TECHNOLOGY DIGEST

Timely Technology Transfer — 99-027

IMPROVING THE ECONOMY OF BULK-COMMODITY SERVICE THROUGH IMPROVED SUSPENSIONS

by Ken Rownd and Russell Walker

Summary

An Association of American Railroads' Strategic Research Initiative aimed at improving the economics of bulk-commodity freight service has demonstrated that an improved suspension system can provide lower rolling resistance and reduced lateral forces. Tests conducted under this program compared the performance of a conventional three-piece truck with that of an improved truck in a baseline 315,000-pound car. Criteria used are described in the Bulk-Commodity Freight Truck Specification developed by Transportation Technology Center, Inc. for this program. Vertical performance was found to be similar for the two truck types.

The improved truck had lateral curving forces 50 percent lower than the three-piece truck and rolling resistance 30 to 50 percent lower than the three-piece truck. Warp restraint was increased by two diagonal links connecting the side frames and lateral stiffness was reduced by a rubber pad installed at each wheel location.

The intended applications are intermodal and double-stack cars used for transporting general merchandise and bulk commodities, and operating at axle loads ranging from 33 tons (100-ton service) to 39 tons (125-ton service) or above. Performance goals were identified to reduce costs associated with vehicle and track maintenance, energy consumption, worn truck components, and car availability.

New designs were solicited using performance goals described in Bulk-Commodity Freight Truck Specification. The program specification is a guideline for this test program. It does not supersede requirements in the AAR *Manual of Standards and Recommended Practices*.

An open meeting was held in October, 1998, to announce the program, distribute the specification, and solicit participants. Test methods for evaluating proposed designs were also released at this time.

Suggested Distribution:

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

Work performed by TTCI Transportation Technology Center, Inc.
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INTRODUCTION AND CONCLUSIONS

Benchmarking tests indicate that an improved suspension system can provide lower rolling resistance and reduced lateral forces. These tests were conducted by Transportation Technology Center, Inc. as part of an Association of American Railroads (AAR) Strategic Research Initiative to improve economy of bulk-commodity service .

A Bulk-Commodity Freight Truck Specification developed specifically for this program was used to solicit new suspension designs for bulk-commodity cars. Two baseline cars were selected for these tests. Both are modern lightweight aluminum coal cars. One was empty and one could be loaded to 286,000 pounds or 315,000 pounds to test prototype designs. To benchmark the performance goals in the solicitation, two truck types were tested under the 315,000-pound car. Exhibit 1 shows the base car used in evaluating suspension types.

Tests of the baseline conventional three-piece truck and a warp-restrained (in this case Standard Car FRAME BRACE™ Truck) three-piece truck demonstrated the following performance improvements of the warp-restrained truck:

- Reduced lateral curving forces by 50 percent.
- Reduced the incremental curve resistance by 40-50 percent.
- Reduced tangent resistance by more than 30 percent.

Additionally:

- Yaw-and-sway criteria were exceeded by the warp-restrained truck.
- Vertical performance was similar for both truck types.
- Minimum vertical wheel load criteria were exceeded in loaded twist and roll for both truck types.
- Minimum vertical wheel loads were 9 percent of static for the warp-restrained truck and 11 percent of static for the three-piece truck (limit = 10%).
- High-speed-stability criteria were exceeded above 60 mph for the baseline truck.

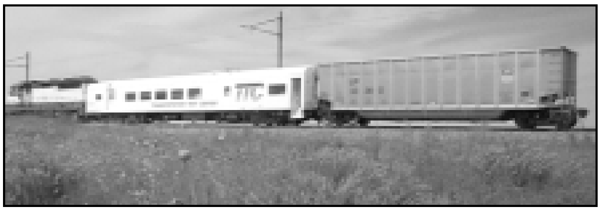

Exhibit 1. Baseline Car for Bulk Commodity Suspension Evaluation

BACKGROUND

The baseline car was originally equipped with Barber S-2-HD FRAME BRACE™ trucks, which are warp restrained and have primary pads. The frame-bracing and primary pads were removed for baseline tests to represent a three-piece truck application.

Tests were conducted according to Chapter XI of the AAR's *Manual of Standards and Recommended Practices*. Test data was compared to performance gaols described in the Bulk-Commodity Freight Truck Specification.

A computer model of the baseline car was made based upon a test that analyzes dynamic parameters. This test documents rigid-body mode frequencies and enables calculation of moments of inertia. The model is available to proponents for design optimization based upon the track tests described in the specification.

TRUCKS TESTED

Baseline Truck

The baseline truck was a Barber S-2-HD of 125-ton design. Snubbing is by four steel friction wedges, each resting on one B-355 outer and one B-356 inner-coil spring. Side bearings are Miner TCC 4500 constant-contact side bearings. The truck uses 38-inch wheels and has a secondary coil-spring suspension. Each side has one D5 outer coil and one D6 inner coil in parallel with a dual-rate spring package consisting of the following:

- Six B-291 main coils
- Six B-297 top coils in series with main coils
- Six B-298 intermediate coils in parallel with main coils

In the empty condition, the dual-rate spring group is soft for the first 1 inch of travel because the top coils are in series with the parallel combination of main and intermediate coils.

W arp-Restrained Truck

For these tests, the Standard Car FRAME BRACE™ Truck was considered as a representative warp-restrained truck. The truck has identical secondary suspension and side bearings. The side frames are connected by two diagonal links to increase warp stiffness. A primary rubber pad is installed at each wheel location. This pad can shear to provide passive axle alignment in curving and reduces lateral stiffness.

TWIST-AND-ROLL TEST RESULTS

The twist-and-roll test measures the ability of a car to negotiate cross-level perturbations. Because the truck center spacing of the high-sided gondola car (40 feet, 6 inches) is very close to the wave length of the perturbations, the car is excited in pure roll mode. Consequently, twist-and-roll is a difficult test for this car. Performance is nearly the same for both truck types.

Exhibit 2 is a plot of the maximum and minimum vertical wheel loads versus speed for the three-piece truck in loaded twist-and-roll tests. The minimum vertical wheel load is less than the 10-percent criteria and the maximum vertical wheel load exceeds 1.5 dynamic load factor for all speeds above 15 mph.

During empty-car twist-and-roll tests, roll angles exceeded the specified criterion at the vehicle's roll resonance speed of approximately 33 mph.

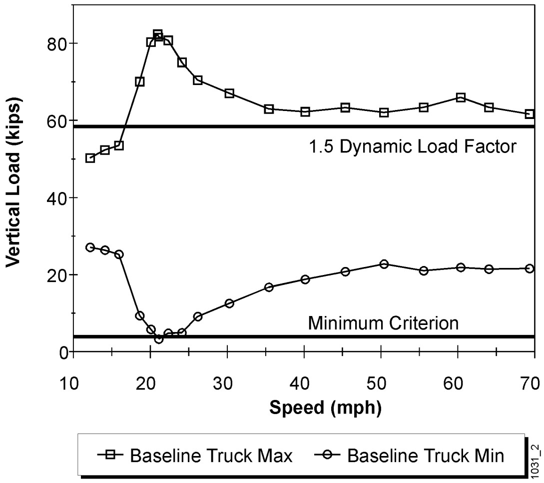

Exhibit 2. Minimum Wheel-Load Performance of Loaded Car with Three-Piece Truck in Twist-and-Roll

PITCH-AND-BOUNCE TEST RESULTS

The pitch-and-bounce test regime measures the ability of the car to negotiate vertical profile deviations. Poor performance results in suspension bottoming and high vertical track loads. The pitch-and-bounce test is performed loaded. The car's truck-center spacing is very close to the wave length of the track perturbations; therefore, the car is excited in an almost pure bounce mode of vibration.

The baseline car and the warp-restrained car met pitch-and-bounce performance criterion for minimum vertical wheel load. The maximum dynamic load factor exceeded the recommended 1.5 dynamic load at the maximum test speed of 70 miles per hour.

YAW-AND-SWAY TEST RESULTS

The yaw-and-sway test measures the ability of a car to negotiate laterally misaligned track. Poor performance results in high lateral track loads. The yaw-and-sway test is only performed in the loaded condition. The base car met yaw-and-sway criteria. The warp-restrained car exceeded the truckside L/V criterion at higher speeds (Exhibit 3).

The warp-restrained trucks are equipped with primary pads at each axle-to-truck connection, resulting in a softer overall lateral suspension. The reduction in lateral stiffness dropped the upper center roll resonant frequency into a range that was excited by the yaw-and-sway test at 65 mph. The resonant frequency for the baseline truck would be at a speed greater than 70 mph.

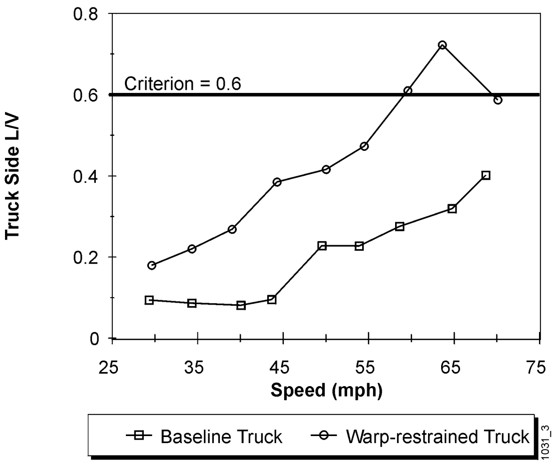

Exhibit 3. Comparison of Truckside L/V Performance of Baseline and Warp-Restrained Trucks in Yaw and Sway

CONSTANT CURVING TEST RESULTS

The constant curving test measures a car's ability to negotiate well-maintained track curves. Poor performance increases costs associated with derailment, track alignment and wheel and rail wear. The baseline truck met constant-curving criteria in both the empty and loaded condition. As shown in Exhibit 4, the warp-restrained truck reduced average lateral curving forces by more than 40 percent in the 7.5- and 10-degree curves.

DYNAMIC-CURVING TEST RESULTS

The dynamic-curving test combines cross-level and gage deviations on a 10-degree curve. The cross-level deviations are similar to those installed in the twist-and-roll test section. As observed in the twist-and-roll test series, vertical-load performance was marginal for both truck types with minimum load approximately 10 percent of static load.

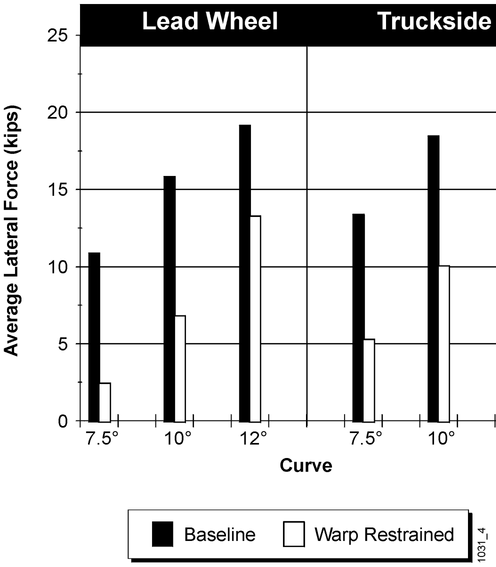

Exhibit 4. Average Lateral Curving Force of Baseline and Warp-Restrained Trucks

HIGH-SPEED-STABILITY TEST RESULTS

The high-speed-stability test is conducted to ensure that the car does not become laterally unstable at speeds up to and including 70 miles per hour. The high-speed-stability test is only performed in the empty condition. The base truck exceeded criteria at 60 miles per hour. A worn baseline truck would probably exceed the criteria at a lower speed.

ROLLING-RESISTANCE TEST RESULTS

Exhibit 5 compares curve resistance in pounds per ton per degree of curve as tested in curves of 4, 7.5, 10, and 12 degrees. Roller-bearing resistance has been removed based on 18 pounds per axle. Tangent-track resistance was removed by subtracting 1.8 pounds per ton for the baseline and 1.55 pounds per ton for the warp-restrained truck. The warp-restrained tangent resistance was measured in a separate long tangent test. The baseline tangent resistance value is the traditional value for a three-piece truck. All tests were performed at 5 mph to minimize aerodynamic resistance.

Warp-restraint reduced the curve resistance by more than 50 percent. Testing was accomplished on a track that has the 4-, 7.5-, and 10-degree curves to the right. The 12-degree curve was to the left. This curve orientation had the effect of reducing the resistance for right-hand curves while increasing the resistance for the left-hand curve.

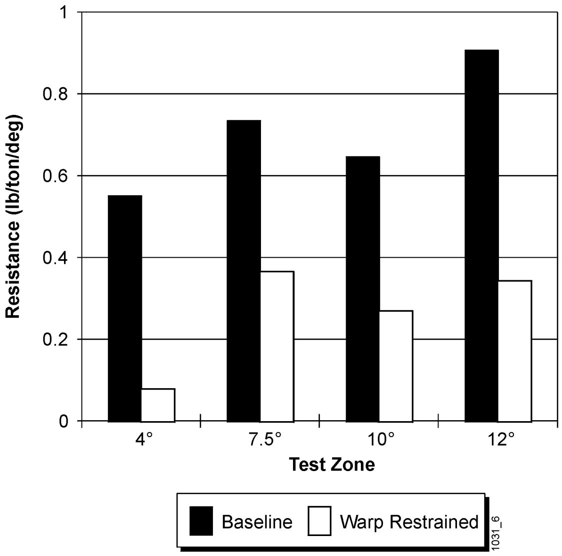

Exhibit 5. Comparison of Rolling Resistance for Baseline and Warp-Restrained Trucks

SUMMARY

The warp-restrained truck performance demonstrates potential to reduce operating costs for bulk-commodity cars through improved suspensions. The Advanced Truck Program offers assistance to designers of new suspensions through AAR modeling support, testing of promising prototypes, and evaluation using AAR cost models.

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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.