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The research described was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Tests of a Center Plate with Modified Relief Shape

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Key Findings:

- A center plate having a 20-inch radius relief contour did not affect truck rotation, wheel forces, or truck turning moment compared to a standard center plate.
- Although the large radius center plate relief was expected to reduce stresses in the horizontal center plate liner, it caused significant extrusion of the liner at relatively low mileage.

Transportation Technology Center, Inc. (TTCI) conducted a test to evaluate the effectiveness of a new center plate relief contour to reduce deformation to non-metallic horizontal center plate liners. This research was performed as a part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) program.

A recent study[1] showed that improper truck rotation is the most common cause of truck-related derailments. The authors recommended that the root causes and potential solutions to this issue be investigated. As part of that study, TTCI conducted inspections of worn M-976 trucks in 2017 and 2018. Many of the trucks inspected had non-metallic horizontal wear liners between the center plate and center bowl. In several cases deformation of the horizontal wear liner was noted. This deformation was concentrated along the line where the center plate relief began.

Center plates are shaped with relief along the lateral edges to prevent point loading of the center plate in the center bowl when the carbody rolls relative to the truck bolster onto the side bearing. The ability of the car body to roll relative to the truck bolster allows the car to maintain adequate vertical wheel load while negotiating spirals and track twist deviations.

The center plates inspected conformed to the alternate standard shown in *AAR Manual of Standards and Recommended Practices*, Standard S-258.[2] The relief starts 1 3/8 inch from the edge of the center plate and has a 3/8-inch radius at the transition (Figure 1). As the car rolls onto the truck side bearing, this produces a line of contact between the plate and bowl that is about 9 inches long.

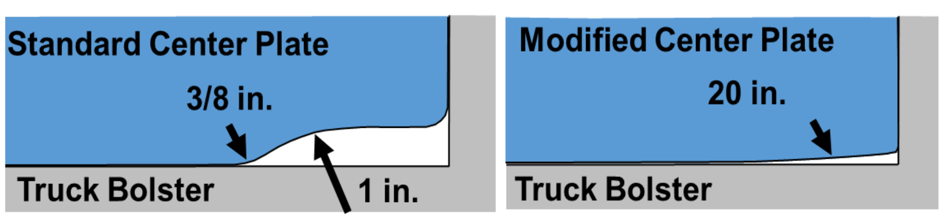

Figure 1. Alternate standard for body center plate relief (l) and modified center plate relief (r)

A car with a gross rail load of 286,000 pounds and 6,000-pound pre-load side bearings might carry over 120,000 pounds in the center plate. When this load is supported on a line of contact 9 inches long with a 3/8-inch radius, the maximum Hertzian contact stress is well above the yield strength of the strongest steels. As shown in Figure 2, increasing the radius along the line of contact reduces the stress considerably.

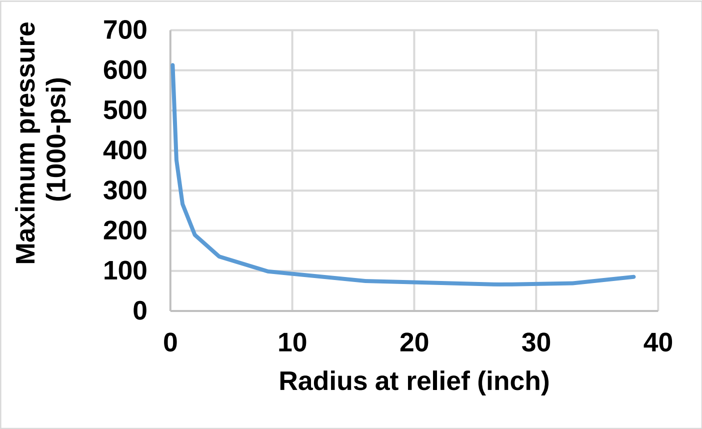

Figure 2. Contact stress on the line of contact between the center bowl and center plate as a function of chamfer radius

The outermost line of contact moves toward the edge of the center plate and becomes shorter as the radius increases. In the extreme case of a flat center plate, this causes point loading at the edge. The minimum stress appears to occur with a radius of about 27 inches. The center plates tested used a 20-inch radius.

Four center plates without relief or heat treating were obtained for the test. TTCI machined relief with a 20-inch radius on each lateral edge. The center plates were then heat treated. TTCI operates a train at the Facility for Accelerated Service Testing (FAST) at Transportation Technology Center (TTC). The center plates were installed on two FAST cars (21 and 45) together with new horizontal liners. Two other FAST cars (43 and 94) with standard center plates and similar gross weight and trucks were selected and new horizontal liners were installed for comparison. All four cars are 125-ton aluminum coal hoppers.

RESULTS

Results from truck rotation measurements, wayside force measurements, turning moment tests using an air table, and inspections after about 25,000 miles are discussed in the following subsections.

On-Track Truck Rotation Measurements

The two cars selected for the center plate modification were tested before and just after the modifications were made. Figure 3 shows truck rotation measured in a 6-degree curve at FAST plotted versus speed. The ideal truck rotation to make the bolster radial with the curve is shown as a red line. The normal tendency of the lead truck to understeer and the trail truck to oversteer is apparent. The performance of the cars is similar before and after the new center plates were installed.

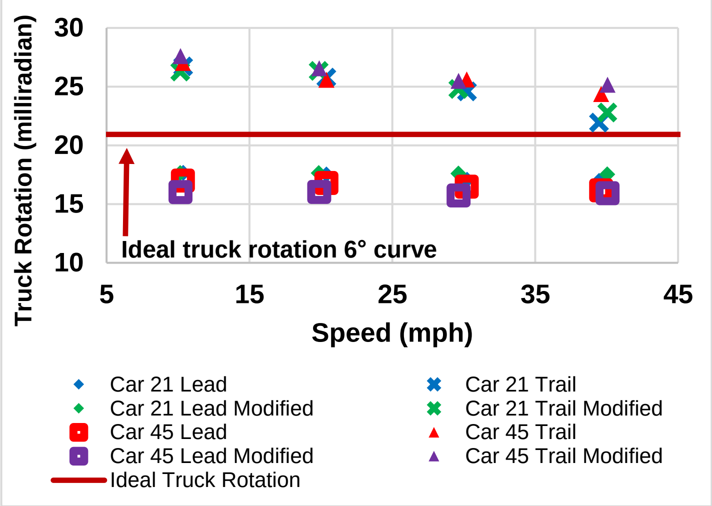

Figure 3. Truck rotation measurements of Car 21 and Car 45 before and after modifications were made

Wayside Force Measurements

A truck performance detector, consisting of a series of strain gauges placed on the rail to measure vertical and lateral forces of passing wheels, is used at FAST to monitor train performance. The wheel forces were analyzed for the modified cars to:

- Verify acceptable performance.
- Identify any difference in performance between modified cars and the standard cars.
- Determine if the performance changed over time.

Figure 4 shows a plot of lead axle high rail lateral force for clockwise operation with A-ends leading for the two modified and the two standard cars. The top plot shows the performance at the beginning of the test and the bottom plot shows the performance at the end of the test.

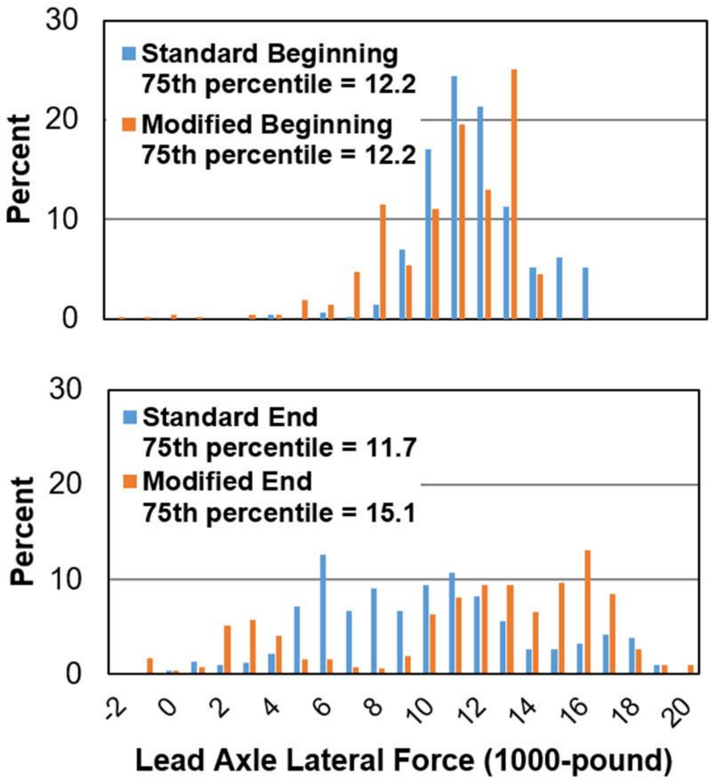

Figure 4.. Comparison of lateral force data for leading axle high rail wheels of modified and standard cars for clockwise runs with A-end leading

The force levels are in a range expected for the FAST cars. Although there are too few cars in the test to apply statisical conclusions, the lateral force of standard and modified cars are similar at the beginning of the test.

The range of forces is much wider at the end of the test than it was at the beginning for both standard and modified. The modified car 75th percentile lateral force value increased by about 3 kips while the standard car remained roughly unchanged. Lateral wheel forces are influenced by a wide range of conditions including car and truck characteristics as well as track conditions such as the prevailing friction condition between the wheels and rails.

Inspections

Between October 2018 and December 2019 the two cars with modified center plates each accumulated about 25,000 miles of service at FAST. One standard car accumulated about 27,000 miles and the other accumulated about 15,000 miles. The standard cars with their original center plates showed some deformation to the horizontal wear liner along the line where the chamfer begins (Figure 5, left). The modified center plate did not produce this line of damage, but it did produce significant extrusion up the side of the center bowl (Figure 5, right).

Figure 5. Horizontal wear liner condition with original lever plate (l) and modified center plate (r)

Air Table Truck Rotation Measurements

Before restoring the modified cars to their original condition, TTCI measured truck turning moment of the modified and standard cars. Each truck of each car was supported on an air bearing table so the torque required to rotate the truck could be measured.

The constant contact side bearings were left in place during the truck rotation tests.

Measurements were made with the cars flat (on track with no crosslevel deviation) and in a twisted condition. For the twisted condition, the wheels on one side of the truck that was not on the airtable were raised 2 inches above the rail. This simulated the maximum allowable track twist rate in a curve entry spiral of 3 inches in 62 feet, calculated over the length of the truck center spacing.

Figure 6 shows the average breakaway turning moments measured during the test. The breakaway moment means the moment required to turn the truck from the zero position. No consistent difference is noted beween the standard and modified center plate or between the flat and twisted conditions.

The comparison of the breakaway turning moment shown in Figure 6 does not reflect differences observed between the turning moment characteristics when the car was flat and when the car was twisted. Figure 7 shows plots of turning moment versus truck rotation over the full rotation angle for one truck with a modified center plate and one truck with a standard center plate.

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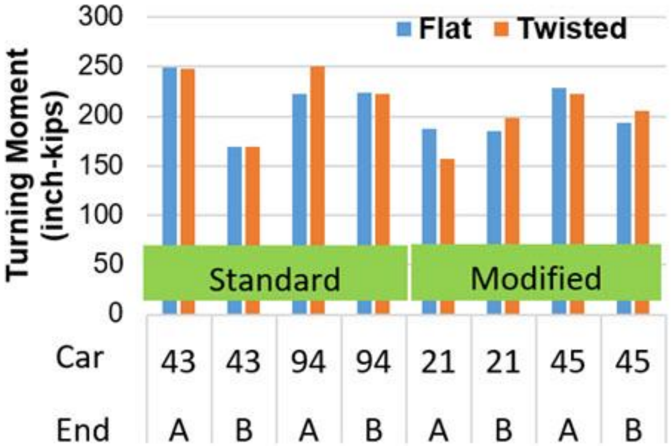

Figure 6. Truck turning torques measured with the car body flat and with the car body twisted

When the car is twisted a distinct step in the magnitude of the turning torque appears. Tournay et al.[3] suggested that these steps are caused by edge contact between the center plate and center bowl. When the car is twisted the line of contact between the center plate and center bowl is offset to one side so the rotation is not centered. This makes edge contact between the bowl and plate more likely.

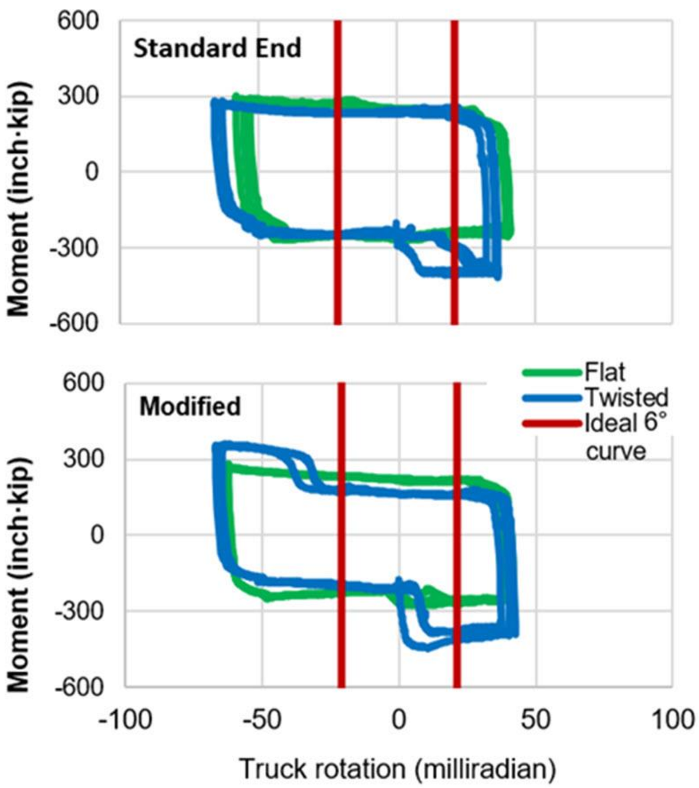

Figure 7. Plot of turning torque against truck rotation for a truck with a standard center plate and a truck with a modified center plate

CONCLUSIONS

A center plate having a 20-inch radius relief did not affect truck rotation, wheel forces, or truck turning moment compared to a standard center plate.

Although the large radius center plate relief was expected to reduce stresses in the horizontal center plate liner, it caused significant extrusion of the liner at relatively low mileage compared to the standard center plate. It is likely the stresses were lower, but were still above the yield strength, and were distributed over a wider area.

ACKNOWLEDGEMENTS

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References

1. Keylin, A. et al., September 2019, "Assessment of Service-Worn, 110-ton M-976 Trucks," *Technology Digest* TD-19-020, AAR/TTCI, Pueblo, CO.
2. *AAR Manual of Standards and Recommended Practices,* 2014, Standard S-258, "Body Center Plate Relief Alternative Standard," Adopted: 1980, Association of American Railroads, Washington, DC.
3. Tournay, H., R. Lang, T. Wolgram, April 2006, "Truck/Carbody Interface Design Principles," *Technology Digest* TD-06-009, AAR/TTCI, Pueblo, CO.

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