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Curving Performance of ATS Radial Freight Truck

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Summary

Curve resistance tests of a radial freight car truck performed by Transportation Technology Center, Inc. (TTCI) show that the curve resistance of an Advanced Truck Systems (ATS) Group's truck stays roughly constant for curvatures between 0 and 12 degrees (versus a typical three-piece truck, in which curve resistance increases approximately linearly as a function of curvature). The axles in the ATS truck are aligned approximately radially to the curve suggesting small angles of attack and accounting for low curve resistance measured. This truck was offered by ATS for evaluation under the Association of American Railroads' (AAR) Improved Freight Car Truck Strategic Research Initiative (SRI) Program.

The tests were conducted on the Wheel/Rail Mechanism loop at the Transportation Technology Center in Pueblo, Colorado. A 286,000-pound hopper car was fitted with two ATS trucks and traversed tangent and curved track with curvature up to 12 degrees. Curve resistance was measured using an instrumented coupler in a manner similar to AAR Specification M-976. Truck axle alignment was measured using on-board string potentiometers.

A more detailed analysis of curve resistance data from regular three-piece trucks, as well as M-976 compliant trucks with shear pads, is desirable to provide more accurate points of comparison for the ATS truck. The dynamic performance of the ATS truck (empty and loaded car hunting, dynamic curving, pitch and bounce, and twist and roll) will also be evaluated and reported.



INTRODUCTION

Transportation Technology Center, Inc. (TTCI) performed curving tests of Advanced Truck Systems (ATS) radial freight truck at the Facility for Accelerated Service Testing (FAST) in order to evaluate the curving performance of these trucks.

The test approach discussed in the paper was chosen in contrast to current practice of measuring the lead axle, low rail traction ratio using instrumented wheelsets (IWS) as these trucks are fitted with wheelsets having inboard bearings. No IWS having inboard bearings are available to the industry.

OVERVIEW OF ATS RADIAL TRUCK DESIGN

The truck offered consists of an H-shaped truck frame, two wheelsets with inboard bearings, two steering arms, and a bolster (Figure 1). Primary suspension consists of elastomeric shear pads between the bearing adapters and the truck frame. Secondary suspension consists of elastomeric spring elements and hydraulic dampers between the truck frame and the bolster. Two steering arms are attached to the bearing adapters and are connected to each other through a joint that allows for yaw motion between the two wheelsets. Carbody weight is carried by two rigid side bearings with a low friction steel on an ultra-high molecular weight polyethylene (UHMW-PE) interface. Longitudinal and lateral forces are transmitted from carbody to bolster via center bowl/center pin assembly. A detailed description, along with design rationale, can be found in References 1 through 3.

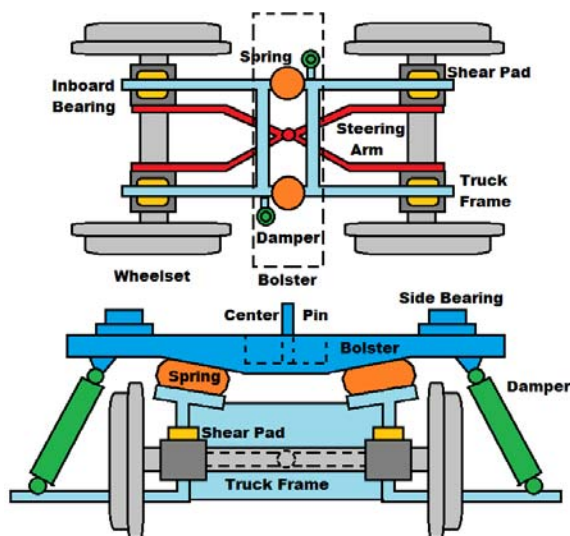


Figure 1. Schematic of ATS Radial Freight Truck Design

TEST PROCEDURE

In order to quantify curving performance of the ATS radial truck design, TTCI conducted a curve resistance test. AAR Specification M-976⁴ was used as a guideline for the test, with some modifications of the test procedure.

The test was performed on the Wheel/Rail Mechanism (WRM) loop at FAST using a 286,000-pound hopper car with two ATS radial trucks that traversed a tangent track section, as well as 3-, 4-, 5-, 7.5-, 10-, and 12-degree curves. Each curve was traversed six times at a constant speed of 5 mph (three times in clockwise direction and three times in counter-clockwise direction) to ensure repeatability and remove the effect of grade resistance.

Total resistance of the car to motion was measured using an instrumented coupler, as prescribed by M-976. In addition, steering arms of the trucks were instrumented with string potentiometers on either side to estimate the yaw angle between leading and trailing axle of each truck (Figure 2).



Figure 2. String Potentiometer Used to Measure the Angle between the Wheelsets

TEST RESULTS

Resistance results from each section of the track are shown in Figure 3. These values, which include both curve and rolling resistance, are expressed in terms of pounds of force per ton of car weight. Each data point represents one test run through a given curve.

Figure 4 shows mean values of resistance from each curve, as well as from the tangent section. For reference, it also shows:

- Resistance test results for a three-piece truck with no adapter pads, tested by TTCI in 2012 using a similar methodology (Truck A)

- Results of a curve resistance test performed in 2000 on a different three-piece truck with no adapter pads (Truck B)^{5,6}
- Results of curve resistance tests performed in 2000 on two different pre-M-976 three-piece trucks equipped with adapter pads (Trucks C and D)^{5,6}

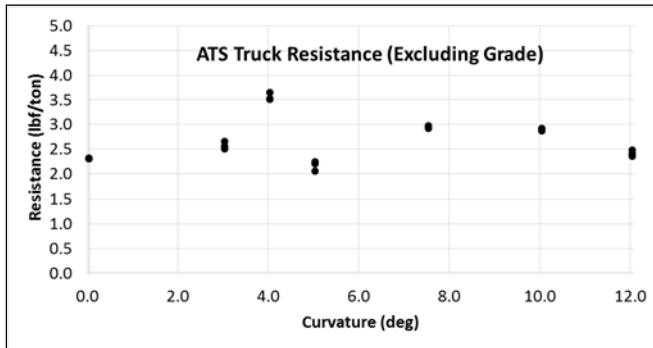


Figure 3. Resistance of ATS Truck as a Function of Track Curvature (Data from Individual Runs is Shown)

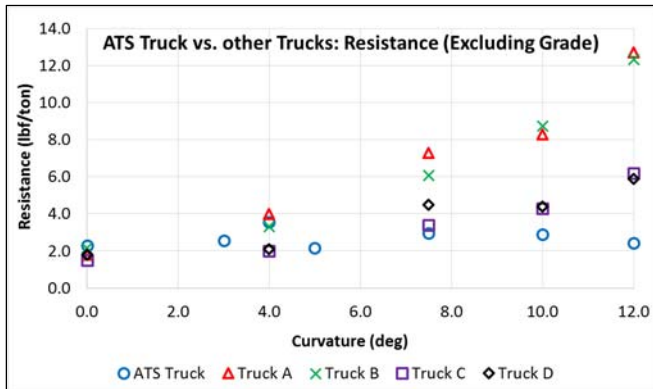


Figure 4. Resistance of ATS Truck and Other Truck Designs

It should be noted that Figure 4 only shows estimated mean values of resistance for each given truck through each section of test track. Assumptions on distribution of mean cannot be made from the limited data available. Track friction conditions under which the test results for different vehicles have been obtained may vary. Although the values of resistance are normalized with respect to car weight, some variation may be caused by the fact that some of the trucks shown in Figure 4 were tested under different vehicles and different loading conditions.

Axle alignment (one-half yaw angle between the two axles of each truck) of the ATS truck is shown

in Figure 5. For reference, the curve for ideal axle-to-axle alignment (i.e., one-half yaw angle between the axles required for ideal curve negotiation with zero angle of attack for each axle) is also plotted. Note that the 12-degree curve of the WRM loop has the opposite orientation from the other curves.

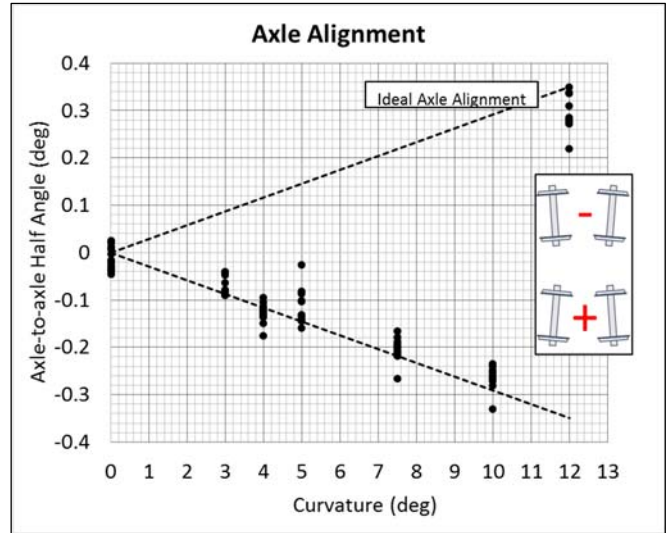


Figure 5. Axle Alignment (One-half Angle between the Axles) as a Function of Track Curvature

CONCLUSIONS AND FUTURE WORK

Curve resistance of a typical three-piece truck increases proportionally to track curvature. For the ATS truck, the curve resistance stays roughly constant for curvatures between 0 and 12 degrees under the conditions tested. Alignment of the axles in the ATS truck appears to be close to radial. This facilitates for small axle angles of attack and accounts for the low curve resistance measured.

Reference 7 lists curve resistance measured during in-service tests of a freight train with typical three-piece trucks, as well as a mixed freight train with radial trucks. This includes Barber-Scheffel trucks and an early version of the ATS truck. While that data may be used for reference, note that it was obtained using a test that was significantly different from the test procedure used for this study.

This study has produced an approximate comparison of curve resistance between the ATS truck and three-piece trucks. Note that the curve resistance testing was performed at 5 mph (underbalance condition) to eliminate aerodynamic resistance.

A more detailed analysis of curve resistance data from regular three-piece trucks, as well as M-976 compliant trucks, is desirable to provide more accurate points of comparison for the ATS truck. Special care should be taken to ensure the consistency of test procedures and the condition of the track between the tests.

In addition to curve resistance tests, the dynamic performance of the ATS truck will also be evaluated and reported, including:

- Hunting (empty and loaded car)
- Curving under a range of underbalanced, balanced, and overbalanced conditions
- Dynamic curving
- Pitch and bounce
- Twist and roll
- Yaw and sway

Conducting the dynamic tests presents a certain challenge, since no IWS for inboard bearing trucks are currently available. For initial testing, vertical and lateral wheel/rail forces will have to be measured indirectly, by using a system of strain gages applied to the truck frame. Later development of an IWS for an inboard bearings truck would facilitate the evaluation of lead axle low rail traction ratios, as well as performance evaluation of the dynamic behavior of the vehicle.

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