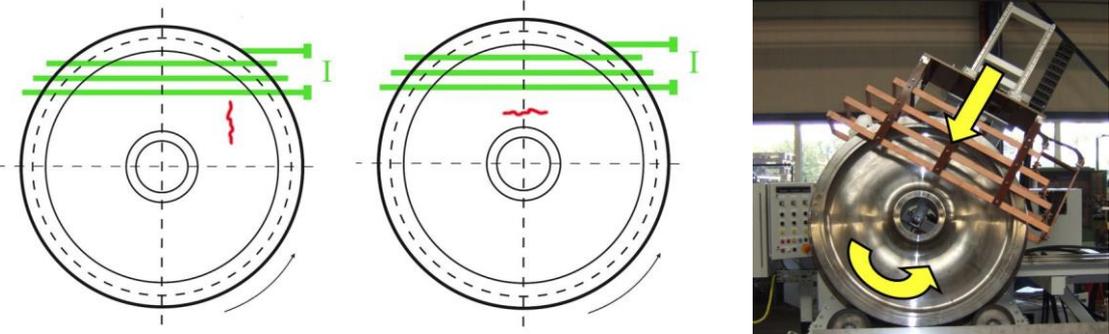
The positioning accuracy of the cranes is approx.  $\pm 1$  mm. The communication within the testing line uses the Profinet protocol.



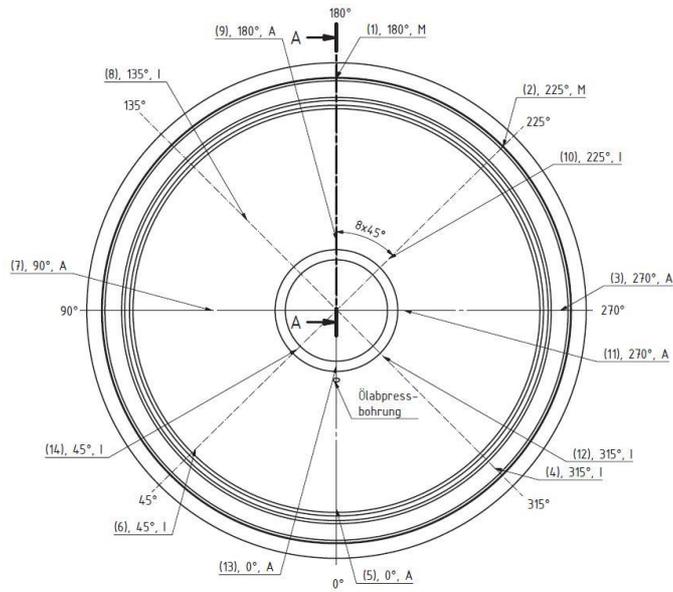
**Figure 2.** Loading of the ultrasonic testing system and insertion of the wheel into the immersion tank with a tilting angle of  $17^\circ$

### 2. Magnetic Particle Testing of Railway Wheels

The magnetic particle testing system uses a coil of trapezoidal shape which is fed with alternating current (AC). During the rotation of the wheel within the coil, defects of all orientations can be detected. The mechanical and electrical design of the coil must provide a sufficient magnetic field strength on the entire wheel surface except the wheel hub, which was not relevant for this project. Test wheels with artificial defects are used to prove the functioning of the testing system. Fourteen cross-shaped notches with lengths of 4 mm were EDM-machined into the test wheel.

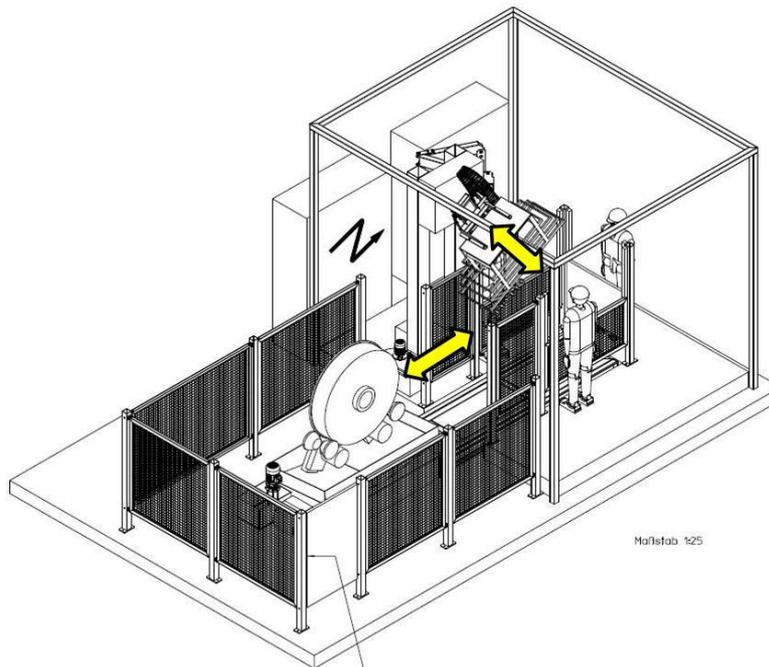


**Figure 3.** Schematic diagrams and implementation of the magnetic particle testing of railway wheels by means of a trapezoidal coil



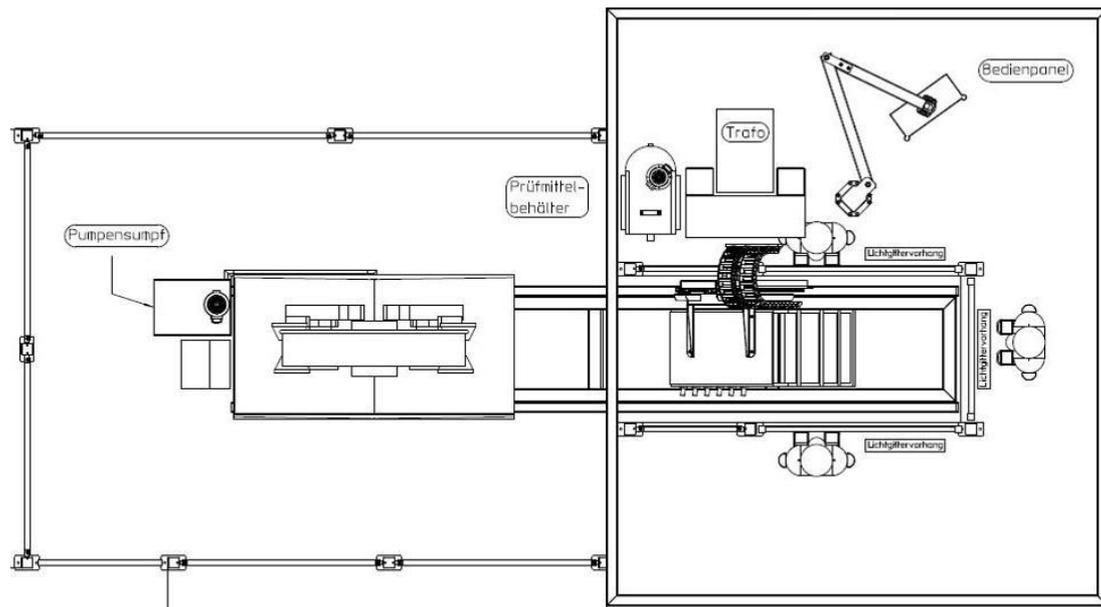
**Figure 4.** Test wheel with 14 EDM-machined cross-shaped notches, which are evenly distributed over the entire wheel surface.

In order to minimize the cycle time, the loading process must be carried out in a very efficient way. The wheel in vertical position moves by means of a carriage between loading and test position.



**Figure 5.** Testing machine with carriage to move the wheels between loading and test position

Up to three operators carry out the visual evaluation under UV-light. The wheel surface must therefore be freely accessible from three sides while operator's safety must also be ensured.



**Figure 6.** Top view of testing system and visual evaluation with up to three operators



**Figure 7.** Magnetic particle testing system for railway wheels. The wheel is supported by a carriage which is currently in loading position.

### 3. Phased Array Ultrasonic Testing of Railway Wheels

The ultrasonic inspection is undertaken in almost vertical position at a tilting angle of  $17^\circ$ . The wheel is inserted into the testing mechanics coming from the top, but only partially immersed in coupling water. Two phased array probes with 128 elements are mounted in the 6 o'clock position of the wheel for immersion testing of the running surface (tread) and the rim.

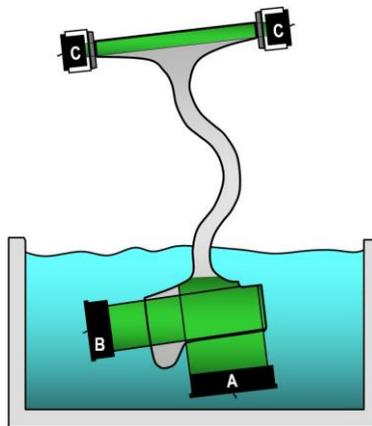


**Figure 8.** Phased array testing system for railway wheel testing using 384 parallel channels (3 modules with 128 channels, left) and with rotating wheel in partial immersion (right)

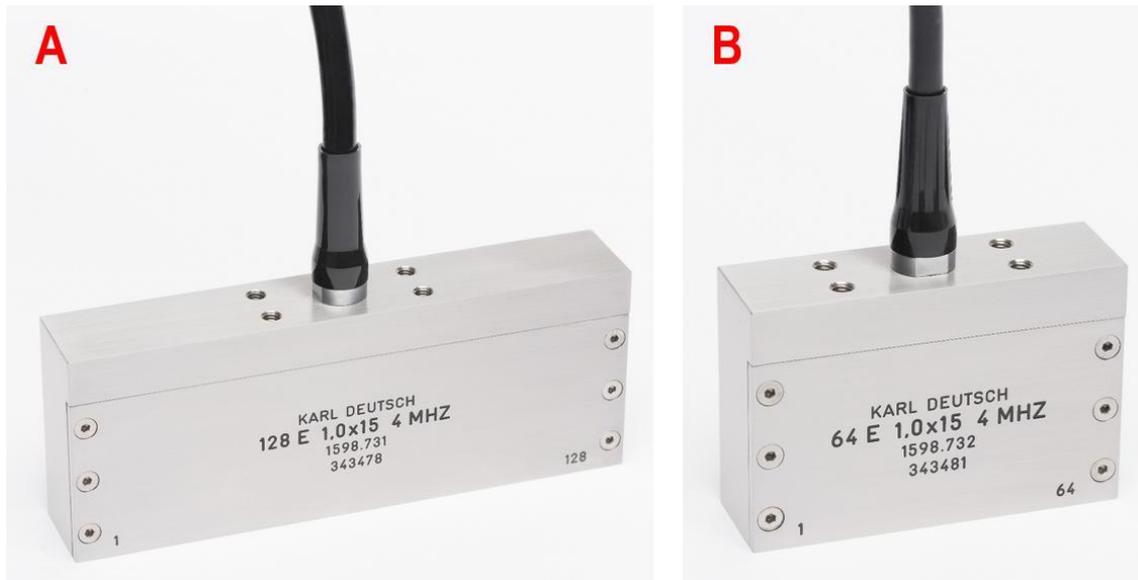


**Figure 9.** Two probes work in full immersion (test of ring-shaped test wheel, left). Two probes work in contact testing (gap coupling) for the both-sided inspection of the wheel hub (right).

The hub is inspected with two 64-element phased array probes which are coupled by means of a narrow water gap. The hub probes must be height-adjustable in accordance with the respective wheel diameter. A sketch of the probe position is shown in the next figure:



**Figure 10.** Probe positions for the ultrasonic wheel inspection, A) array for tread testing, B) array for rim testing, C) two-sided hub testing

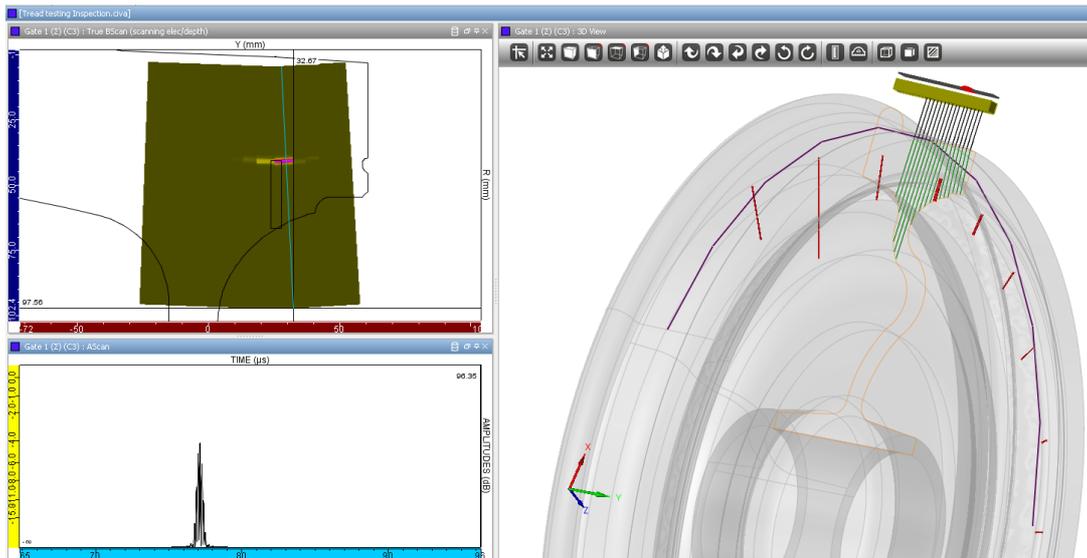


**Figure 11.** Phased array probes for ultrasonic wheel testing, A) array for tread and rim testing, B) array for hub testing

The wheels can be quickly tested within only one revolution with the phased array technique. The testing electronics consists of three MultiX++ modules of the French company M2M. KARL DEUTSCH is a 33%-shareholder of M2M since 2009. A parallel testing electronic was chosen in order to ensure the highest possible testing speed and the ability of parallel firing within the same array probes. The slightly curved rim surface requires a precise adjustment of the delay laws of the phased array probes for perfect insonification of the various flat bottom holes (FBH) of the test wheels. The smallest FBH in the test wheels had a diameter of 1.5 mm. The delay law adjustment is done in-house at KARL DEUTSCH by simulation with the CIVA-software. This software allows perfect modelling of the test task and theoretically confirms the chosen probe parameters. A basic software version is pre-installed on every test electronic by M2M.

The calibration of the testing system is checked with several FBH's in varying depths and diameters. Two test wheels were manufactured. The test wheel containing the FBH's for the tread testing required a ring shape, see figure 9. This ring also contains the FBH's for the rim testing. The FBH's for hub and disc testing were introduced into the second test wheel. For the tread and the rim, the detection of 2 mm FBH's is normally required, while hub and disc are normally tested for 3 mm FBH. The disc testing is only carried out for prototype wheels with a new geometry. Therefore, it was decided to test the disc manually with a portable flaw detector, type ECHOGRAPH 1095. A mechanized disc inspection is challenging concerning the probe positioning and would require for example robotic probe handling.

After insertion of the wheel into the testing system, one full rotation is carried out with a rotational speed of approx. 0.4 mm/s. An encoder which is connected to the motor for the wheel rotation produces the position signals. The support rollers in the immersion tank were carefully shaped in order to achieve a slip-free wheel rotation. The ultrasonic test results are presented in A-scan format selectable for each virtual probe (active group of elements within one phased array probe), as amplitude strip chart (ranging from 0° to 360°) and in B-scan format (cross-sectional view of wheel).



**Figure 12.** CIVA-simulation for tread testing (example shows a 4 mm FBH in a depth of 40 mm)



**Figure 13.** Online presentation of ultrasonic test results. Three amplitude strip charts for rim, flange and tread are produced. In this example, four A-scans were activated. The test result for the test wheel naturally shows a defective wheel.

## Summary

The testing system for new railway wheels comprises:

- A system for inspection with magnetic particles applying a trapezoidal coil, which enables the detection of flaws in all orientations during rotation of the wheel
- And a system for ultrasonic inspection using the phased array technology