

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

Simulation and Testing of Very Heavy Axle Loads on Track at FAST

Adam Klopp, Dana Martin, and David Davis

Summary

Transportation Technology Center, Inc. (TTCI) simulated and tested overloaded high sided gondola cars to evaluate the potential effects of very heavy axle load (VHAL) operations on track and structures. The term VHAL is used for railway operations at or above 36-ton axle loads. NUCARS^{®*} simulations were performed to determine the feasibility of conducting a short-term test at the Facility for Accelerated Service Testing (FAST) using existing 315-kip high sided gondolas overloaded to 360-kip and 400-kip gross rail loads (GRL); i.e., 45- and 50-ton axle loads.

Results from the simulations showed that wheel/rail forces generally increased with increases in speed and axle load. For 40 mph heavy haul operations on track with 5- and 6-degree curves that are maintained to FRA class 4 standards, the maximum vertical and lateral wheel/rail forces from the simulations did not exceed 90 kips and 35 kips, respectively. Other simulation outputs analyzed were also within acceptable limits. Simulation data indicated that a short-term test could safely be conducted at FAST with cars overloaded to 45- and 50-ton axle loads.

Existing gondola cars were loaded to 360- and 400-kip GRL and were tested on the High Tonnage Loop (HTL) at FAST. The overloaded cars were tested at speeds of 25, 30, and 40 mph on the HTL. With the curves elevated for 33 mph balance speed, this results in 1.8 inches of overbalance at 25 mph and 1.6 inches of underbalance at 40 mph. Test runs were recorded on the main and bypass tracks in both clockwise and counterclockwise directions. The test did not include speeds from 15 to 20 mph to prevent potential carbody roll resonance issues.

Instrumented wheelsets (IWS) and Truck Performance Detector (TPD) measured wheel/rail forces were similar to NUCARS predictions. IWS vertical force measurements were higher than the simulation predictions, possibly due to suspension differences between the base 315-kip vehicle model and the actual IWS test car. TPD measurements showed that wheel/rail forces increased with increases in speed and axle load. NUCARS simulations tended to over predict the magnitudes of wheel/rail forces at the TPD locations.

TTCI conducted the test to measure the track related effects due to increased axle loads. This data will be used to further calibrate and extend the range of track and bridge models. Vehicle performance was monitored only to ensure safe test operation. A future *Technology Digest* will describe the track related measurements and the performances of specific track components. This project was funded under TTCI's IR&D program.

*NUCARS[®] is a registered trademark of Transportation Technology Center, Inc.



INTRODUCTION

TTCI simulated and tested overloaded gondola cars to evaluate the potential effects of 45- and 50-ton axle loads on track and structures. This *Technology Digest* (TD) details the modeling of overloaded cars at FAST and the wheel/rail forces measured during the test. A future (TD) will discuss the effects and measurements related to specific track structures and components.

TTCI performed NUCARS simulations of gondola cars overloaded to 360- and 400-kip GRL to determine the feasibility of conducting a short-term VHAL test at FAST. Simulation results showed that wheel/rail forces generally increased with increased speed and axle load; however, these outputs were within safety limits. Simulation data indicated that a short-term test could be safely conducted on the HTL at FAST.

Existing high sided gondola cars were overloaded to 360- and 400-kip GRL for the test at FAST. Two aluminum high sided gondola cars were loaded to 360-kip GRL, and two steel cars were loaded to 400-kip GRL. Steel cars were used for the heaviest loads, because their design made them best suited to handle higher dynamic forces. The overloaded cars were tested on the HTL at FAST to measure the track related effects of increased axle loads. Vehicle specific performance issues were not evaluated during this test. Vehicle performance was monitored only to ensure safe test operation.

MODELING DESCRIPTION

TTCI developed NUCARS models of overloaded high sided cars using an existing 315-kip vehicle model. Mass properties of the base vehicle were increased to simulate overloaded vehicles weighing 360 and 400 kips. The modified properties included mass, rotational inertias, and center of gravity height of the carbody. Other components of the car, such as the bolsters, side frames, and axles, were not changed from the base 315-kip model.

Preliminary simulations indicated that “spring bottoming” might occur with the overloaded vehicles due to insufficient suspension capacity. When spring bottoming occurs, vertical accelerations and vertical wheel loads drastically increase. The suspensions of the overloaded vehicle models were modified to give each car additional spring capacity and reduce the likelihood of exceeding the suspension limits. The modified suspensions were made up of nine D3 inner and outer springs at each spring nest.

Rail profile measurements were taken at various locations around the HTL for use in the simulations. Recent track geometry measurements were also used in the simulations to model the most current track conditions on the HTL.

MODEL PROJECTIONS

Results from NUCARS simulations showed that wheel/rail forces increased by an amount similar to the static wheel load

increases. Maximum vertical forces increased by a margin slightly larger than the static wheel load increases. Maximum lateral forces increased by a margin slightly smaller than the static wheel load increases. When static wheel loads were increased to 45 kips (14-percent increase), maximum lateral and vertical forces increased on average 13 percent and 18 percent, respectively. When static wheel loads were increased to 50 kips (24-percent increase), maximum lateral and vertical forces increased an average of 22 percent and 32 percent, respectively. Maximum forces simulated in the vertical and lateral directions were approximately 90 kips and 35 kips, respectively.

At speeds above 20 mph, wheel/rail forces generally increased with increasing speed. At speeds of 20 mph and below, simulated forces were elevated due to poor vehicle performance at certain track geometry sections. Simulation data indicated that the overloaded cars might experience resonance issues at speeds from 15 mph to 20 mph. Tests on the HTL were performed at speeds outside of this range to avoid adverse effects.

Figure 1 shows a plot of the maximum forces simulated from counterclockwise (CCW) operations on the HTL.

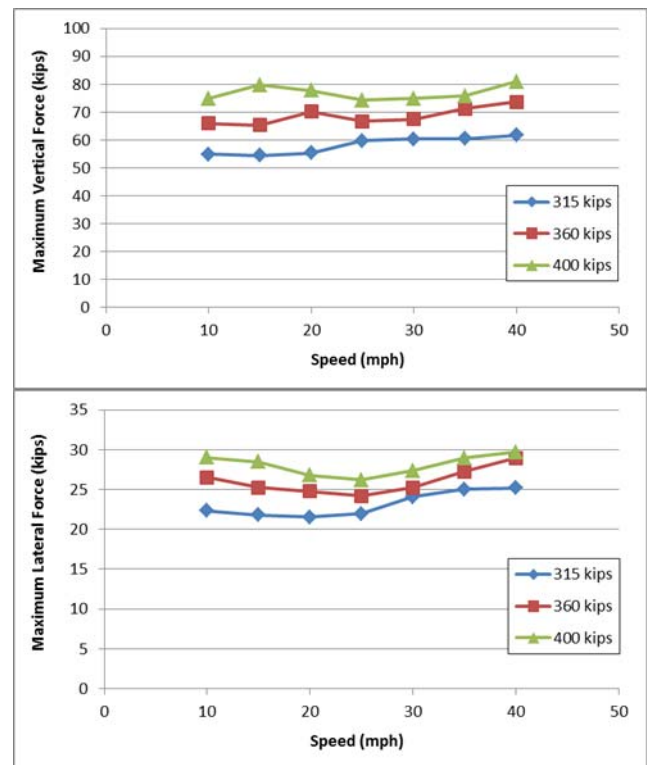


Figure 1. Maximum Forces around the HTL – CCW Direction

In addition to wheel/rail forces, other simulation outputs were examined, including lateral to vertical force (L/V) ratios and carbody accelerations, to determine the feasibility of conducting the test. Simulation results were examined using Chapter 11 criteria from the AAR’s *Manual of Standards and*

*Recommended Practices.*¹ All of the examined outputs were within the selected Chapter 11 performance specifications, except the maximum loaded spring capacity of the 400-kip car.

The overloaded car suspensions were not expected to have ideal reserve capacity, because the loading conditions were not realistic. The suspensions modeled and used for the test were not designed to support overloaded carbodies. Because the test focused on track related effects due to increased axle loads, the suspension makeup of the overloaded cars was deemed acceptable if it reduced the likelihood of suspension bottoming. Simulation results indicated that the modified suspensions could provide enough spring capacity to minimize spring bottoming and adverse vehicle effects.

Table 1 lists some of the criteria examined for each simulation case and the limiting Chapter 11 values.

Table 1. Car Performance Analysis Using Chapter 11 Criteria

Simulation Output	315-kip Model	360-kip Model	400-kip Model	Chapter 11 Limiting Value
Minimum Vertical Wheel Load	54%	49%	44%	10%
Maximum Vertical Acceleration (g)	0.32	0.34	0.35	1.0
Maximum Loaded Spring Capacity	80%	92%	98%	95%
Maximum Wheel L/V	0.66	0.63	0.62	1.00
Maximum Truck Side L/V	0.36	0.35	0.30	0.60
Maximum Axle Sum L/V	1.10	1.07	1.07	1.50
Maximum Peak-to-Peak Carbody Roll (degree)	2.15	2.38	2.61	6.00

NUCARS simulation results showed that a short-term VHAL test at FAST could be safely conducted using cars overloaded to 45- and 50-ton axle loads. Preparations for the on-track tests, including instrumentation planning and vehicle loading, were made using the modeling results.

TEST DESCRIPTION

Two aluminum high sided gondolas that operate as part of the FAST train were overloaded to 360-kip GRL using a combination of concrete and steel weights. Two steel gondolas were overloaded to 400-kip GRL using primarily large steel coils. All four cars initially weighed about 315 kips and were loaded with shale to provide a typical center of gravity. The aluminum cars were loaded with approximately 45 kips of

additional weight to achieve the desired 45-ton axle loads. The steel cars were loaded with approximately 85 kips of additional weight to achieve the desired 50-ton axle loads. Steel cars were used for the heaviest loads, because their steel construction made them less susceptible to top chord buckling under high dynamic loads. Figure 2 shows the steel gondola cars used for the test.



Figure 2. Steel Gondola Cars Overloaded to 400-kip GRL

The test train consisted of the following cars:

- Two locomotives
- One instrumentation car
- Two cars with 315-kip GRL (IWS Car and Instrumented Freight Car)
- Two cars with 360-kip GRL
- Two cars with 315-kip GRL
- Two cars with 400-kip GRL
- Two cars with 315-kip GRL
- One empty car

The train consist included cars with different axle loads to allow for measurement comparisons between the cars for each test run. IWS were installed under one of the 315-kip cars to measure dynamic wheel loads. Data from the IWS car was used to provide a basis for model-to-test comparisons. Spring nest displacements were measured on the four overloaded test cars to ensure that the suspension capacities of the cars were not exceeded during the test.

Numerous wayside measurements were recorded during the test to examine track performance. The measurements included vertical and lateral wheel/rail forces, rail strains, steel bridge deflections, concrete bridge girder strains, subgrade pressures, and track deflections. A future TD will describe the track related measurements and the performances of specific track components.

The test was conducted on the HTL at FAST over the main and bypass tracks with the following test sequence:

- 25, 30, and 40 mph CCW, Main Track
- 25, 30, and 40 mph CCW, Bypass Track
- 40 mph CW, Bypass Track
- 40 mph CW, Main Track

For test runs on the bypass track, diverging speed through one of the number 20 turnouts was limited to 25 mph to protect equipment and ensure safe test operation. Train speeds between 15 and 20 mph were avoided during the test to prevent possible roll resonance issues.

TEST RESULTS AND MODEL COMPARISONS

Wheel load and speed effects were measured during the test and were compared to simulation results. IWS measurements from the 315-kip car showed that wheel/rail forces predicted using base 315-kip NUCARS model were similar to forces measured during the tests. Maximum vertical forces in the simulations were approximately 10 percent less than IWS measurements. Maximum lateral forces in the simulations were within 5 percent of the IWS measurements. Possible sources of error include modeling simplifications, differences in measured and simulated track geometry, and differences in train handling. Figure 3 shows a comparison of the results.

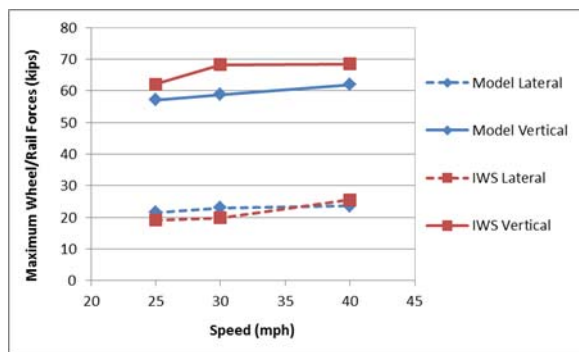


Figure 3. Model and IWS Maximum Forces – 315-kip Car

TPDs collected wheel/rail force data at three locations on the HTL. Each location contained two cribs of wheel/rail force measurements on both the high and low rails. The TPD sites were located in Section 7 (right-hand 5-degree curve), Section 9 (tangent), and Section 25 (left-hand 5-degree curve) on the HTL. Balance speed was approximately 33 mph for both curves containing TPDs. At 25 mph, vertical forces in the curves tended to be higher on the low rails, because the cars were operating with about 1.8 inches of overbalance (i.e., 4 inches of superelevation in the curve when 2.2 inches is required for 25 mph balanced operation). At 40 mph, vertical forces in the curves tended to be higher on the high rail, because the cars were operating with about 1.6 inches of underbalance.

Measured TPD forces correlated well with the forces generated in NUCARS simulations. The NUCARS model tended to over predict wheel/rail force magnitudes at the TPD locations. Most of the NUCARS predictions were within 10 percent of forces measured at the TPD locations. Figure 4 shows a comparison of forces measured at the right-hand curve TPD site and forces generated by the model. Figure 5 shows a comparison of forces measured at the left-hand curve TPD site and modeled forces.

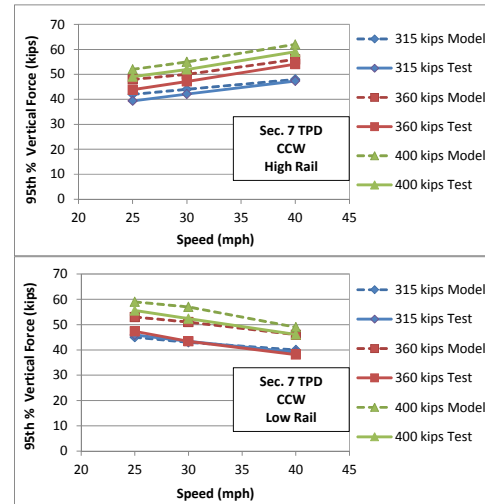


Figure 4. Vertical Force Comparison – Section 7 Model and Test

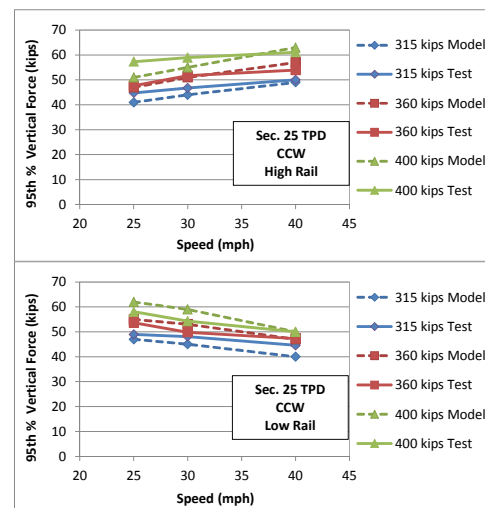


Figure 5. Vertical Force Comparison – Section 25 Model and Test

CONCLUSION

TTCI performed NUCARS simulations of high sided gondola cars overloaded to 360- and 400-kip GRL to determine the feasibility of conducting a short-term VHAL test at FAST. Modeling results showed that wheel/rail forces generally increased with increases in speed and axle load; however, these simulation outputs were still considered within the safety limits. Gondola cars were overloaded to 45- and 50-ton axle loads and were tested on the HTL at FAST. Vertical and lateral force data was similar for the simulation and test results. A future TD will describe track related measurements and the performances of specific track components.

REFERENCES

1. Association of American Railroads. 2007. *Manual of Standards and Recommended Practices*, M-1001, Chapter 11, “Service Worthiness and Analyses for New Freight Cars.” Washington, DC.

Visit our website at <http://www.ttci.aar.com>