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Vehicle Performance of Short Heavy Axle Load Cars

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Summary

Transportation Technology Center, Inc. (TTCI) is investigating the effects of heavy axle load (HAL) traffic on infrastructure, specifically as related to minimum length interchange cars. Testing at the Facility for Accelerated Service Testing (FAST) and vehicle characterizations were conducted to determine differences in vehicle dynamics of 42-foot (short) cars compared to 53-foot (standard length) cars (coal gondola or open-top hopper). TTCI developed NUCARS®* simulation models based on carbody characterization and resonance tests and validated the models using instrumented wheelset data from the test at FAST.

In addition, simulations of Association of American Railroads (AAR) Chapter 11 tests on a generalized short hopper model were conducted. Most results were benign, and performance was generally satisfactory. Additional simulations were conducted with track geometry inputs representative of Federal Railroad Administration (FRA) Class 2, 3, and 4 track.

The key findings of the study are as follows:

- Short cars perform similarly to standard length cars in terms of wheel-rail forces, provided the same trucks are used for both car types.
- Under extreme uncompensated superelevation conditions, short cars may exhibit slightly higher wheel unloading and lateral to vertical (L/V) force ratios than standard length cars.
- Simulations show the capacity of the suspension springs may be a concern in both short and standard length cars under certain track geometry perturbations typical of AAR Chapter 11 testing regimes and FRA Class 2, 3, and 4 track.

A future digest will focus on the analysis of data obtained from the wayside instrumentation. The presented work is developed under funding from Association of American Railroads' Strategic Research Initiatives Program on Effects of Short Cars on Track and Bridges.

*NUCARS® is a registered trademark of Transportation Technology Center, Inc., Pueblo, Colorado



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INTRODUCTION

TTCI is investigating the effects of HAL traffic on infrastructure, specifically as related to minimum length interchange cars. For the purposes of this study, HAL cars are considered to be cars with a gross rail load (GRL) of 286,000 pounds or more. Data from the railroad industry equipment database, UMLER®, shows the number of HAL cars shorter than 48 feet have increased from 40,000 to more than 85,000 during the last 5 years, and the majority of these short HAL cars are ~42-foot-long covered hoppers. The areas of particular focus are those that might be different for cars of minimum interchange length (about 42 feet) as compared to the common 53-foot coal cars that have been used in HAL studies. Preliminary studies identified embankments and bridges as the major areas of concern.

A railroad provided 12 short HAL cars loaded with sand to perform testing at FAST. Figure 1 shows photographs of a short HAL car and a standard length HAL car on one of the steel bridges at FAST. The main purpose of the test was to evaluate the effects of short cars on bridges by analyzing the data from wayside instrumentation. An additional goal of the test was to aid in developing a computer model of a short car. To accomplish this, characterization/resonance test was performed, and instrumented wheelset (IWS) data was collected from one of the short cars during the FAST test.



Figure 1. Short Cars (top) and Standard Length Cars (bottom) on Bridge at FAST

CHARACTERIZATION AND MODEL DEVELOPMENT

The 12 short 286,000-pounds hoppers from different manufacturers were roughly similar in terms of dimensions and weight, but varied in terms of trucks and body construction. Two of these short hopper cars were selected for modeling:

- Car A was selected for carbody resonance testing because it had the most symmetrical carbody weight distribution among the 12 cars provided in the sample.
- Car B was selected for on-track testing because it had a combination of properties (suspension, weight distribution, etc.) deemed the most representative of the 12 cars in the

sample; furthermore, its trucks were compatible with the available instrumented wheelset (IWS).

Carbody characterization and resonance tests were performed on Car A and involved instrumenting the car with accelerometers and exciting its rigid body modes (pitch, bounce, roll, and yaw) to determine carbody moments of inertia and center of gravity height. Locations of some of the accelerometers used for carbody resonance testing are circled in red in Figure 2.



Figure 2. Carbody Characterization/Resonance Tests

Results of carbody resonance testing are summarized in Table 1. Pitch and bounce modes proved very difficult to excite during the test, thus no reliable test data for these modes is available. The reasons for this are not completely clear, but may have to do with the low-frequency flexible body modes of the carbody and high damping due to the type of cargo in the hopper (sand). Lower and upper center roll frequencies differed somewhat between the test and the model, but the results of subsequent NUCARS® simulations using this model closely correlated with the actual test results (see section “NUCARS® Modeling”). The model used for NUCARS® simulations had a combination of properties of Car A and Car B. This model was designed to represent a generic 286,000-pound covered hopper car with 29-foot truck center spacing.

Table 1. Rigid Body Mode Frequencies for Test Car vs. NUCARS® Model

Mode	Frequency (Hz)	
	Test	Model
Bounce	-	1.86
Pitch	-	2.86
Lower Center Roll	0.84	0.62
Upper Center Roll	3.04	3.71
Yaw	2.35	2.36

NUCARS® MODELING

NUCARS® simulations and FAST test results for short hopper cars generally show good correlation. L/V ratios for leading axle at the speed of 10 mph are presented in Figure 3. (Blue series designate test data; red series designate simulation results). Figure 4 shows median L/V ratios at 10 mph. Other speeds and opposite train direction were analyzed and showed similar findings.

Simulations correctly reflected the trends and patterns of vertical and lateral wheel-rail forces, as well as their steady state magnitudes in curves. In some sections of the track, simulations

under predicted the transient wheel-rail forces and accelerations associated with track geometry irregularities. Causes of discrepancies between test data and simulation results include:

- Short-term variations of rail profile, rail joints, turnouts, variability in track stiffness, and other irregularities not included in the track input to the simulations
- Flexible carbody modes associated with hopper carbody and truck components not included in the model
- Differences between a generalized short hopper car model and the specific hopper car used during the test (weight distribution between A- and B-end, etc.)

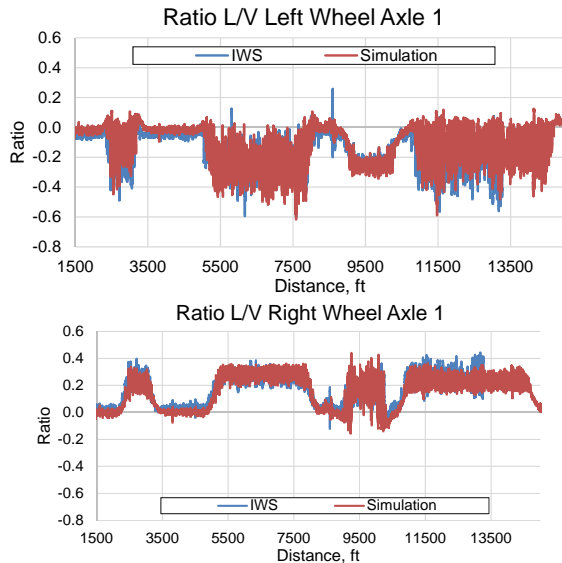


Figure 3. Comparison of L/V Ratios for Leading Axle, FAST Test (blue) vs. Simulation (red) at 10 mph

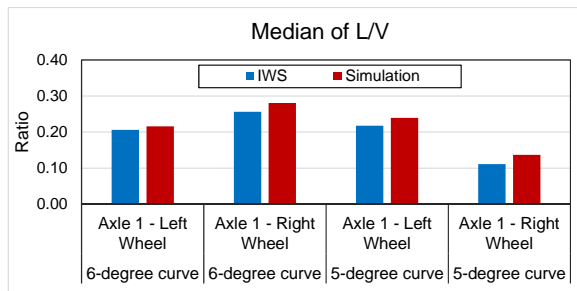


Figure 4. Median L/V Ratios of a Test & Simulation on 5 and 6-degree curves at FAST

COMPARISON OF RESULTS FOR SHORT AND STANDARD HOPPERS

A NUCARS® model representative of a covered 286,000-pound 53-foot-long hopper car with 40.5-foot truck center spacing was constructed. Carbody data was taken from FRA report FRA/ORD-81/75.2² (data for a covered hopper car with 3,500 cubic foot volume capacity, 198,000-pound weight capacity, and 41-foot truck centers) and then it was scaled to make the loaded carbody weight equal to that of a representative short hopper car. The standard length hopper model featured the same trucks and suspension springs arrangement as the short hopper model; only truck center spacing, center of gravity height, and carbody inertia varied between the models.

To compare performance of fully loaded standard length and short hopper cars, both models were run through simulated High Tonnage Loop track at FAST. At higher speeds, the differences in wheel-rail forces between the two car types were negligible.

At lower speeds (and higher unbalanced superelevation), short hopper cars tended to show slightly higher L/V ratios and lower minimum vertical wheel forces than standard length hoppers due to a higher center of gravity. An excerpt from simulation results is shown in Figure 5. Figures 6 and 7 show median L/V ratios at 40 mph and 10 mph.

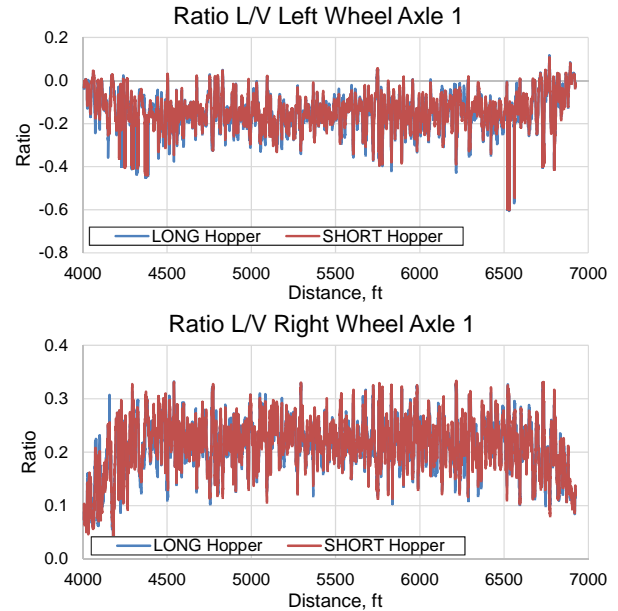


Figure 5. Comparison of Short Hopper (blue) vs. Standard Length Hopper (red) L/V Ratios on 5-degree curve at FAST (CW direction) at 40 mph

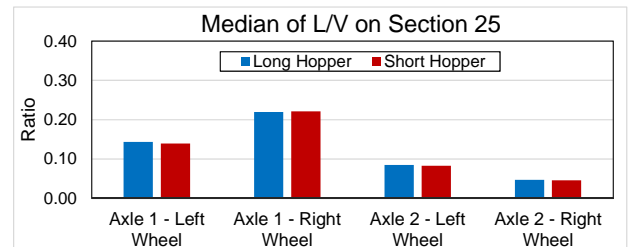


Figure 6. Median L/V Ratios of a Short Hopper Car & Long Hopper Car from simulation on 6-degree curve at 40 mph

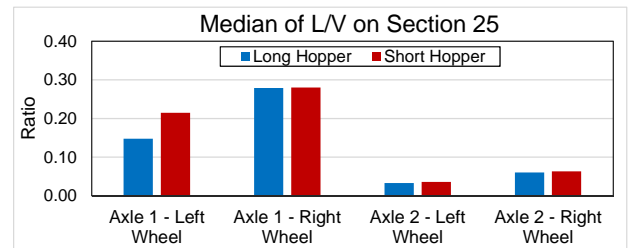


Figure 7. Median of L/V Ratios of a Short Hopper Car & Long Hopper Car from simulation on 6-degree curve at 10 mph

CHAPTER 11 SIMULATIONS

Simulations of AAR Chapter 11¹ tests on a generalized short hopper model were conducted. Most results were benign, and performance was generally satisfactory. However, two potential areas of concern were identified (see Figure 8 and Figure 9, which also show simulation results for a standard length hopper for comparison).

- In the pitch and bounce regime at speeds between 65 and 68 mph, the 95 percent spring capacity limit was nearly reached (94 percent). Note that static spring deflection for this set of hopper cars was between 60 and 65 percent of the total spring capacity, depending on the individual car weight and spring configuration.
- In the yaw and sway regime between 65 and 68 mph, the 6-foot maximum truck side L/V ratios reached (but did not exceed) the 0.6 limit.

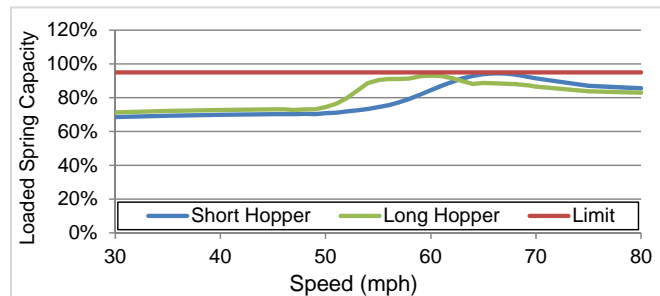


Figure 8. Maximum Percentage of Spring Capacity during Pitch and Bounce Regime

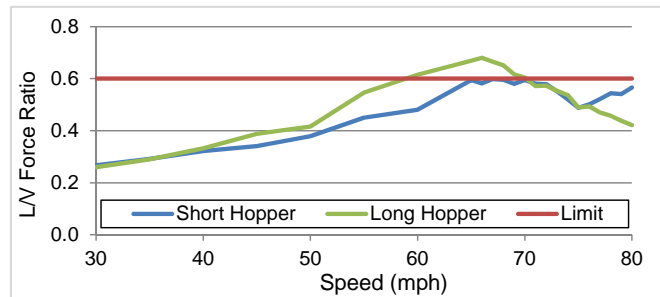


Figure 9. 6-ft Maximum Truck Side L/V Ratio during Yaw and Sway Regime

CLASS 2, 3, AND 4 TRACK SIMULATIONS

Additional simulations were conducted with track geometry inputs representative of FRA Class 2, 3, and 4 track. These are the standard inputs used for AAR S-2043³ simulations. AAR Chapter 11 limits are shown in Figure 10 and Figure 11 for comparison only. The simulations predicted that suspension springs' capacity may be exceeded at speeds 30 mph and higher due to certain combinations of vertical and lateral track geometry perturbations. Both long and short cars show exceedances; the short car exceeds the criterion in Class 3, whereas the standard car exceeds it in Class 4 track geometry.

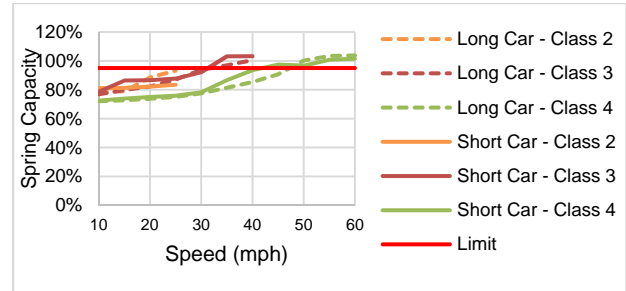


Figure 10. Maximum Percentage of Spring Capacity

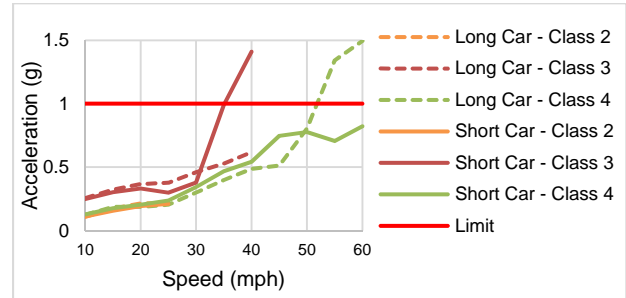


Figure 11. Maximum Carbody Vertical Acceleration

CONCLUSION

Analysis of test data obtained during FAST testing, combined with NUCARS® simulations, suggests that short (42-foot-long) HAL hopper cars perform similarly to standard length (53-foot-long) HAL hopper cars in terms of wheel-rail forces, provided the same trucks are used for both car types. Under extreme unbalanced superelevation, short hopper cars exhibit higher wheel unloading and L/V force ratios due to their higher center of gravity. For Chapter 11 test regimes, simulations showed a very similar performance between short and standard length hoppers. One noticeable difference was that maximum truck side 6-foot L/V ratios during the yaw and sway test regime were exceeded for a standard length hopper between 60 and 70 mph. For Class 2, 3, and 4 track geometry simulations, behavior of standard and short hopper cars was very similar. In both cases, suspension springs' capacities were exceeded for some track geometry perturbations. For both short and standard length hopper cars, simulations raise a concern about possible exceedance of suspension spring capacity during severe track geometry perturbation negotiation.

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