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Tycho ACWDS Service Implementation

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Key Findings:

- After hardware maintenance and software upgrades performed in late 2019, Tycho ACWDS detected seven broken wheels and 23 wheels with subsurface fatigue crack defects, which were removed from the FAST train consist. In total, there were 12 passes of the FAST train through the ACWDS and 5,204 axle inspections (10,408 wheels) performed in the spring of 2020.
- Certain shattered rim crack defects can cause high impact on the ultrasonic probe/spring assembly that can lead to permanent damage. Redesign of the probe and spring assembly, or some protection from wheel defects, is recommended.
- Wheel flange speed sensor failure can cause issues with ultrasonic probe function and data quality.
- The 70-degree angled probes did not operate well beyond 5 mph.
- TTCI identified a number of environmental-induced issues during the 7-year test period. These issues should be addressed in revenue service with some combination of regular maintenance, small changes in materials or design, and/or an environmental shelter over the detector site.

Since May 2013, [Transportation Technology Center, Inc. \(TTCI\)](#) has been testing and evaluating the Automated Cracked Wheel Detector System (ACWDS), Version 4.2, produced by Nanjing Tycho Information Technology Company, Ltd. (Tycho). Evaluations at the Facility for Accelerated Service Testing (FAST) have included assessing the FAST heavy axle load (HAL) train (120 cars with 39-ton axle loads) on a regular basis. From installation through July 2020, a total of 62,912 axles passed through the ACWDS — roughly 150 total train passes (assuming 420 axles in a fully loaded train). TTCI concluded testing of the Tycho ACWDS at the end of 2020.

This *Technology Digest* describes the detection performance of the Tycho ACWDS after a significant probe and software updates were performed in late 2019. Multiple test reports describing the ACWDS and its capability have been published.¹⁻² This publication also describes some of the experiences and lessons learned from the service implementation of the ACWDS at FAST, details some of the operational issues recently observed from testing, and offers recommendations to mitigate these issues in the revenue service.

BACKGROUND

TTCI evaluated the Tycho ACWDS from 2013 to 2020 as part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) program. The Tycho ACWDS is an adaptation of the technology currently used in China to inspect train wheels. China's system configuration is based on their busiest depot and includes daily testing of between 50 and 60 trains with 64 and 80 axles (3,500-5,000 axles daily) at low speed (max. 5 mph). Testing of the system at FAST was performed at speeds up to 15 mph, which was found to be the maximum practical speed for performance of the spring-loaded piezoelectric ultrasonic transducers. FAST is located at the Federal Railroad Administration's Transportation Technology Center (TTC) near Pueblo, Colorado.

GENERAL SYSTEM LAYOUT

The ACWDS evaluated was a wayside ultrasonic non-destructive evaluation (NDE) system using contact ultrasonic transducers to inspect moving train wheels for internal flaws. The trackwork used a wide gage segment with inboard ultrasonic probes and a standard gage segment with outboard ultrasonic probes to span the entire tread width. For a single pass, every wheel (max. 38-inch diameter) was inspected over two full revolutions of the wheel in the wide gage section and over one full revolution in the standard gage zone.

This provided for a complete inspection of the wheel tread with 0-degree probes, as well as inspection of the flange and rim with angled 70-degree probes. It should be noted that the 70-degree angled probes did not operate well beyond 5 mph but 0-degree probes could operate at speeds up to 15 mph. Arrays of ultrasonic probes were used to identify internal fatigue cracks in the tread, near the rim face, and at the flange of the wheel. Each ultrasonic probe inspected a sector of the wheel and the individual inspections were seamed together to provide a view of the wheel's entire circumference. As shown in Figures 1 and 2, the system uses wheel flange speed sensors laid next to the ultrasonic probes to count axles and measure train speed. These sensors are necessary to synchronize the triggering of ultrasonic probes with the arrival of the wheels. Additionally, the system uses transmitter/receiver pairs of photoelectric sensors to wake up and shut down the system as the train enters and exits.

couplant re-circulation pump. This reduced the risk of a false start of the system cause by blowing debris.

The Tycho ACWDS is also equipped with self-diagnostics to help ensure continuous operation. When a probe malfunctions, the Tycho ACWDS acquisition software notifies the operator to replace the probe. Similarly, if any ultrasonic hardware or data collection units such as those inside the wayside cabinets malfunction or fail to communicate properly, the ACWDS acquisition software will alert the operator. These systems performed as intended.

Operational Requirements

The requirements document established at the beginning of this research project¹ calls for a 99 percent detection rate (only one true defect per 100 wheels with detectable defects is allowed to be missed), and a false alarm rate below 0.001 percent (only one good wheel per 100,000 wheels inspected may be incorrectly identified as bad). These requirements are intended to ensure that defects are properly identified with high confidence and as demanded for efficient economic performance, while simultaneously ensuring the detector is accurate and does not indicate the removal of good wheels. Detection performance after the 2019 maintenance and updates was consistent with results reported over the course of several years.^{1,2}

SPRING 2020 FAST DETECTION PERFORMANCE

During spring 2020 FAST operations (Feb. 11–May 19), there were 12 passes of the FAST train through the ACWDS and 5,204 total axle inspections (10,408 wheels). ACWDS detected seven broken wheels for removal. All broken wheels were verified with hand-held ultrasonic testing (UT). Table 1 shows the list of broken wheel detections and removals during spring 2020 FAST operation.

During this period, there were 284 yellow alarm alerts and 40 red alarm alerts. The majority of the red alarm alert wheels (23) were due to subsurface fatigue cracks and were removed from the FAST train upon hand-held UT verification. Out of 40 red alarms, 10 alarms were false positive. Subsequent analysis of the ultrasonic data revealed improper triggering of ultrasonics due to an inaccurate speed calculation. Rim backwall echo reflections registered by the newly installed outboard probes were the cause of these false calls. Tycho resolved these issues through software updates and algorithm changes. Figure 3 shows examples of the broken wheels detected by ACWDS and removed from the FAST train during spring 2020 FAST operation. In addition, prior work attempted to estimate the false-negative rate with the hospital train (with all known wheel conditions).² Subsequent updates and addition of the outboard probes would address the previously missed detections. However, inconsistent triggering of the system may still generate false negatives.

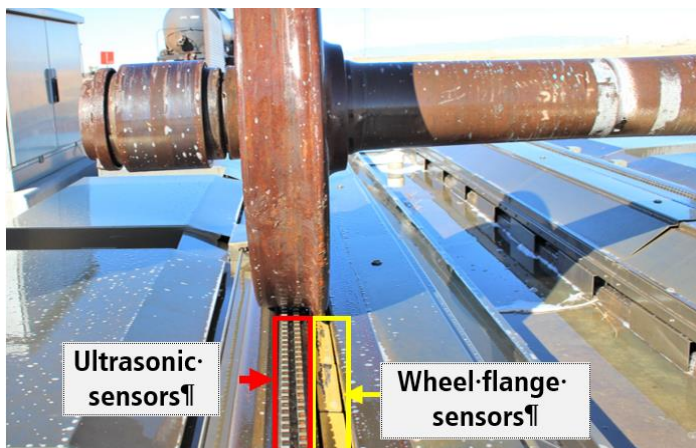


Figure 1. Wheel flange sensors and inboard ultrasonic probes in the wide gage section

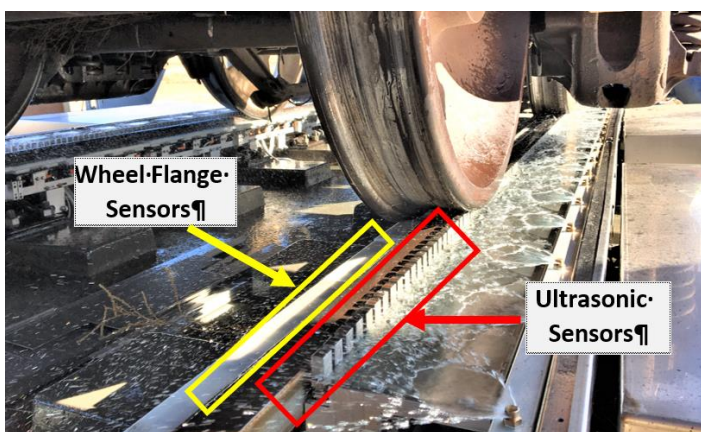


Figure 2. Wheel flange sensors and outboard ultrasonic probes in the standard gage section

On the advice of TTCI, Tycho added wheel sensors to supplement the photoelectric system wake-up sensors. These wheel sensors ensured a train was present before starting the

Table 1. Seven broken rim wheels detected in spring 2020

Car position	Car No.	Wheel position alarmed	FAST mileage (miles)	Transducer alarmed	Hand UT verification results
71	33150	R3	201,751	0° outboard	3.2"×1.5"×0.5"
62	33395	R3	219,281	0° outboard 0° wide gage	3.25"×2.75"
7	33166	L2	138,761	0° outboard	3.4"×1.1"×0.2-0.4"
17	33396	R1	194,466	0° outboard	1.0"×1.2"×0.25"
88	33317	L2	162,145	0° outboard	7.0"×1.8"×0.3"
58	33164	L3	156,027	0° outboard	5.25"×1.5"×0.2-0.7"
72	33290	L2	56,829	0° outboard	3.5"×0.9"×0.3"

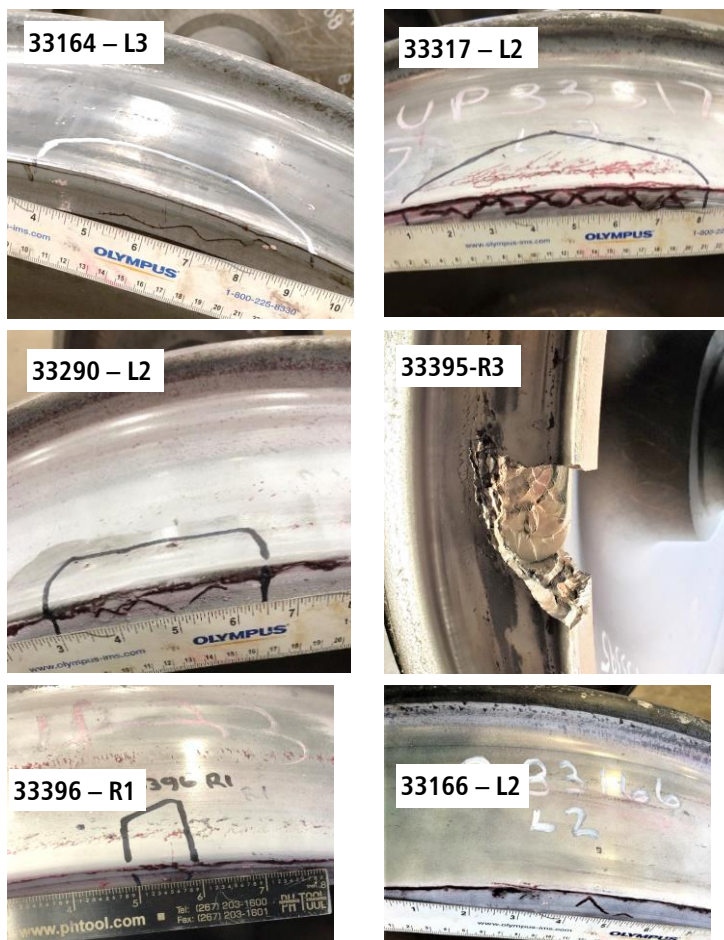


Figure 3. Broken wheels detected in FAST spring 2020 operation.

OPERATIONAL CONSIDERATIONS

The following sections report on lessons learned based on TTC experience of the Tycho ACWDS at FAST.

Effects of Broken Wheels

If train wheels ride on wide gage trackwork, a wheel with a shattered rim crack (SRC) can produce large impacts and damage the spring probe assemblies. Because vertical clearances are

minimal under the probes, there is no allowance for spring compression beyond the normal stroke of the probe. The spring is compressed with a coil-to-coil contact when the top face of the probe is flush with the guide plate. As a result, SRC wheels with material missing near the rim face can cause over-compression of the springs and damage them. This, in turn, causes the ultrasonic probes to lose effectiveness because they are positioned too low to contact each passing wheel. Figure 4 shows an example of spring damage caused by an SRC wheel.

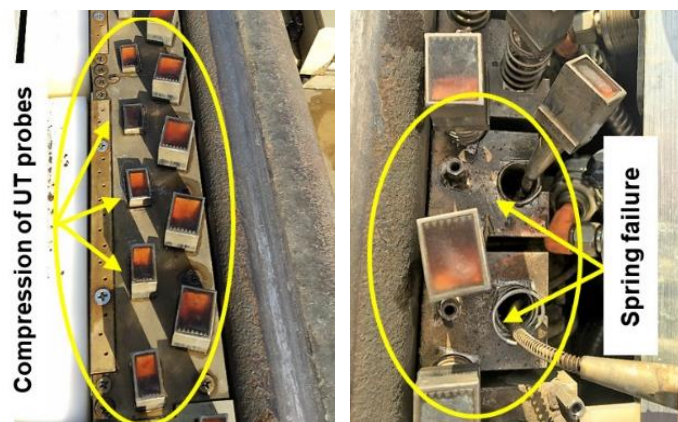


Figure 4. Damaged springs and spring seats

ACWDS Sensor Components Durability

During prolonged use of the system, several ultrasonic probes, wheel flange speed sensors, and wheel flange sensor boards were found to be damaged and degraded. Some had lost sensitivity from prolonged sunlight exposure. Degradation of some of the wheel flange speed sensors, such as wheel sensor boards affected by photo-oxidative degradation of the polymer board, was attributed to prolonged exposure to the sun. Additionally, some of the newer type wheel sensor boards were damaged in a severe hailstorm in 2018. Figure 5 shows examples of the damage caused by these types of environmental factors.

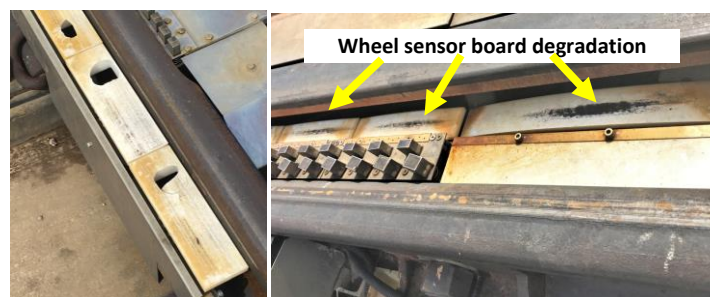


Figure 5. Wheel sensor boards damaged by hailstorm (left) and photo-oxidative degradation (right)

OTHER OPERATIONAL RECOMMENDATIONS

The research revealed several operational events and associated recommendations; however, it is important to note the differences between testing the Tycho ACWDS at TTC and actual

operation in the revenue service. For instance, the quantity of wheels that would be scanned in an actual revenue service installation will be much higher than the number resulting from the train running through the Tycho ACWDS at FAST. Consequently, observed wear on probes and trackwork was minimal and might not reflect performance in revenue service.

Environmental issues were also identified through testing at TTC, and these could be different depending on location. Debris (e.g., tumbleweeds, sticks, dirt) was often found covering couplant return drains or clogging their filters. In other regions of the country, leaves or pine needles could be an issue. Similarly, regional weather and climate can cause damage to system hardware. As mentioned, photo-oxidative degradation caused by excessive sunlight on the wheel sensor board was evident in the Tycho ACWDS at TTC. Thus, adding ultraviolet light absorbers to the boards is recommended. Additionally, southern Colorado, where TTC is located, can be subject to severe hailstorms. A stronger, shatter-resistant material is suggested to protect boards from impacts .

The false triggering of the photo-electric sensor from wind-blown debris, snow, and rain can activate the system and cause the couplant vault to empty even when no train was present. At TTC's recommendation, Tycho added a pair of wheel sensors to the photo-electric sensor circuit to recognize a train's presence and turn the water couplant spray system on or off accordingly. A similar augmentation is recommended for revenue service installation of the Tycho ACWDS.

Finally, a safeguard must be designed to pre-screen the severe SRC wheels from entering the system. In addition, protections must be designed to protect the spring-loaded probes and flange sensors from dragging operational lever equipment.

CONCLUSIONS

TTCI evaluated the Tycho ACWDS at TTC over the course of seven years. During this period, the system underwent upgrades, updates, and maintenance, and represented Version 4.2 hardware and software. During the last round of testing in spring 2020, the system correctly identified seven cracked rim wheels that were subsequently hand-UT verified and removed. It also identified 23 wheels with verified subsurface defects. During the spring FAST run, there were 12 passes of the FAST

train through the ACWDS and 5,258 total axle inspections (10,516 wheels.) The vast majority of the wheel population remained unchanged between the individual inspections, but car set-outs and wheel replacements do affect nightly train makeup. Thus, detection statistics are based on repeat sampling of a captive population and may not represent the performance achievable in revenue service.

The ACWDS at TTC was a relatively unprotected installation, so its maintenance requirements were both unique to its location and higher than if it were protected by a shelter building. As such, the frequent maintenance necessary to control environmental factors would be impractical in actual revenue service. TTCI recommends a design update along with regular maintenance of the system for any installations of the Tycho ACWDS. The location of any system for revenue application should take into consideration its distinctive environmental conditions. TTCI concluded the research, development, and testing of Tycho ACWDS at TTC at the end of 2020.

References

1. Poudel, A. and M. Witte, January 2017, "Tycho ACWDS Detection Performance Summary," *Technology Digest* TD17-003. AAR/TTCI, Pueblo, CO.
2. Poudel, A. and M. Witte, January 2017, "Automated Cracked Wheel Detection with Tycho ACWDS," *Technology Digest* TD17-002, AAR/TTCI, Pueblo, CO.

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