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Evaluation of Wheel Impact Load Cracked Rim Detector

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As part of the Strategic Research Initiatives (SRI) program of the Association of American Railroads (AAR), and with the cooperation of BNSF Railway and commercial vendors, Transportation Technology Center, Inc. (TTCI) evaluated three wheel impact load detector (WILD) systems for their ability to detect cracked wheels with damage near the field edge of the tread. WILD systems from three individual vendors were tested. Twin systems from each vendor were placed on curved and tangent track for comparison of measurements under both conditions. Results indicated that wheels with surface defects outside of the tapeline can be detected when the tracking positions of wheels move outboard off of the tapeline. Operating conditions influence the reliability of detection, and these effects are discussed.

Conventional WILD systems are installed on tangent track and are used to inform wheel removal decisions. However, many broken wheels fail in service absent of high impacts as measured by conventional WILD. The current investigation compares impact readings between WILD systems where the wheels are riding on the tapeline at one system and on the edge at the other. The system is termed "WILD EDGE." Tests were performed at Sections 33 and 31 on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST).

TTCI tested and evaluated the capability of each WILD EDGE system to detect wheel fractures that occur on the rim side of a wheel tread rather than at the tapeline. The primary objective of this work was to determine feasibility and to evaluate WILD EDGE detector systems for detecting rim fractures that occur outboard of the tapeline, near or into the rim face. The WILD EDGE was evaluated for repeatability and consistency.

BACKGROUND

Wheel impact load detectors (WILD) in revenue service are wayside detectors on tangent track that use a series of strain gages installed onto the rail web to measure vertical and lateral load forces of passing wheels.¹ The strain gages are grouped in cribs between the ties. Each instrumented crib is optimized to measure vertical load. Crib placements are strategically chosen to maximize the portion of the wheel circumference measured.

Key Findings:

- A new concept for determining wheel cracked rim defects was proposed by the BNSF Railway and was developed/tested at the High Tonnage Loop (HTL) at Transportation Technology Center (TTC) by installing WILD systems on curved track.
- Results indicated that wheels with defects outboard of the tapeline (close to rim face) can be detected on curved track.
- Test trains traveling between 30 and 40 mph show potential for recording impact forces on curve at levels similar to tangent WILD.
- Two out of three WILD EDGE systems recorded higher impact loads on curves at axles with defective wheels.
- Train operational conditions do affect results.
- Future work should address the estimation threshold targets for wheel impacts loads associated with broken rims, and also investigate methods of making the results more consistent.

Current WILD sites are installed on tangent track. Results obtained from these detectors are used to effect wheel removals for the purpose of reducing infrastructure damage and broken wheel derailments. However, many broken wheels (~74% according to a 2015 AAR AHSC study) fail in service absent of high impacts as measured by WILD. Many wheels that fail exhibit signs of damage at or near the edge of the tread on the field side of the wheel, or zone 1 as shown in Figure 1. Zone 1 is not typically exposed to the instrumented zone of the WILD on tangent track.

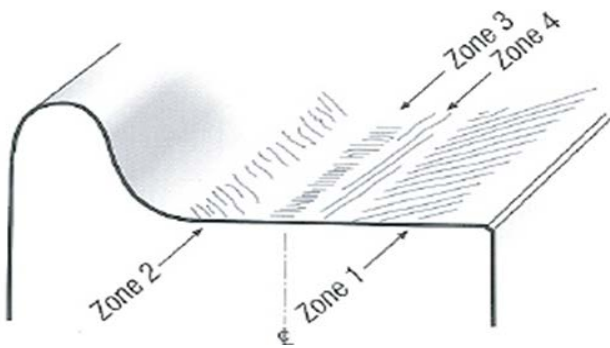


Figure 1. Damage zones in a railcar wheel tread³

PRIOR WORK

This *Technology Digest* (TD) is a continuation of the work referenced in TD-18-009 in which NUCARS[®] was used to determine the likely wheel contact position for a hypothetical hopper car in both loaded and empty states.² Based on results of NUCARS[®] modeling, TTCI determined a range of curvatures and conditions for demonstrating proof-of-concept (POC) on the HTL, at FAST. Wheel positions on leading axles during testing at 40 mph on the HTL should represent a realistic case for WILD EDGE operation.²

SYSTEM LAYOUT AND SITE PREPARATION

TTCI selected the low rail of Sections 31 and 33 on the HTL, which are in close proximity. Section 31 is a 5-degree curve with 4.3 inches of super elevation. Section 33 is tangent track. The curve has a balance speed of just under 40 mph. For a revenue installation, the system likely would be positioned on a reverse curve that follows a traditional WILD detector so that wheels on both rails can be monitored. Wide gage in tangent/curve also was considered but was much more invasive to engineering and operations, requiring track work and guardrails with associated speed. As a result, it was not further considered for this initial testing.

WILD EDGE systems from three commercial vendors were installed. For the proof-of-concept (POC) testing at TTC, WILD cribs are required on only one rail. Vendor 1 had 16 instrumented strain gauge-based cribs each on the low rail in Sections 31 and 33. Vendor 2 had eight accelerometer-based cribs each on the low rail in Sections 31 and 33. Vendor 3 had six fiber optics-based cribs on both the high and the low rail in Sections 31 and 33. TTCI spaced the concrete ties to 24 inches on-center (nominal 12-inch gap) per request of the WILD vendors. TTCI also performed surface align and grind on the rails and conducted ultrasonic non-destructive evaluation (NDE) to verify no internal defects were present in the rails.

TEST CONSIST

The test consist had three, loaded aluminium hopper cars. Figure 2 shows the two cracked wheels that were installed in axle positions R1 and R4 in the cracked wheel consist. Test wheel placements represent the best and the worst case scenarios, based on prior NUCARS[®] simulation results.²

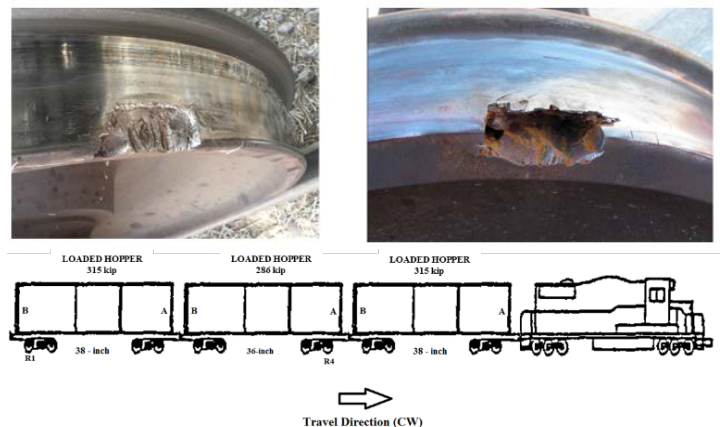


Figure 2. Test wheels and their locations in the cracked wheel consist.

The cracked wheel consist car I was a loaded 125-ton car (315,000 pounds) with 38-inch diameter wheels. The defective wheel was in the R1 position. The second car was a loaded 100-ton car (286,000 pounds) with 36-inch diameter wheels. The defective wheel was in the R4 position. The center-to-center axle spacing in both cars was approximately 6 feet.

CALIBRATION AND TESTING

There were two parts to this testing effort: calibration and testing. Two of the systems (accelerometer-based and fiber optics-based) required dynamic calibration, which was accomplished by running, a locomotive and loaded hopper of

known weights, over the systems to provide a known reference load. Similarly, strain gage-based system was calibrated using instrumented drop tests.

Testing runs were completed at 10, 20, 30, and 40 mph in clockwise (CW) and counter-clockwise (CCW) directions. For the test runs, the train consisted of a locomotive, a loaded hopper of measured weight, and two loaded cars with defective wheels. The locomotive was moved to the opposite end of the test consist for runs in the opposite direction. This kept the test wheels on the lower rail at all times. It should be noted that CW moves started on tangent track and ended on curved track, while CCW moves started on curved track and ended on tangent track. This means that the WILD EDGE systems were encountered before a spiral transition in the CCW direction only. This operational difference may be significant regarding wheel position over the detectors on the curved track.

RESULTS AND DISCUSSION

Data from the three WILD vendors were examined and analyzed separately. The analysis presented is based on the dynamic vertical force (the difference between the peak vertical force and the static wheel force). This generally accounts for the difference between loaded and empty cars. Static wheel weight was not available from Vendor 3, thus peak forces are reported there. The wheel defects were at axle No. 11 and axle No. 18 in the test train. Results reported are for loaded cars in the CW direction.

Figure 3 shows the dynamic vertical force for each axle and for each run from a single vendor. Axles 11 and 18 experienced higher impact load forces at the WILD EDGE at 30 and 40 mph than on the tangent track WILD. Tests at lower speeds did not show a negligible difference in impact loads between curved and tangent track. This was expected as wheel position is closer to center in the curves at lower speeds.

Runs in the CW direction created higher dynamic vertical forces than CCW runs. This is likely a result of the varying operating conditions regarding starting in a curve versus on tangent. Wheel position was more favorable during the CW runs.

Figure 4 shows the test in a counterclockwise direction. Even though axles 11 and 18 have higher dynamic vertical forces than other (non-defective) wheels, using the same

threshold as used for the CW runs could lead to false positive detections.

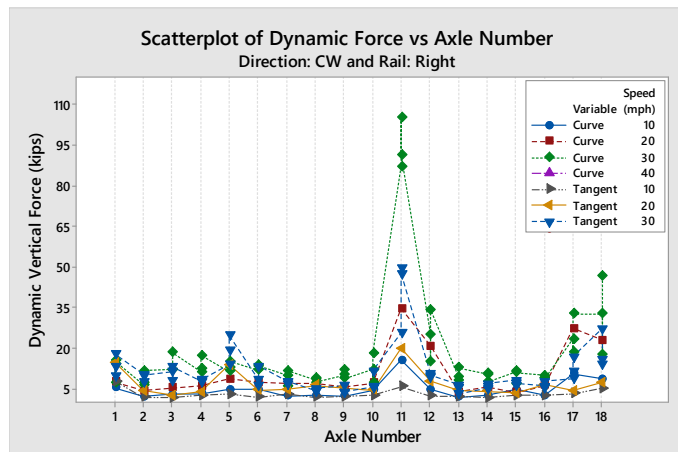


Figure 3. Dynamic vertical force versus axle number of loaded cars – clockwise direction

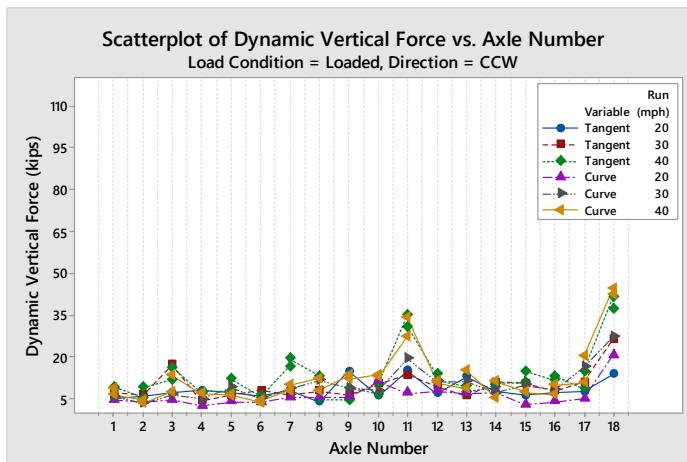


Figure 4. Dynamic vertical force versus axle number of loaded cars – counterclockwise direction

Another way to analyze performance was by studying the variation in the readings. The variation in range of dynamic force from a defective wheel in a curve was higher than on tangent track. Figure 5 shows a box plot indicating higher dynamic vertical forces for wheels with defect (axles 11 and 18) versus a typical non-defect wheel.

The data used for the next part of the study contained three runs: one at 30 mph and two at 40 mph. The methodology applied was the individual control chart, which examined variation in individual sample results over time. The upper control limit on a control chart is not a strict threshold. It is related to the statistical variance and identifies the outlier forces. The outliers are more pronounced in the curve rather

than in the tangent track. In Figure 6, the top control chart shows the data collected at the tangent track, and the bottom control chart reflects data collected at the curve.

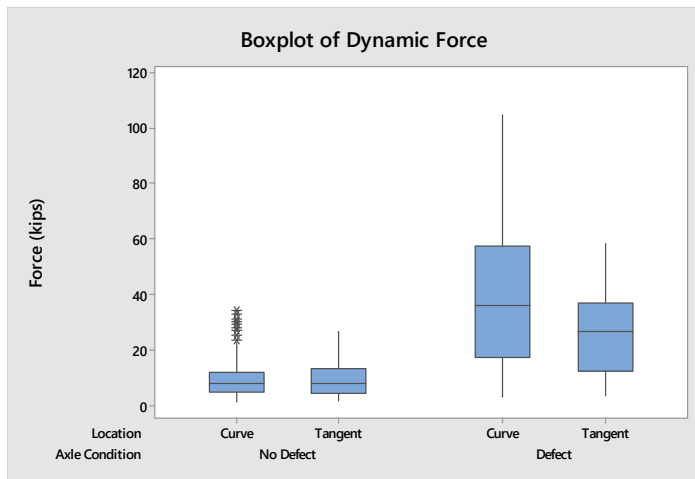


Figure 5. Boxplot of dynamic vertical force versus axle condition and wayside detector location

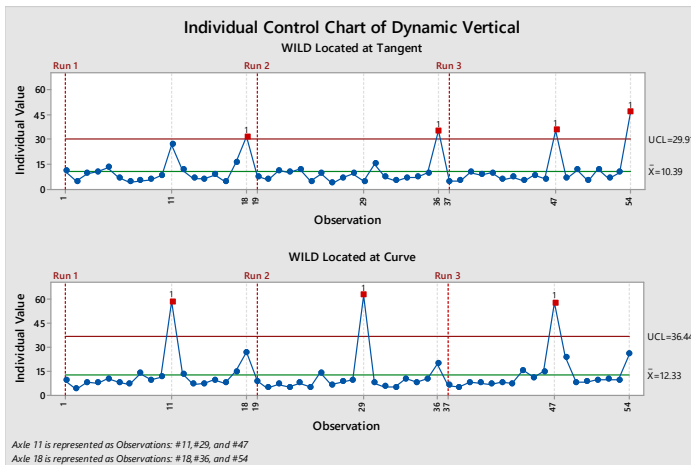


Figure 6. Individual control charts of dynamic vertical sub-grouped by detector position (curved versus tangent)

The defective axle No. 11 is represented at the control chart as observations number 11, 29 and 47. In addition, axle 18 is represented at the control chart as observations number 18, 36 and 54.

Tangent WILD recorded 15 kips above average dynamic vertical forces for defective wheels. WILD EDGE recorded over 40 kips above average dynamic vertical forces. Overall, tangent WILD would have flagged five of six defective wheels using control chart analysis. WILD EDGE would have flagged six of six.

CONCLUSIONS

The primary objective of this work was accomplished: demonstrating the capability of a WILD EDGE to find rim fractures that occur outboard of the tapeline. Two out of three of the WILD EDGE systems tested would have identified the cracked wheels at speeds above 30 mph. Varying operating conditions affect wheel position; and thus, the ability to reliably detect such defects with WILD EDGE.

The WILD EDGE (curved track) and WILD (tangent track) detector systems were tested using two cracked wheels installed at leading and trailing axle positions. The range of dynamic force in a defective wheel detected by the WILD EDGE system is higher than in the WILD system. The defect installed at the leading axle produced the highest dynamic forces between both defective wheels.

FUTURE WORK

Future work should address the estimation threshold targets for wheel impacts loads associated with broken rims, and also investigate methods of making the results more consistent.

References

1. Kalay, S. "Wheel Impact Load Detector Tests and Development of Wheel-Flat Specification," Report R-829, AAR Chicago Technical Center, Chicago, IL, May 1993.
2. Witte, M., A. Poudel, and C. Grimes, "NUCARS® Simulation of a Wheel Impact Load Cracked Rim Detector," *Technology Digest* TD-18-009, AAR/TTCI, Pueblo, CO, November 2017.
3. Association of American Railroads, *Field Manual of the AAR Interchange Rules*, Rules 41.L.4. Washington, DC., 2017.

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