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Tycho ACWDS Detection Performance Summary

Anish Poudel, Ph.D. and Matthew Witte, Ph.D.

Summary

Transportation Technology Center, Inc. (TTCI) has evaluated the ultrasonic portion of Automatic Cracked Wheel Detector System (ACWDS) produced by Tycho Information Technology Company, Ltd. (Tycho) for its suitability to the North American railroads. Prior *Technology Digest* (TD) publications have reported TTCI's findings of the trackwork and preliminary detection performance of the Tycho system.[1,2] This TD reports on the detection performance of the Tycho ultrasonic ACWDS as measured during confidence testing during the summer of 2016 at the Transportation Technology Center (TTC) in Pueblo, Colorado. Results reported represent the 75th percentile confidence for wheel defect detection rates. Detection performance was found to depend highly on the actual wheel defect location and orientation rather than the specific defect type (e.g., vertical split rim, shattered rim). Factors such as physical shape, size, orientation, and location of the flaw greatly affected ultrasonic response; and therefore, the ultrasonic detectability of the defect.

Test trains with a variety of naturally occurring wheel defects were assembled to test the performance of the Tycho ACWDS. These included vertical split rim (VSR) wheels, shattered rim cracked (SRC) wheels, wheels with shallow sub-surface delaminations at depths ranging from 0.14 inch to 0.25 inch (3.5mm to 6mm), delaminated/spalled wheels, and wheels with non-condemnable shelling and tread surface buildup. In addition, the test train had four calibration wheels that had 17 flat-bottom holes of varied diameters and depths.

Testing at TTC was performed at speeds of 5, 10, 12, and 15 mph (8, 16, 19, and 24 km/h.) Test results demonstrate that this technology is capable of detecting VSR wheels, SRC wheels, and shallow sub-surface delaminations at speeds up to 15 mph (24 km/h). Detection capability did not trend consistently with speed. Some defects were detected more reliably at higher speeds than lower speeds, although one test wheel with a critical VSR defect did trend to lower detection rate as speed increases. Overall, only one false detection event was noted during the 60 confidence test runs. This alarm was related to a missed flange sensor triggering event.

Wheels with non-condemnable shelling and tread surface buildup passed the ultrasonic sensors without alarm. Also, wheels with poor surface condition cannot achieve adequate acoustic coupling with ultrasonic probes; hence, may not be properly inspected for internal flaws. Tycho added machine vision cameras to identify wheels with surface damages. Work is currently in progress for creating automated compensation routines to identify wheel surface conditions that would compromise the ultrasonic testing inspection quality.

Please contact **Anish Poudel (719) 584-0553** with questions or concerns regarding this *Technology Digest.* E-mail: Anish_Poudel@aar.com.

INTRODUCTION

There are over 1.6 million freight cars and 26,000 locomotives currently in use on North American railroads.[3] Assurance of wheel structural integrity is of the utmost importance to the railroads and their customers. Wheel integrity has both safety and economic impacts on railroad operation. Each year, an estimated 582,000 wheelsets are replaced in Class I railroads due to tread-related damage in the wheels.[4] Automated systems that can perform wheel inspection for flaw detection and characterization on moving trains in revenue service would be the least disruptive to operations and present the most advantage to the railroads.

Testing performed by Transportation Technology Center, Inc. (TTCI) on the Tycho ultrasonic Automated Cracked Wheel Detector System (ACWDS) show the system's capabilities to achieve this goal by providing faster, more reliable inspections along with greater through-put and more frequent inspection of wheels compared to existing robotic cracked wheel detectors. This publication discusses the detection performance statistics of the ultrasonic system of the Tycho ACWDS at different inspection speeds. Evaluations were conducted at the Facility for Accelerated Service Testing (FAST) located at the Transportation Technology Center, (TTC) Pueblo, CO.

SYSTEM DESCRIPTION

The Tycho ACWDS technology is a wayside non-destructive evaluation (NDE) system designed to inspect/characterize moving train wheels for surface and subsurface damage. Figure 1 shows the Tycho ACWDS installed at TTC. The structural components consist of a custom-designed concrete foundation and special wide gage trackwork to expose the wheel tread. The detector itself is made up of spring-loaded ultrasonic probe arrays, a machine vision system, an automatic equipment identification (AEI) tag reader, a water couplant delivery and recirculation system, wayside data collection units, and a central processor housed in a nearby control building. Details on this system and special trackwork validation can be found in a previously published AAR report[5] and two *Technology Digests*.[1-2]

The Tycho ACWDS uses arrays of spring-loaded ultrasonic probes arranged in lines between the rail and a guardrail[1] where they can contact the wheel tread. There are a total of 720 2.5-MHz ultrasonic probes with 480 0-degree probes and, 240 70-degree angled probes. Zero-degree ultrasonic probes generate longitudinal waves and operate in pitch-catch mode. They look straight up into the tread and are sensitive to cracks running parallel to the tread surface (circumferential cracks) (Figure 2).

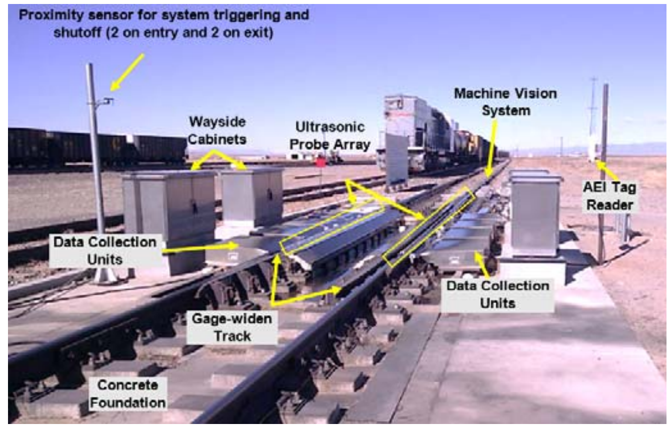

Figure 1. Tycho Wayside ACWD System Installed at TTC

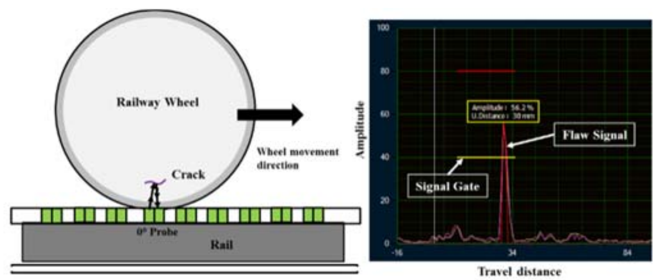

Figure 2. Principle of Operation of 0-degree, Dual-element Longitudinal Wave with Characteristics Waveform

The 70-degree, angled ultrasonic probes generate shear waves and operate in pulse-echo mode, which detects cracks oriented in the radial direction as shown in Figure 3.

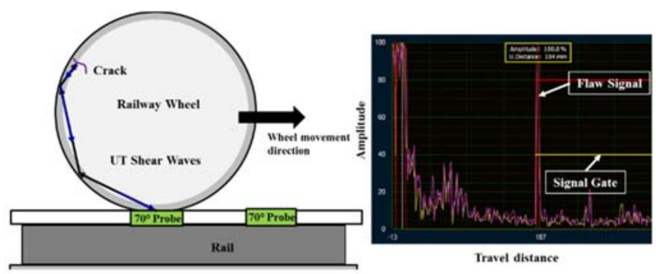

Figure 3. Principle of Operation of 70-degree, Single-element Shear Wave with Characteristics Waveform

These probes are connected to a wayside data collection unit and central processing computer that runs the software program for analyzing ultrasonic signals for wheel defects.

ACWDS Performance Requirements

TTCI developed a requirements document at the beginning of this research project, which defined the technical specification of next generation ACWDS as requested by the North American railroads. The intent was to have commercial contractors demonstrate and develop their ACWDS technologies to the level defined in these requirements in the controlled research environment at TTC. Some of the technical specifications of ACWD included:

1. Automated inspection of railcar wheels for condemnable AAR conditions[6] on a 24-hour/365-day basis at a desired minimum speed of 20 mph, with an absolute minimum acceptable speed of 12 mph and adaptability to the North American freight rail environment.
2. Successful operation on an automatic, unattended basis and inspection of all wheels (all train car types, in all loading states) at both ends of each car in each train that passes the site.
3. Reliable function in temperatures ranging from -20°F to 110°F, and conditions ranging from extremely dry to rain, snow, freezing rain, and fog.
4. Compatibility of the ACWDS and sub-components with the electromagnetic environment encountered on the North American freight rail network.
5. A detection rate of 99 percent and a false alarm rate below 0.001 percent.
6. Ability to generate alarm reports and provide customer notification when non-compliant wheel defects are found on individual railcars
7. Must perform internal self-test, as well as diagnostic and health monitoring activities to create periodic status reports, indicate out-of-tolerance performance, and generate alarm reports and customer notification when system is out-of-service, offline, or producing inaccurate data.

These requirements would assure that all wheels with defects are properly identified as defective (high confidence for safety) while simultaneously assuring that the detector is accurate and does not indicate the removal of good wheels (efficient economic performance).

SYSTEM TESTING

Test trains with a variety of naturally occurring wheel defects were configured to evaluate the performance of Tycho ACWDS. These include vertical split rim (VSR) wheels, shattered rim cracked (SRC) wheels, wheels with subsurface delamination at depths ranging from 0.14 to 0.25 inch (3.5 to 6 mm), delaminated/spalled wheels, non-condemnable shelling and tread surface buildup. In addition, the test train contained four calibration wheels with several flat-bottom holes of varying diameters and depths drilled at various locations in the rim behind the tread.[2] Figure 4 shows images of defective wheels installed in the cracked wheel consist.

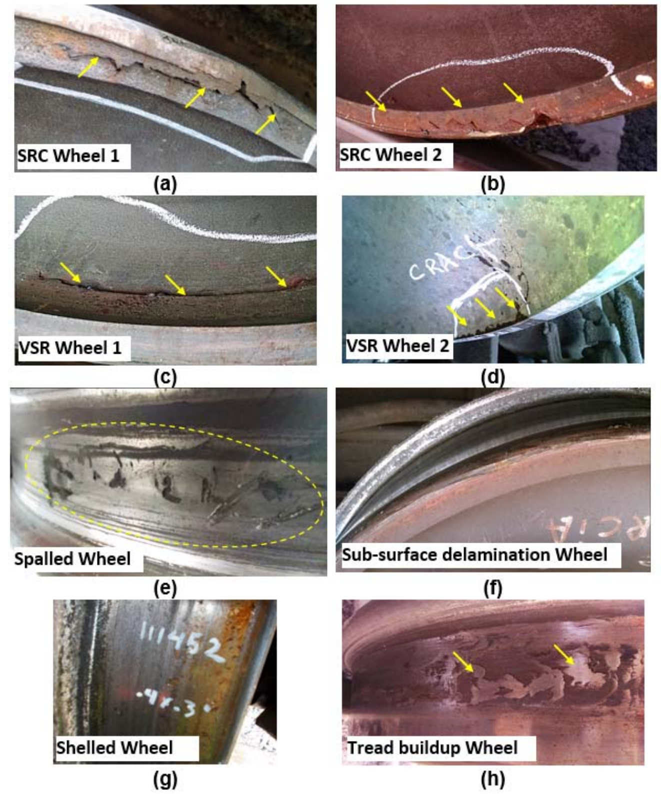

Figure 4. Defective Wheels Installed in Cracked Wheel Consist

Visual and hand-held ultrasonic testing (UT) verifications were conducted in defective wheels to validate the ACWD findings. For handheld UT inspection, 0-degree longitudinal wave scans were conducted using 5 MHz dual-element transducers. UT calibration was done using IIW-Block before and after testing each wheel to verify the measurements.

RESULTS

Testing was performed at four speeds: 5, 10, 12, and 15 mph (8, 16, 19, and 24 km/h), and 15 runs were made at each speed. This sample size provides 75th percentile confidence in the results. Table 1 shows the detection summary of the Tycho ACWDS for all 60 runs. Only one false detection event was noted during the 60 confidence test runs, and it was related to a missed flange sensor triggering event.

The positive detection results revealed several trends. First, there was not a strong correlation between detection capability and speed. While results did vary with speed, the correlation was not direct. Only VSR#1 showed a consistent decrease in performance with speed. Other wheels showed less dependency on speed. For instance, VSR #2 and SRC #1 wheels were detected 100 percent of the time at all speeds; whereas, SRC # 2 wheel was poorly detected at all speeds.

Similarly, shallow surface delamination wheels were detected more often better at 10 mph than at 5 mph. Overall, the detection rate depended more on the specific defect location/orientation than on the type of defect or the speed. The physical shape, size, orientation, and location of a defect will determine the magnitude of its ultrasonic reflection. It is the magnitude of the received/recorded ultrasonic reflection that determines the ultrasonic detection rate. While the detection threshold (ultrasonic gate) is configurable, Tycho made significant efforts to optimize ultrasonic detection capability without compromising the false alarm rate.

Table 1. Tycho ACWDS Detection Performance Summary

TYCHO ACWD DETECTION CONFIDENCE				
Defect Type	5 MPH	10 MPH	12 MPH	15 MPH
	Detection	Detection	Detection	Detection
Shattered Rim (SR) wheel 1	100%	100%	100%	100%
Shattered Rim (SR) wheel 2	13%	7%	13%	7%
Subsurface delamination	53%	13%	7%	33%
Vertical Split Rim (VSR) Wheel 1	100%	93%	87%	73%
Vertical Split Rim (VSR) Wheel 2	100%	100%	100%	100%
Shallow delaminations	33%	80%	33%	27%
FALSE CALLS	0	0	0	1

The ultrasonic system of ACWDS is specifically designed to detect critical internal flaws in the railroad wheel. Wheels with pure surface defects may not cause an alarm. Also, flaws occurring below surface defects may not be reliably detectable with ultrasonic system because of inadequate acoustic coupling condition with ultrasonic probes. As a result, test wheels with non-condemnable shelling and tread surface buildup, as seen in Figure 4g and 4h did not produce alarms during this testing. An alarm for "non-inspection event due to surface condition" could be generated by machine vision system and will be addressed in future.

FUTURE STEPS

Tycho added a machine vision system to the ACWDS to compensate for surface quality during ultrasonic testing. The machine vision system uses an array of vision cameras to inspect the tread surface quality. Each camera images the tread prior to ultrasonic inspection. The main objective of the machine vision system is to supplement the existing UT inspection and to assist the operator in identifying wheels with damaged tread such as spalling or tread buildup. Work is in progress to create automated compensation routines based on the vision data. Currently, results are presented graphically on the user interface so the operator can view tread condition when verifying detection results (Figure 5).

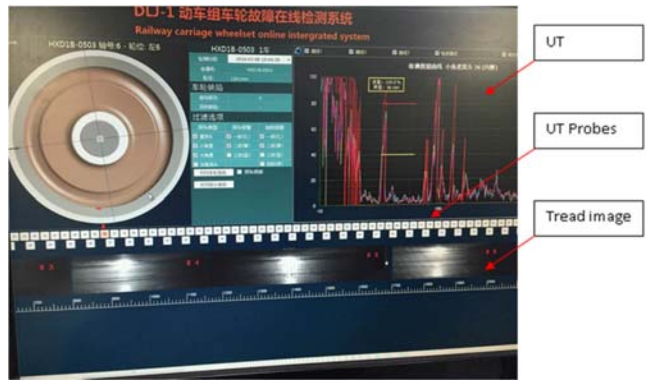

Figure 5. Output Screen with Vision Data Overlay

CONCLUSION

Test results demonstrate that this technology is capable of detecting many vertical split rim wheels, shattered rim cracked wheels, and shallow subsurface delaminations at speeds up to 15 mph (24 km/h). Detection capability is not sufficient to assure that all critical defects will be found.

References

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