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Integrated Freight Car Truck Curving: Part 1-Test Procedure

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Summary

Transportation Technology Center, Inc. (TTCI) has proposed a new test procedure to evaluate the curving performance of trucks and classify as non-steering (three-piece), steering (M-976), and better steering (Integrated Freight Car Trucks or IFCT). The test procedure uses low rail traction ratio rather than the current curve resistance-based testing. A series of truck curving tests were completed with the new test procedure at the Transportation Technology Center Wheel Rail Mechanism (WRM) loop in Pueblo, Colorado. The proposed test procedure offered three main advantages over curve resistance tests:

- Although curve resistance is an indirect indicator of steering or lower wheel and rail tangential forces, it does not adequately quantify the curving performance.
- The new test procedure uses the low rail traction ratio, which is a key parameter for the surface initiated rolling contact fatigue that results in high impact wheels.
- The use of a non-steering truck (reference truck) and the test truck simultaneously is expected to minimize variations in test such as friction coefficient, wind speed, temperature, humidity, and rail and track condition.

Under the AAR Strategic Research Initiatives Program, TTCI investigated and evaluated truck designs submitted by truck manufacturers that would minimize tangential forces between the wheel and rail during curving. The IFCT design aims to reduce high impact wheels and fuel consumption further while maintaining empty and loaded lateral stability. Low rail-wheel traction ratios are used to quantify these three categories of trucks (Non-steering, M-976 and IFCT) instead of the current curve resistance-based testing.

In 2004, the North American railroad industry adopted the S-286 standard for interchange cars weighing 286,000 pounds. This standard required M-976 trucks.¹ Research has shown the superiority of M-976 trucks over non-steering trucks, in terms of improved curving and better stability.^{2,3,4} The IFCT research program aims to take the improvements found with the M-976 trucks one step further. Design improvements of the IFCT include optimizing the longitudinal inter-axle stiffness and improving warp restraint stiffness and clearances without compromising the life of the components.

The second part of this study will be presented in a future *Technology Digest* and will discuss the detailed test data analysis results and steering quantification.



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INTRODUCTION

TTCI investigated and evaluated trucks designed to minimize tangential forces between the wheel and rail during curving. The Integrated Freight Car Truck (IFCT) design aims to reduce high impact wheels and fuel consumption while maintaining empty and loaded lateral stability. The IFCT tests were conducted under the AAR Strategic Research Initiatives (SRI) Program, at the Transportation Technology Center Wheel Rail Mechanism (WRM) Loop in Pueblo, Colorado.

BACKGROUND

In 2004, the North American railroad industry adopted the S-286 standard for interchange cars weighing 286,000 pounds. This standard requires testing trucks in accordance with AAR M-976 specifications, and includes the following tests:¹

- AAR Chapter XI steady-state curving tests that measure the wheel lateral-to-vertical force (L/V) ratios to confirm they are within safe limits during curve negotiation at 3 inches underbalance, balance, and 3 inches overbalance speeds for the test car/truck.
- Rolling resistance tests to distinguish steering trucks from non-steering trucks by measuring the pulling forces at the couplers via load cell on 1.5-, 4-, 7.5- and 10-degree curves with a loaded car with test truck only. Curving resistance is calculated by subtracting the tangent track rolling resistance of a standard three-piece truck per tonnage and dividing it by the degree of curvature. Resistance values derived from the four curve tests are then averaged to determine the final curve resistance value. The standard M-976 test compares the test truck average resistance to the limit (0.4 lb./ton/deg.).²

Previous research has shown the improved performance of M-976 trucks over non-steering trucks. The improved performance included lower wheel-rail tangential forces, which can result in reduction of high impact wheels and fuel consumption, as well as better stability.^{3,4,5}

OBJECTIVE

The IFCT research program aims to take the improvements made with the M-976 trucks one step further by optimizing longitudinal inter-axle stiffness, and improving warp restraint stiffness and clearances without compromising the life of the components.

¹NUCARS® is a registered trademark of Transportation Technology Center, Inc.

Proposed Methodology

TTCI proposed a methodology to assess the curving performance of freight car trucks based on the low rail traction ratio.⁶ Low rail traction ratio is the available tangential force per unit vertical load. Total tangential force is the vector sum of the lateral and longitudinal forces that are generated in the wheel and rail contact patch. Figure 1 illustrates traction ratios and

Figure 2 provides the equations for calculating those traction ratios. Root causes of these forces were investigated previously.⁷ These forces can easily and reliably be measured by instrumented wheelsets (IWS). The forces can also be simulated in multibody dynamic simulation packages such as NUCARS®.*

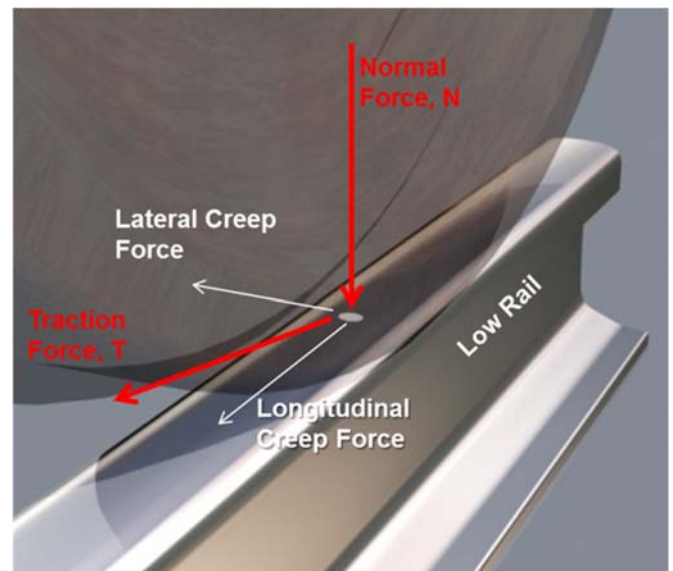


Figure 1. Low Rail Traction Ratio

$$\begin{aligned}
 &Vert = \text{Vertical Load from IWS} \\
 &Lat = \text{Lateral Force from IWS} \\
 &Long = \text{Longitudinal Force from IWS} \\
 &\alpha = \text{Contact Angle (rad)} \\
 &N = \text{Normal Force Perpendicular to the Wheel Surface} \\
 &T = \text{Total Tractive Force} \\
 &T = \sqrt{(Long)^2 + ((Lat) * \cos(\alpha) - (Vert) * \sin(\alpha))^2} \\
 &N = (Vert) * \cos(\alpha) + (Lat) * \sin(\alpha) \\
 &\text{Traction Ratio} = T/N
 \end{aligned}$$

Figure 2. Traction Ratio Calculation

A new “curve resistance” test is proposed using the low rail traction ratio. Traction ratios are the key criterion for wheel and rail rolling contact fatigue as used in Shakedown Theory.⁸ Traction ratios are also an indicator of curve resistance. When maximum resistance occurs,

the traction ratio maximum is also reached at the given friction coefficient. This is called “creep saturation.”

Low Rail Traction Ratio Test Based on Curving Assessment

A new low rail traction ratio test can be used to assess the steering performance of a truck. The test has two main components:

- Simultaneous testing of both the test truck and a reference truck. The reference truck is in a different freight car.
- The reference truck is a common three-piece truck that has been modified to include: 1) shims between the bearing adapters and pedestal lugs to ensure a non-steering feature, and 2) longitudinal shims that minimize the wheelsets’ yaw degree of freedom to induce angle-of-attack during curving.

The IFCT curving test consist is comprised of two coupled hopper cars loaded to approximately 286,000 pounds. The reference truck is located in the leading car. The test truck is located as the lead truck in the second car. Both trucks are instrumented with IWS as a lead axle in the truck.

Figure 3 shows the IFCT test arrangement with reference and test truck in the consist. Testing with both the reference non-steering truck and the test truck simultaneously minimizes variations due to test environment (e.g., friction coefficient, wind speed, temperature, humidity, rail, track condition).

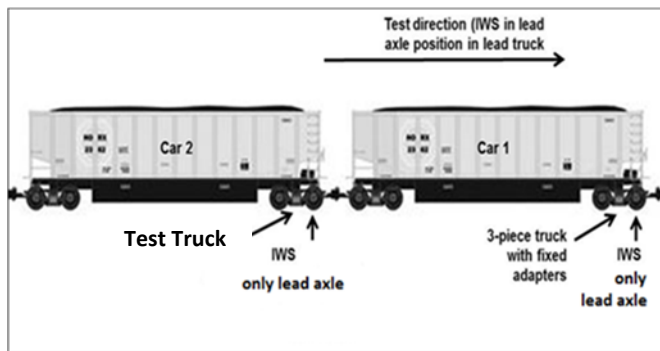


Figure 3. IFCT Curving Test Consist

IFCT curving tests were performed at the WRM loop, which is where TTCI conducts official M-976 curving tests. The tests were performed at balance speed as shown in Table 1. Top-of-rail (TOR) friction measurements were taken before each test. A friction coefficient minimum of 0.45 was sought. In the case of lower friction readings due to contamination (e.g., tumbleweeds, diesel, oil), the TOR was cleaned with a steam cleaner until a dry rail condition

was obtained. Data was collected through three clockwise and three counterclockwise runs at balance speed.

Table 1. WRM Curvature, Superelevation, and Balance Speed

Curvature	Superelevation	Balance Speed
3 degrees	2 inches	32 mph
4 degrees	3 inches	33 mph
5 degrees	4 inches	34 mph
7.5 degrees	3 inches	25 mph
10 degrees	4 inches	24 mph
12 degrees	5 inches	25 mph

Light detector plates (automatic light detection or ALDs) and high accuracy GPS coordinates were used to identify the smoothest 500 foot sections in the body of the curve. The 500-foot sections defined by the ALDs were used to minimize freight car dynamics caused by track geometry deviations. Figure 4 shows is example of an ALD and the high accuracy GPS measurement used during testing. Figure 5 is a map of the curves used in the tests.



Figure 4. ALD to Define Test Zone and High Accuracy GPS Reading



Figure 5. WRM Map with Defined, 500-foot Circular Curve Test Zone

Data Sampling and Statistical Method

IWS data was sampled at 1,200 hertz (Hz) using a 450 Hz 8-pole Bessel filter. The data was post processed with a 100-Hz low pass filter. The vertical, lateral, and longitudinal forces; along with contact location, were measured and recorded. Using the contact location and IWS wheel profile, a contact angle transformation was used to calculate the forces on the wheel tread surface, as shown in Figure 6.

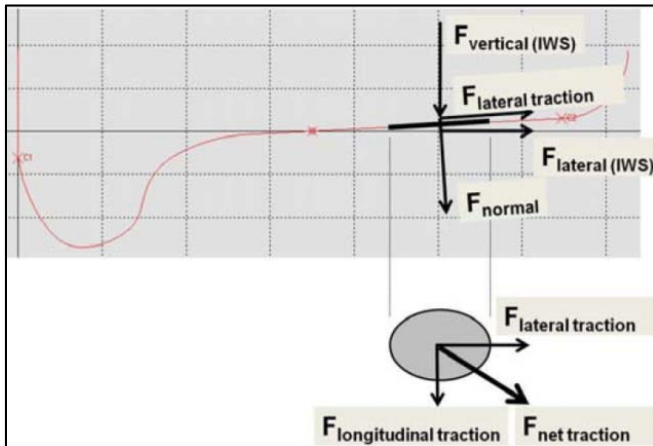


Figure 6. Forces on the IWS in Relation to Normal and Lateral Traction

CONCLUSIONS

A new curving performance test procedure is proposed to segregate non-steering (three-piece), steering (M-976), and better steering (IFCT) trucks. The test uses low rail traction ratio as opposed to the current curve resistance based testing. A follow-up *Technology Digest* will present the detailed data analysis.

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