TECHNOLOGY DIGEST

Timely Technology Transfer — 99-019

EVALUATION OF END-OF-CAR CUSHIONING DESIGNS USING THE TOES MODEL

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SUMMARY

Two prototype end-of-car cushioning unit designs were evaluated in 1998 by Transportation Technology Center, Inc. engineers using Train Operations and Energy Simulator (TOES) software. Results predict substantial ride-quality improvement for these active-force cushion designs.

End-of-car cushion unit improvements have the potential to improve ride quality for automobiles shipped by rail by reducing the frequency and magnitude of longitudinal in-train accelerations. Two new active-force designs are modifications of the current M-921D unit.

Like the conventional M-921D, these prototype designs have 10 inches of buff stroke and possess identical buff return characteristics. This large amount of buff protection is designed to guard against yard impacts. The modified designs go a step further by incorporating 1.5 inches of draft protection, which may improve ride quality. The first design, a "high-force" unit, incorporates a 121-kip spring force that centers the unit when fully extended (1.5 inches) in the draft direction. A "low-force" unit is similar, but has only a 7-kip draft spring force.

The Quality and Maintenance of Equipment (QME) worked with auto manufacturers and chose the route from Georgetown, Kentucky, to Portland, Oregon, for this study. The Cushioning Device Task Force provided data on the characteristics of the prototype designs and worked with the QME to define unit and mixed trains for simulation. Car-body acceleration, cushion-unit displacement, and coupler-force data from TOES simulations were used to evaluate cushion-unit performance.

The simulations demonstrated the following:

- In unit-train simulations, the prototype designs spend 80 percent less time at acceleration levels above 0.4 g, as compared to the conventional M-921D.
- The low-force cushion unit spent 20 percent more time at acceleration levels over 0.4 g than the high-force design in dedicated auto-rack train simulations.
- In mixed-train simulations, the low-force cushion unit spent 35 percent less time at acceleration levels above 0.4 g than the high-force unit.

Suggested Distribution:

- ❑ Car Department
- ❑ Research & Development
- ❑ Equipment/Rolling Stock
- ❑ Intermodal

Work performed by TTCI Transportation Technology Center, Inc.

a subsidiary of the Association of American Railroads

June 1999©

INTRODUCTION AND CONCLUSIONS

Approximately 70 percent of finished automobiles in North America are transported by railroads. Because of the valuable nature of the cargo, shippers urge the railroads to provide the best ride quality possible to prevent ride-related damage. The loss and damage total for automobiles shipped by rail is approximately $18 million per year. It is estimated that 60 percent ($10.8M) of this damage is attributed to longitudinal ride quality. For several years, Transportation Technology Center, Inc. (TTCI) engineers have worked with the Quality and Maintenance of Equipment (QME) and Cushion Device Task Force (CDTF) committees to evaluate ride-quality performance.

In 1998, TTCI engineers performed simulations using the Association of American Railroad's (AAR) Train Operation and Energy Simulator (TOES) software to characterize the relative performance of various M-921D end-of-car cushioning device designs. The TOES model was used to evaluate ride-quality performance of two prototypes, a "high-force" M-921D unit, and a "low-force" unit. The performance of the prototype units was compared with performance of a conventional M-921D cushion unit. Car-body acceleration histograms were used as the criterion to evaluate ride-quality performance.

In 1996, the AAR implemented Recommended Practice 803-96 "Minimum Ride Quality Performance Requirements for Motor Vehicle Shipments," which suggests no more than 100 acceleration events greater than 0.4 g per 1,000 miles. In light of this criterion, car-body acceleration histograms were created from simulations of the three cushion-unit designs.

The simulations demonstrated:

- Active draft (high-force and low-force) M-921D designs spent 80 percent less time at acceleration levels above 0.4 g than the conventional M-921D for dedicated auto-rack simulations.
- The low-force cushion unit spent 20 percent more time at acceleration levels above 0.4 g than the high-force unit in dedicated auto-rack simulations.
- The low-force cushion unit spent 35 percent less time at acceleration levels above 0.4 g than the high-force unit in mixed-train simulations.
- Car-body acceleration is very sensitive to location in train. Auto racks located at the front and rear of the unit train spent much less time at high acceleration levels than railcars located near the middle of the train.

CUSHION UNITS TESTED

Conventional M-921D

The conventional M921-D end-of-car cushioning unit is the standard device used on most auto-rack railcars. This unit has a 10-inch stroke in the buff direction, but has no draft protection.

"HIgh-Force" Unit

The high-force cushioning unit has the same 10-inch stroke and buff return force as the M-921D, but also incorporates a 1.5-inch stroke in the draft direction. There is a 121-kip spring force to center the unit when fully extended in the draft direction. The spring force values for both the high- and low-force units were determined by cushion unit manufacturers.

"Low-Force" Unit

The low-force cushioning unit has a lower spring force (7-kip) to center the unit upon fully extended draft excursions, but is otherwise identical to the high-force unit. Exhibit 1 shows how much quicker the high-force unit returns from a full-draft excursion as compared to the low-force unit.

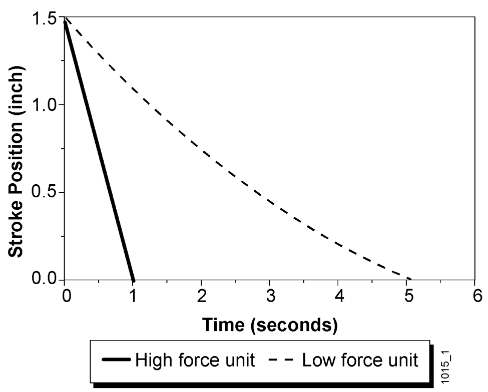

Exhibit 1. Draft Return Characteristic of High- and Low-Force Units

TOES MODEL AND ASSUMPTIONS

To model longitudinal train dynamics, TOES requires three input parameters, which are, track geometry, train makeup (including coupler, draft gear, and cushion-unit definitions), and train handling. Definitions of these three parameters for this work are described below.

TRACK GEOMETRY

The track-geometry parameters required by TOES are grade, elevation, curvature, spiral length, superelevation, and speed limit. TOES "track files" for the Georgetown, Kentucky, to Portland route were created by entering the required data from Norfolk Southern and Union Pacific track charts.

TRAIN MAKEUP

A unit train and a mixed train were modeled over the Georgetown, Kentucky, to Portland route. The unit train consisted of two SD60 locomotives and 60 bi-level auto racks. In order to analyze the ride quality of railcars distributed throughout the train, car numbers 3, 30, 45, and 58 were chosen for analysis.

The mixed train was taken from an actual roster and was approved by the CDTF for modeling. Four SD60 locomotives headed the mixed train, followed by 74 railcars of mixed variety. Two groups of auto racks were located in the consist, one group of nine auto racks started at the 53nd railcar, and another group of nine auto racks was located near the end of the train. Cars 54, 59, 74, and 77 were chosen for analysis on the mixed train.

TRAIN HANDLING

TOES requires a command file consisting of throttle, dynamic-brake, and air-brake settings. For this work, TOES command files were generated using the Association of American Railroads' Train Energy Model (TEM), specifically the Generalized Automatic Train Handling (GAT) logic. The GAT logic computes the throttle and brake settings required to match the posted speed limit. Exhibit 2 shows the ability of TEM to maintain speed. Train handling is a critical parameter in the TOES model, as poor train handling procedures adversely influence in-train forces.

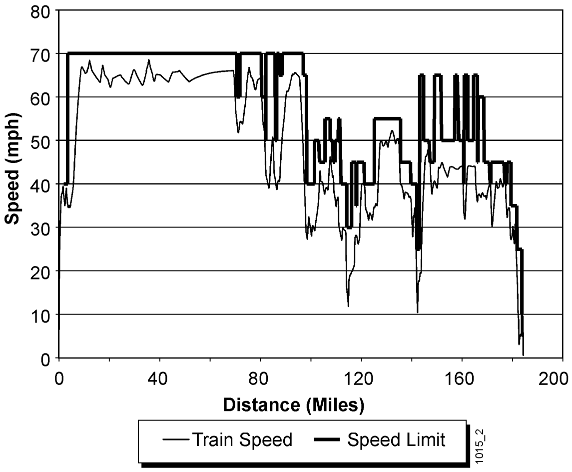

Exhibit 2. Speed Chart, TOES Performance from Hinkle to Portland, Oregon

ANALYSIS PROCEDURE

Car-body accelerations and cushion-unit displacements were calculated to evaluate the performance of the cushion units. Histograms were deemed the most efficient means of comparing unit performance. For this work, values on a histogram's x-axis represent the left boundary of the bins; for example, an acceleration value greater than 0.0 g and less than 0.1 g would be counted in the 0.0 g bin of the acceleration histogram. Likewise, a value greater than –0.3 g and less than –0.2 g would be counted in the -0.3 g bin.

RESULTS

Exhibit 3 is an acceleration histogram showing the maximum bin value for the four railcars analyzed on the unit train for the entire Georgetown, Kentucky, to Portland, Oregon, route. The histogram does not represent any one position on the train, but the worst of the four chosen positions on a bin-by-bin basis.

Exhibit 3 indicates the following:

- The conventional unit spent much more time at high acceleration levels than either of the active-force units.

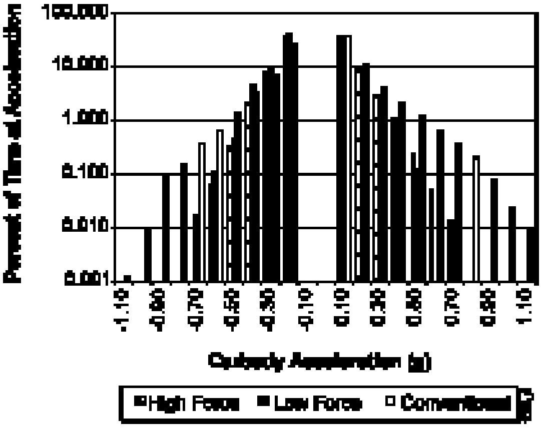

Exhibit 3. Unit-Train Car-Body Acceleration Histogram

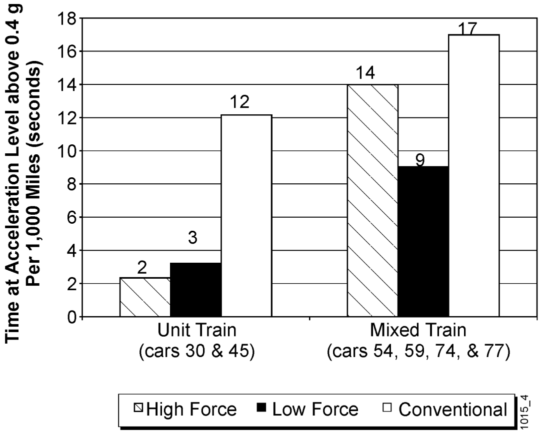

Exhibit 4. Peak Acceleration Event Comparison

- The low-force unit spent more time at high acceleration buff levels than the high-force unit, but less time at high acceleration draft levels than the high-force unit. This implies that some force level between the two might provide the best overall unit-train performance.

Exhibit 4 shows the amount of time spent above 0.4 g for the each of the cushion unit designs. This data was normalized for 1,000 miles from data collected over the entire Georgetown-to-Portland route. The unit train values in Exhibit 4 are the average of car locations 30 and 45. Cars 3 and 58 were excluded because they spent very little time at acceleration levels exceeding the 0.4 g criterion. The mixed-train data in Exhibit 4 are the average of car locations 54, 59, 74, and 77.

The time-at-level data produced by TOES simulations cannot be directly compared to the peak-event criterion defined by RP-803-96. However, the performance trends depicted in Exhibit 4 indicate substantial ride-quality improvement for the active-force cushion designs. Exhibit 4 also shows that for the modeled train make-ups, dedicated-train operation provides better ride quality than mixed-train operation.

ACKNOWLEDGMENT

The authors acknowledge the QME and CDTF committees for their support in funding and promoting the improvement of end-of-car cushion units.

REFERENCE

"Minimum Ride Quality Performance Requirements for Motor Vehicle Shipments," AAR Recommended Practice RP-803-96, Association of American Railroads, Pueblo, CO, April, 1996.

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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.