Advances in Ultrasonic Inspection of High Speed and High Integrity Rail Wheels

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Abstract.

Paper describes a state of the art system for rail wheel inspection that uses phased array ultrasonic inspection technique. The results for tread inspection near surface resolution 1mm FBH @ 6mm deep are discussed. Data presented for both ultrasonic simulation and actual results. Novel dual cycle table approach is used to simultaneously detect near surface and deep defects.

1.0 Introduction

Rail Industry is moving towards use of high speed trains as well as trains that carry crude oil and ore. The increased risk of potential accidents has prompted government regulators to develop new stringent safety standards. The intent of new regulation is to identify and eliminate or mitigate potential risk factors. Resulting in increased inspection and non-destructive testing of various components to mitigate those risk factors.

Ultrasonic testing is one such way. Table below list several different regulations for different section of a rail wheel. This paper describes testing of tread section of a rail wheel with increased defect detection using phased array ultrasonic technique.

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2.0 Design Criteria

2.1 Critical system requirements

a. System should be capable of detecting 1mm FBH throughout the thickness with a near surface resolution of 6mm on the tread side.

b. Less than 2 dB variation in detection of 1 mm FBH during a scan.

c. Total scan time less than 6 minutes.

d. Minimum SNR of 16 dB (Excluding the probe ring down area and geometric echoes).

e. 5 MHz probe required by specification.

2.2 Ultrasonic Simulation

CIVA simulation software is used to optimize the virtual probe size, determine the scan index size, virtual probe index and distance amplitude curve.

The approach applied is to study the virtual probe size needed to cover the depth and studying the defect response of a 1mm FBH at different depths to determine the minimum index sizes while maintaining less than 2 dB variation.

Simulation is performed at 36mm and 6 mm depths. Figures 1,2 and 6 below show the civa simulations of expected sound fields and defect responses. The figures 3-5 and 7-10 show the expected amplitude width for 2 dB points for 1mm FBH defect response as the probe is moved across the defects at various positions.

Fig.1 Sound Field Perpendicular to the field at the focal point 36 mm

Fig. 2 Sound field parallel to the field with 36 mm focus
The results of simulations indicate that the approach of scanning with focused probe would cover the near surface requirements while the 36 mm depth focus would cover the region from 10 mm to the back wall.
3.0 Experimental Verification

Experimental verification of the concept described above is performed is a batch scanning system (figure 11).
Scans are performed on a wheel with standard 1 mm FBH defects at various depths. The probe used to perform these tests was a 5MHz, 128 element probe with 0.75 mm pitch. Each virtual probe consists of 16 element combination. Figure 12 shows scan area.

The scan is setup such that the wheel region is scanned twice. Once with focused focal law (cycle table) and once with non-focused (36 mm) focal law in the same cycle. The index is such that 1mm FBH is found with less than 2dB drop in amplitude for the whole cycle. Figure 13 shows the focused and unfocused virtual probe regions. The high amplitude region between 54-56 micro sec is the 1mm size defect 10 mm from the surface clearly seen on both focused and un focused table as predicted by Civa.
Fig. 13 B-scan showing 1mm FBH @ 10mm deep and showing separate regions of focused and un focused scan areas.

Fig. 14 B-scan showing 1mm FBH @ 6mm deep in the focused region and the figure below is the zoomed in view of the same.
Figure 14 shows a B-scan with 1mm FBH @ 6mm deep. This defect is located just before 54 microsec. This defect is not seen in the standard cycle table but clearly seen in the focused cycle table confirming Civa modelling.

Additionally, the scan index and the virtual probe index are applied based on the Civa simulation results.

Figure 15 shows a C-scan result of a dynamic scan with the data collected for the wheel. The focused region can detects defects in the range of 6-10 mm and the non-focused region detects defects from 10 mm to 65 mm till the back of the tread. Providing complete coverage for detection of 1mm FBH (equivalent reflector size). The scan time for scanning a wheel with 980 mm diameter was 4.5 minutes which is under 6 minutes.

Fig. 15 C-scan showing 1mm FBH @ different depths. In the focused region 6 and 10 mm deep holes are identified and in the unfocused region 10, 32 and 65mm deep FBH are detected.

4.0 Conclusion

An ultrasonic phased array testing machine with the capability of detecting 1 mm FBH using a combination of cycle tables (focal laws) is designed using Civa simulations. The resulting system achieve the key system requirement of throughput of less than 6 min, SNR of 16 dB minimum (figure 16), near surface resolution of 6mm for a 1mm FBH and less than 2 dB variations in scan result is achieved.
Fig. 16 Gain is raised till an noise echo is 60% screen height (same as amplitude from 1 mm fwh). The difference in gain gives the signal to noise value of 20 dB.