TECHOLOGY DIGEST

Timely Technology Transfer — 99-023

DYNAMIC VEHICLE/TRACK TESTING ON THE HEAVY TONNAGE LOOP

by Dingqing Li and Lamont Smith

Summary

A series of vehicle/track interaction tests conducted by Transportation Technology Center, Inc. in 1998 and 1999 indicate that improved-suspension trucks significantly reduce lateral wheel forces and vertical dynamic-impact forces. These tests, conducted on the Heavy Tonnage Loop (HTL) at the Federal Railroad Administration's (FRA) Transportation Technology Center, included measurements of vehicle responses such as wheel loads and car-body accelerations, as well as characterization of dynamic car-body motions. The test vehicle was a 125-ton heavy-axle-load (HAL) gondola equipped with improved-suspension trucks. Additionally, in one test, a 100-ton covered hopper equipped with standard trucks was used in the same test consist with the 125-ton gondola vehicle for comparison.

Results presented here concern dynamic vehicle responses as influenced by vehicle suspension characteristics and car weight. Test results concerning dynamic car-body motions of the 125-ton test car are also discussed. Dynamic actions of the 125-ton HAL test car are shown to mainly result from lower center roll of the car body at approximate 1.1 Hz.

At all speeds tested (20 to 45 mph), the 125-ton test vehicle equipped with improved trucks consistently generated lower lateral forces than the 100-ton covered hopper with standard trucks. For a 6-degree curve and at 40 mph, the 125-ton car mean lateral force (leading axle) was approximately 8 kips lower. Use of improved trucks under the 125-ton vehicle led to lower dynamic vertical impact forces. At 40 mph and for less than 0.5 percent of occurrences, dynamic forces generated by the 125-ton car were 55 to 70 kips, while the corresponding range for the 100-ton covered hopper was 60 to 80 kips.

In addition, track-geometry conditions were recorded for the HTL using two different systems — an inertial system based on laser technology, and the EM80 vehicle that uses rail-contacting measurements. When the inertial system was used, geometry conditions were recorded simultaneously with measurements of vehicle responses for the two test vehicles. A separate Technology Digest will discuss HTL track-geometry conditions as well as their relationships to HAL vehicle responses. This study was jointly funded by the Association of American Railroads and the FRA.

Suggested Distribution:

- ☐ Mechanical Car Dept.
- ☐ Planning & Analysis
- ☐ Track Maintenance
- ☐ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads
July 1999©

INTRODUCTION AND CONCLUSIONS

Results presented here come from several vehicle/track interaction tests conducted on the Heavy Tonnage Loop (HTL) at the Transportation Technology Center. Wheel/rail forces and car-body accelerations were measured at several different speeds to characterize vehicle responses with two different suspensions as well as the major mode of HAL-car dynamic motions. The test vehicles were a loaded 125-ton heavy-axle-load (HAL) gondola equipped with improved-suspension trucks and a loaded 100-ton covered hopper equipped with standard trucks. Main conclusions from these tests are listed below.

- At all speeds tested (20 to 45 mph), the 125-ton test vehicle equipped with improved trucks consistently generated lower lateral forces than the 100-ton covered hopper with standard trucks. For a 6-degree curve and at 40 mph, the 125-ton car mean lateral force (leading axle) was approximately 8 kips lower.
- Use of improved trucks under the 125-ton vehicle led to lower dynamic vertical impact forces. At 40 mph and for less than 0.5 percent of occurrences, dynamic forces generated by the 125-ton car were 55 to 70 kips, while the corresponding range for the 100-ton covered hopper was 60 to 80 kips.
- In curves, and at all speeds tested, lateral forces on either rail generated by the two test vehicles were primarily in the field direction, indicating lateral wheel/rail interaction in a gage-widening mode.
- Dynamic actions of the 125-ton test vehicle were mainly a result of car-body lower center roll. At approximate 1.1 Hz, this car-body roll motion occurred at all test speeds, but was more active at higher speeds.

TEST METHODS

In 1998 and 1999, several vehicle/track interaction tests were conducted on the HTL. Exhibit 1 shows a consist assembled for one test. The test objectives were to compare vehicle responses between a 125-ton HAL car equipped with improved-suspension trucks and a car equipped with standard-suspension trucks, to measure HAL-car responses to HTL geometry conditions, and to support other HAL test programs. The HAL test vehicle was a 125-ton gondola. The trucks used under the HAL cars were three-piece trucks with improved-suspension characteristics, including diagonal bracing between the side frames and primary suspension pads. In one test, a 100-ton covered hopper was also used. The covered hopper was equipped with standard three-piece trucks with constant damping and without primary suspension.

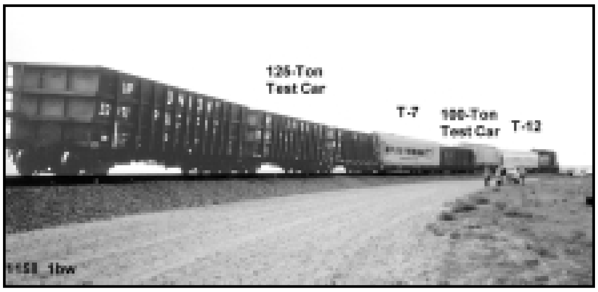

Exhibit 1. Test Consist including Two Test Vehicles

Vehicle response measurements included wheel loads under the lead trucks using instrumented wheelsets. To help characterize the dynamic motions of the HAL test vehicle, the car body was instrumented with eight accelerometers (one pair of vertical accelerometers and one pair of lateral accelerometers at each car-body end).

Tests were conducted at several speeds ranging from 20 to 45 mph. Note that all the results shown in this TD are based on test data (forces and accelerations) low-pass filtered at 15 Hz.

RESPONSES OF TWO VEHICLES WITH DIFFERENT SUSPENSIONS

In one test conducted in 1998, the test consist included both the 125-ton gondola and a 100-ton covered hopper. Therefore, with train operations and track conditions similar during this test, any differences in vehicle responses between the two vehicles resulted mainly from the difference in car characteristics.

Exhibit 2 shows comparisons of lateral wheel forces between the two test vehicles. These lateral forces were measured in a 6-degree curve. At all the speeds tested, the lateral forces generated by the 125-ton car were significantly lower than those generated by the 100-ton covered hopper. The difference in measured lateral forces between these two test cars also increased as train speed increased. At 40 mph, the median lateral forces for the 125-ton car were approximately 8 kips lower.

The results shown in Exhibit 2 are consistent with what has been found overall during the HAL test program. That is, trucks with increased warp stiffness and primary suspension pads generate lower lateral forces.

Also shown in Exhibit 2, most of the lateral forces generated on both rails had a positive sign, meaning forces in the field directions. In other words, lateral forces generated by the two test vehicles were primarily in a gage-widening mode.

Exhibit 3 shows comparisons of measured vertical forces for the entire HTL between the two test vehicles. They were the results under the leading axles obtained at 40 mph (nominal HAL-train operation speed). As expected, the 125-ton HAL car generated higher vertical forces than the 100-ton covered hopper for approximately 99.5 percent of the measured forces (the entire population). However, for a small percentage (less than 0.5 percent) of the entire population of the measured forces, the 100-ton covered hopper actually produced higher dynamic forces (ranging from 60 to 80 kips) than the HAL car (55 to 70 kips). Although few in number, these high impact forces might be detrimental to the performance of both track and vehicles. This reduction in high impact forces under the HAL test vehicle was considered to result from the use of primary suspension pads, which may attenuate vertical forces at higher frequency ranges.[1] In fact, a comparison of vertical-force frequency contents showed much lower energy for the HAL test car above 2 Hz (see Exhibit 4) than for the covered hopper.[1]

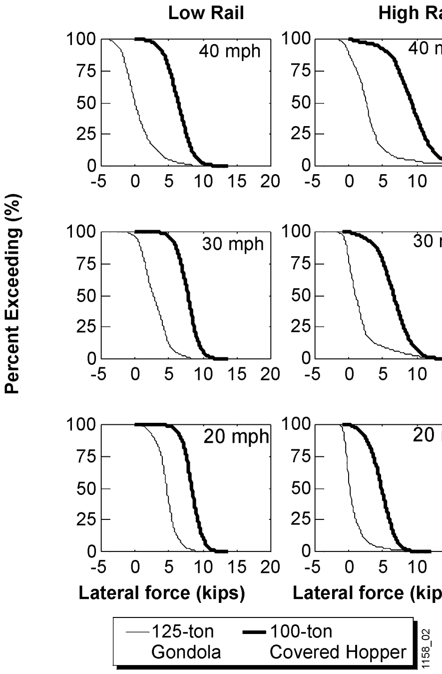

Exhibit 2. Comparison of Lateral Forces in 6-Degree Curve

MAJOR MODE OF HAL VEHICLE DYNAMIC MOTIONS

To better understand the dynamic actions of the HAL test car, wheel-set forces and car-body accelerations were analyzed both in time and frequency domains. The results shown below are frequency contents (i.e., power-spectrum densities). However, waveforms plotted between right and left wheels and for each pair of acceleration results can also help to characterize the car-body modes.[1]

Exhibit 4 shows frequency contents of measured vertical and lateral forces over the entire HTL for the 125-ton gondola test car. Because

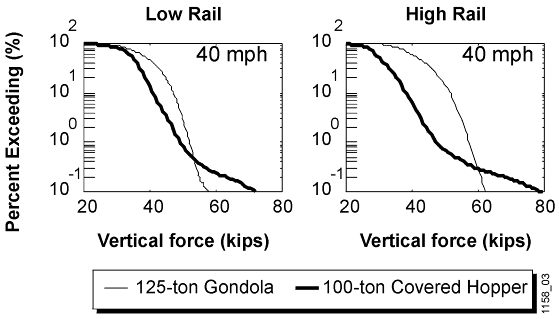

Exhibit 3. Comparison of Vertical Forces for Entire HTL

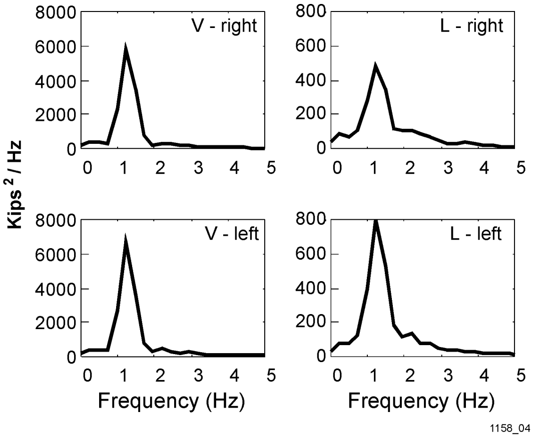

Exhibit 4. Frequency Contents of Wheel Loads

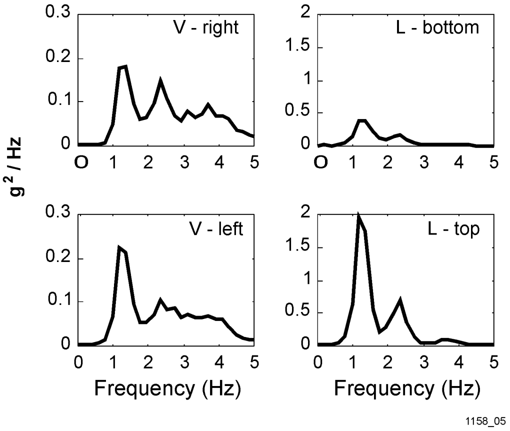

Exhibit 5. Frequency Contents of Car-Body Accelerations

rigid car-body motions for loaded conditions have frequencies generally lower than 5 Hz, these results are plotted only up to 5 Hz. As shown, the major dynamic actions for both vertical or lateral forces occurred at approximately 1.1 Hz. Because major dynamic actions occurred both laterally and vertically at the same frequency, they should have resulted from car-body roll. This dynamic motion was also evident in waveforms of either vertical or lateral forces, which were mostly anti-phase between the two rails,[1] showing wheel-load characteristics due to car-body roll.

To further confirm this dynamic-roll mode, results of car-body accelerations are shown in Exhibit 5. Among the four accelerometers installed at one end (leading end shown), one pair (top and bottom of the car body) measured lateral accelerations, and another pair (left and right sides) measured vertical accelerations. As can be seen in Exhibit 5, several peak frequencies existed. However, major dynamic actions occurred at 1.1 Hz, consistent with wheel-set results. Apparently, car-body roll generated significant motions both vertically and laterally away from the roll center. These lateral and vertical motions occurred at the same frequency (1.1 Hz). Results shown in Exhibit 5 therefore agree with Exhibit 4, in terms of the major car-body dynamic motions.

Exhibit 5 also shows that the lateral acceleration energy (at 1.1 Hz) measured by the top accelerometer was higher than by the bottom accelerometer. For lower center roll, the roll center should be below the car-body, thus the car-body should experience more dynamic motion at the top than at the bottom.

It appeared the 125-ton gondola test vehicle tended to roll easily. Dynamic actions resulting from lower center roll were found to be true at all testing speeds (20 to 45 mph). Nevertheless, larger dynamic actions were measured at higher train speed.

REFERENCE

1. Li, D. and Smith L. "Vehicle / Track Interaction Tests on the Heavy Tonnage Loop," DOT / FRA / ORD, to be published.

Contact: Dingqing Li at (719) 584-0740 with questions or comments about this document.

E-mail: **dingqing_li@ttci.aar.com**

Web site: www.**ttci.aar.com**

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.