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NUCARS® Modeling Optical Geometry Detector Wheelset Tracking

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Summary

As part of the Association of American Railroads' (AAR) Strategic Research Initiatives Program, the Transportation Technology Center, Inc. (TTCI) examined the ability of an optical geometry detector (OGD*) to identify trucks with worn truck components, and its effectiveness to identify specific worn characteristics.

NUCARS®** multi-body rail dynamics models were developed to simulate non-hunting railcars with worn truck components. Three common railcar types were selected for simulation to represent a large percentage of the railcar fleet. The NUCARS model includes equipment, track, and operational components used to assess the performance of various truck designs. Over 120 simulations were analyzed considering direction, load, and wheel condition. The truck components modeled for wear were spring groups, friction wedges, shifted load, side frames, center bowls, and adapter pads. An additional optimized model of 63 runs was created updating some components.

Results of the simulations when comparing best-of-the-best (BOB) and worst-of-the-worst (WOW) trucks for each car type were as follows:

- Railcars when not hunting in tangent track are not distinguishable between BOB and WOW trucks with new AAR-1B wheels without a large array (about 12) of detectors.
- Railcars (with trucks in both the as-new and worn conditions) equipped with wheels that have asymmetrical wheel flange wear (AWFW) have a larger mean tracking position shift than cars equipped with new AAR-1B wheels in either truck condition (BOB or WOW).
- OGDs installed in 4- or 5-degree curves may detect worn trucks with and without worn wheels.
- OGDs may be installed in a 4- or 5-degree curve and adjacent tangent track to reduce false positives from AWFW.
- An OGD installed in a curve may not detect worn trucks as well as or better than a 3-unit OGD in tangent track that measures hunting.

*The abbreviation OGD is an industry term used since April 2011, and it does not identify a specific vendor.
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INTRODUCTION

The optical geometry detector (OGD) measures the tracking position (TP) and angle of attack (AOA) of wheelsets on a truck.

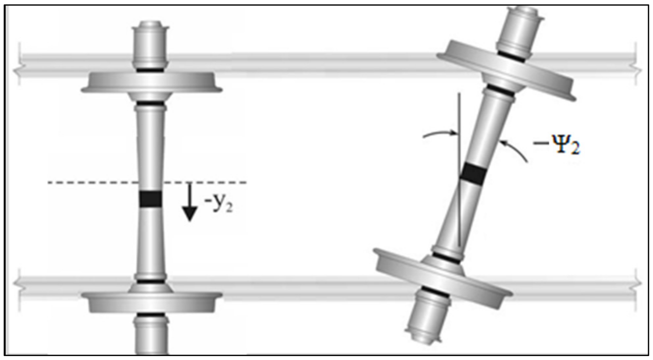

Figure 1. TP (left) and AOA (right)

OGDs have been used to identify worn flanges, worn truck components after significant wheel wear, and hunting when using a system with three detectors (hereafter referred to as the 3-unit OGD). OGD systems have been installed in tangent track in all cases.[1]

This investigation examined the ability of the OGD to identify trucks with worn truck components when not hunting, and its effectiveness to identify specific worn characteristics regardless of wheel condition.

NUCARS Model Development

Three NUCARS® multi-body rail dynamics models were developed to simulate non-hunting railcars with worn truck components.[2] Three common railcar types were selected for simulation to represent a large percentage of the railcar fleet:

- 263,000-pound boxcar with standard 3-piece trucks
- 286,000-pound coal hopper car with M-976 trucks
- 5-platform double stack intermodal car with 40-foot platforms and 125-ton standard 3-piece trucks

Over 120 simulations were analyzed considering direction, load, and wheel condition. An additional optimized model of 63 runs was created updating some components. The Wheel Rail Mechanism (WRM) loop at the Transportation Technology Center was used as an input track because of its diversity of curves. The WRM includes seven sections of tangent track, six curves of 3, 4, 5, 7.5, 10, and 12 degrees, and 14 spirals. Most simulations were conducted at a constant 32 mph (balance speed in the 4- and 5- degree curves). No rail lubrication was factored into any section of track. The sample rate of the model is one measurement taken every 0.6 feet of track.

The truck components modeled for wear include spring groups, friction wedges, shifted load, side frames, center bowl, and adapter pads. Each component was modeled as 85 percent worn, per the *Field Manual of AAR Interchange Rules* or AAR *Manual of Standards and Recommended Practices* including Chapter 11. For example, if a spring has a nominal free height of 10 inches and a condemnable free height of 9 inches, then the spring is modeled at 9.15 inches.[3]

Spring group and friction wedge components were modeled as worn based on travel distance from nominal positions.[3] To simulate a shifted load, a center of gravity shift was placed on the load of the car. The length of a side frame was increased so that it was at the maximum distance in length that would still be considered a 1 button mismatch (about 1.8 button lengths) using the side frame button measurement system.[4] The center bowl was modeled as worn by increasing the coefficient of friction between the body and the center bolsters. The coefficient of friction between the side frame and bearing adapters was increased. Consulting with the manufacturer of an M-976 adapter pad, the adapter pads were more likely to become contaminated than to wear and that contamination of the pad results in an increased coefficient of friction. For standard adapters the increased coefficient of friction simulates damage to the surfaces such as gouging.

The simulations were configured so that after completion two truck conditions would be compared: (1) trucks in nominal, new condition, and (2) trucks with all of the specified wear components as 85 percent worn. The trucks in nominal, new condition are described as the best-of-the-best (BOB) while the others are described as the worst-of-the-worst (WOW).

Additional simulations were completed with BOBs and WOWs that had wheels with asymmetric wheel flange wear (AWFW) to analyze the influence of wheel condition. These wheels were modeled using profile measurements from four wheelsets that had developed AWFW in revenue service. The minimum flange width was 1.0625 inch (26.98 mm) and the maximum wheel hollow was 0.118 inch (3 mm) for these eight wheels.

Analysis

The primary measures of performance analyzed from the NUCARS model were axle lateral displacement and axle yaw rotation. Axle lateral displacement and axle yaw rotation are comparable to OGD's TP and AOA respectively. The following four major comparisons were considered in the analysis of these simulations:

- BOB vs. WOW with new AAR-1B wheels on tangent track
- BOB vs. WOW with new AAR-1B and AWFW wheels on tangent track
- BOB vs. WOW with new AAR-1B wheels on curve track sections
- Curve vs. tangent track sections with BOB and WOW trucks, new AAR-1B and AWFW wheels

Pairwise differences between the BOB and WOW trucks on tangent track sections were compared. Figure 2 shows axle lateral displacement on a tangent track section for BOB and WOW simulations. When the vertical distances at each point are put into a histogram, the result fits a normal distribution.

This is an indication of natural variation between the simulations and not another cause.

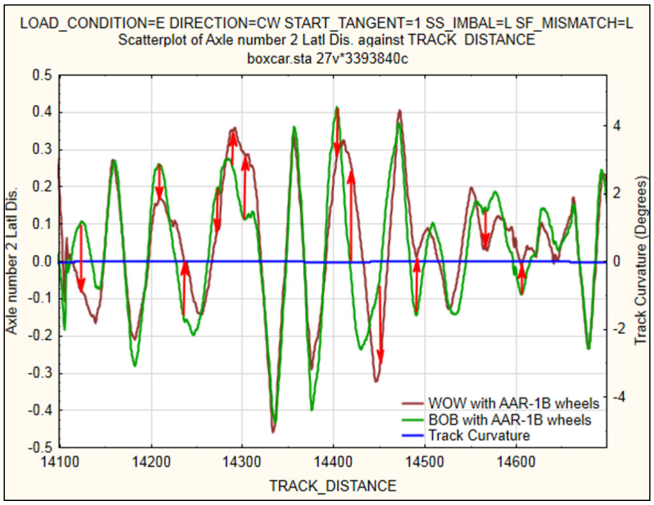

Figure 2. Tangent Track Axle Lateral Displacement. Red Arrows Show Differences between BOB and WOW Truck with New AAR-1B Wheels

To measure the pairwise differences between identically configured BOB and WOW simulations, a 1-sample t-statistical test was used. This test concluded that there was a statistically significant difference between the identically configured BOB and WOW simulations. But when looking at the most extreme cases of mean shift for each car type, the differences are minimal:

- Boxcar – 0.0794 inch (2.0 mm) TP and 0.32 mRad AOA
- Hopper – 0.0943 inch (2.4 mm) TP and 0.33 mRad AOA
- Double Stack – 0.1846 inch (4.69 mm) TP and 0.78 mRad AOA

Therefore, based on the simulation model, non-hunting cars in tangent track are not distinguishable between BOB and WOW trucks with new AAR-1B wheels without a large array (about 12) of detectors.

Next, the measurable differences between BOB and WOW trucks with new AAR-1B or AWFW wheels while on tangent track sections were examined. Figure 3 shows the new AAR-1B wheels tend to have similar variation for BOB and WOW trucks, while the AWFW wheels are shifted with more variation regardless of BOB or WOW trucks. A repaired BOB truck with AWFW wheels may have an elevated TP and consequently be a false positive (red and blue lines). Figure 4 shows little mean difference between trucks with new AAR-1B wheels (blue circle) and significant differences with AWFW wheels (brown circle) for both BOB and WOW trucks. For the cars modeled, worn trucks will first need to wear the wheels before truck issues become evident.

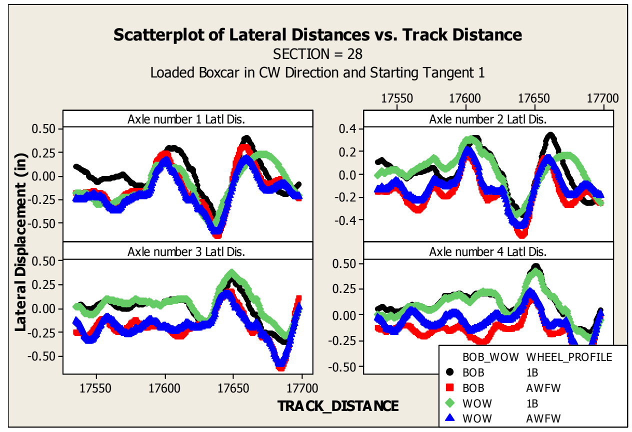

Figure 3. Example of Loaded Box Car in the Tangent Clockwise Direction

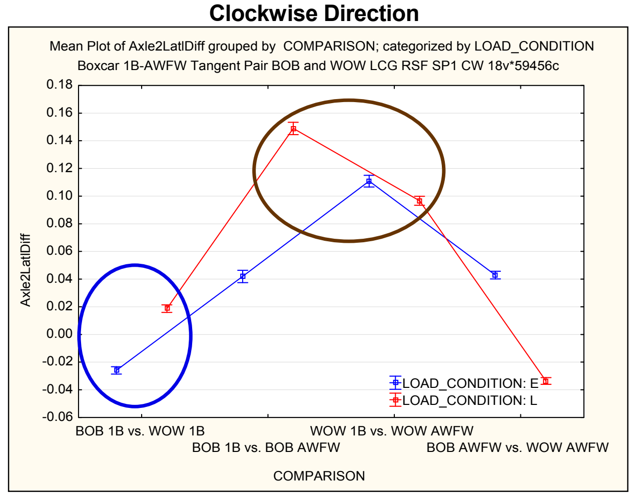

Figure 4. Shows Significant Mean Shift with AWFW (Brown) and Little with New AAR-1B Wheels (Blue)

Third, the measurable differences between BOB and WOW simulations with new AAR-1B wheels in curved track sections were considered. Analysis of the curves indicated there may be some conditions in which worn truck components can be detected. OGDs installed in 4- or 5-degree curves may detect worn trucks with and without worn wheels. The OGDs would have to be installed on the field side of the high rail and only TP measurements toward the detector would be counted toward alerts.

The following considerations would affect detector performance:

- Balanced speed through the curves should minimize false positives and negatives.
- Rail lubrication may affect the alert find rate
- The false positive rate may be high because of AWFW on BOB trucks
- Imbalance speeds and shifted loads on the high side of the curve may produce false positives
- Not all trucks of a multiple-platform car may be detectable in the curve
- At least two OGDs would be required in the curve

In addition to the list above, direction of travel, load condition, and truck design may reduce the detectability of truck conditions in a curve. An example of this can be seen in Figures 5 and 6. Figure 5, as indicated by the blue oval, shows some lateral displacement for trailing axles on the double stack car while loaded in the 4- and 5-degree curves traveling in the clockwise direction. Some trailing axles show considerable lateral displacement in the 12-degree curves (brown circles). In Figure 6, the hopper car equipped with M-976 trucks has higher lateral displacements for trailing axles while loaded in 3- to 5-degree curves in either direction.

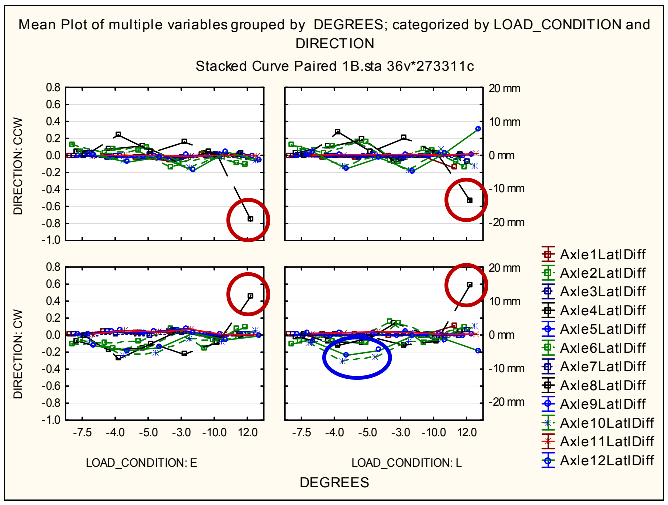

Figure 5. Double Stack Mean Differences between BOB and WOW Simulations in the Curve by Axle and Degree of Curvature

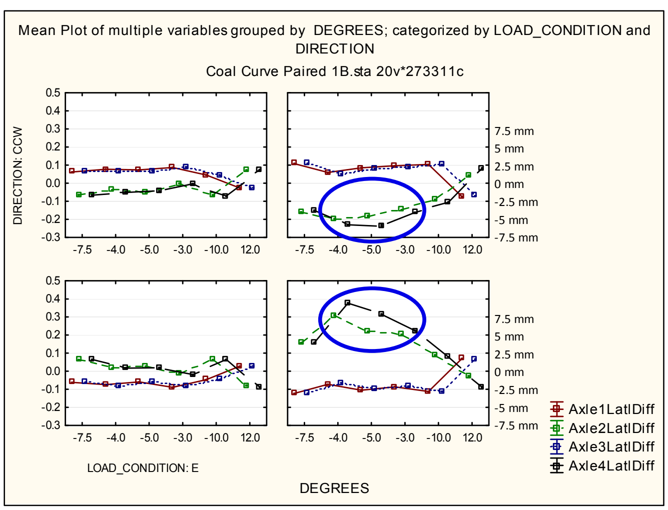

Figure 6. Hopper Mean Differences between BOB and WOW Simulations in the Curve by Axle and Degree of Curvature

Finally, the measureable differences of an axle's TP between tangent and curve track sections are estimated. An examination of the results from the tangent and curve sections indicates there may be some conditions in which worn truck components can be detected. OGDs installed in a 4- or 5-degree curve and adjoining tangent track can reduce alerts from AWFW. In order to find a significant difference in performance between the tangent and curved track sections, three OGDs would need to be installed in each adjoining section. Previously mentioned considerations that affect detection performance may also be significant for this result.

CONCLUSION

Results of the NUCARS modeling show the three selected car types when not hunting in tangent track are not distinguishable between BOB and WOW trucks with new AAR-1B wheels. Differences in TP might be seen with a large array of detectors (about 12).

The same cars equipped with AWFWs have a larger mean TP shift than cars equipped with new AAR-1B wheels in either truck condition (BOB or WOW). A repaired truck (BOB) with AWFW wheels may have an elevated TP and consequently produce a false positive. For the cars modeled, worn trucks will first need to wear the wheels before truck issues become evident.

OGDs installed in 4- or 5-degree curves may detect worn trucks with and without worn wheels. The detectors would be installed on the field side of the high rail and only alert a TP toward the detector. There are many considerations that can affect the performance of the detector.

OGDs installed in a 4- or 5-degree curve and adjoining tangent track may be able to compensate for measured performance due to AWFW. This may not be practical because of the need for three detectors to be placed in each of the adjacent tangent and curve track sections.

An OGD installed in a curve may not detect worn trucks as well as or better than a 3-unit OGD in tangent track that measures hunting.

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