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Work performed by Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads.
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Warp Characteristics of Bulk Commodity Suspensions:

Conventional and Frame Brace™ Truck

Part 1 of 3

by Ken Rownd and Corey Pasta

Summary

Three improved bulk commodity suspensions showed significantly increased warp resistance as compared with standard three-piece trucks in tests carried out by Transportation Technology Center, Inc. Substantial truck warp restraint is needed to enable implementation of design features intended to reduce curving forces, vehicle dynamics, wheel wear, rail wear, and fuel consumption.

Truck warp is a longitudinal misalignment of the side frames resulting in rotation relative to the bolster. Suspensions with low-warp restraint contribute to rail spreading derailments and higher track maintenance costs. Low-warp resistance trucks frequently exhibit high-speed instability.

In 2002, a new truck performance specification, *M976 Truck Performance Specification for Rail Cars*, was adopted by the Association of American Railroads (AAR) for 286,000-pound cars. M-976 requires dynamic performance not achievable by traditional bulk suspensions. Several candidate suspensions rely on movement of the axles relative to the side frames to reduce lateral curving forces and rolling resistance. This movement is accomplished through shearing of elastomeric pedestal pads placed between the axle bearing adapters and side frames. Industry experience shows that suspensions with high warp resistance will allow these pads to survive and that the same pads applied to conventional suspensions will quickly fail.

This *Technology Digest* (TD) documents tests with the conventional (base) truck and the same truck with frame bracing applied. The base truck has low warp restraint. The Frame Brace™ feature is believed to provide adequate warp restraint to ensure long-term elastomeric pedestal pad life and maintain good dynamic performance in railroad service. The warp restraint of two new suspension designs will be compared to the Frame Brace™ truck in Parts 2 and 3 of this TD series.

Warp restraint may decrease with truck wear. Increased warp restraint for the Frame Brace™ truck is accomplished by linking the side frames together with two diagonal connections. Increased warp restraint for the other two improved suspensions is a result of modifications to the friction wedges. Long-term dynamic performance will be dependent on the wear life of the wedges and the integrity of the elastomeric pedestal pads. Warp tests for service worn suspensions are needed. The AAR Mechanical Research Committee has guided this research.

Suggested Distribution:

- Mechanical
- Planning & Analysis

TECHNOLOGY DIGEST

INTRODUCTION AND CONCLUSIONS

TTCI performed a test series to determine warp resistance characteristics of a base truck and three improved trucks. This TD summarizes results for the base truck and the same truck with Frame Brace™. These two trucks are variably damped, which means that damping is proportional to dynamic vertical loads.

Better suspension performance is required to control vehicle dynamics and reduce forces imparted to the track. Substantial warp restraint is needed to enable implementation of design features intended to reduce curving forces, vehicle dynamics, wheel and rail wear, and fuel consumption. Tests were performed with and without elastomeric pedestal pads.

Truck warp is longitudinal misalignment of the side frames resulting in rotation relative to the bolster. Suspensions with low warp restraint contribute to rail spreading derailments and increase track maintenance costs. Low warp resistance trucks frequently exhibit high-speed instability. The results were as follows:

Adding elastomeric pedestal pads to the base truck:

- Reduces loaded car warp stiffness and damping by 40 percent
- Reduces empty car warp stiffness by 13 percent and warp damping by 30 percent

Adding elastomeric pedestal pads to a Frame Brace™ truck:

- Increases loaded car warp stiffness 7 percent and decreases warp damping 19 percent
- Increases empty car warp stiffness 38 percent and warp damping is reduced 25 percent

Adding the Frame Brace™ to the base truck with elastomeric pedestal pads (note 0.001 radian = mrad):

- Increases loaded car warp stiffness 800 percent and warp damping 54 percent
- Increases loaded car warp moment at 5 milliradians (mrad) warp from 310 to 950 inch-kips.
- Increases empty car warp stiffness 4,400 percent and warp damping 63 percent.
- Increases empty car warp moment at 10 mrad warp from 110 to 1,250 inch-kips.

Background

A strategic research initiative to solicit and evaluate improved bulk trucks was conducted from 1999-2001. Most successful prototypes relied on elastomeric pedestal pads between the side frame and bearing adapter to reduce curving forces and rolling resistance. Figure 1 shows the primary pad and the end of one Frame Brace™ (under side frame).

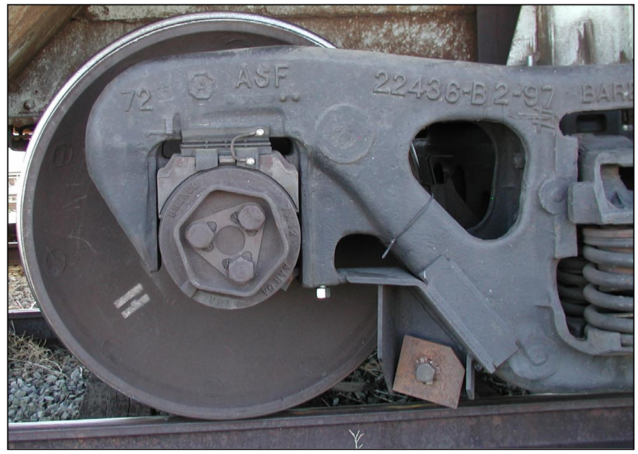

Figure 1: Elastomeric Pad and Frame Brace™

In 2002, the Equipment Engineering Committee adopted a new Truck Performance Specification for 286,000 pound gross rail-load cars that requires performance not achievable with conventional suspensions.

Most prototypes offered to meet this new specification rely on friction wedges to generate warp restraint and have good dynamic performance when the trucks are in nearly new condition. Two issues have been raised concerning the new designs: (1) Will the elastomeric pedestal pads survive in railroad service? (2) At how many miles of service will the warp restraint still be adequate?

Canadian Pacific Railway has experienced acceptable primary pad performance at 500,000 miles of service (to date) when the pads are in a Frame Brace™ truck. TTX has reported that elastomeric pedestal pads applied to conventional suspensions did not survive. Assuming the pads are strong enough to support the vehicle weight, the issues of pad life and warp strength seem to be intertwined.

Where does warp resistance come from?

Conventional truck warp stiffness comes from the interface between the friction shoe, side frame, and bolster pocket as the friction shoe is pushed into the bolster pocket by the control springs. Twisting of the coil springs and elastomeric pedestal pads (or bearing adapters) as the side frames move with respect to each other provides additional warp stiffness. In the Frame Brace™ truck, additional stiffness comes from diagonally tying the side frames together.

TECHNOLOGY DIGEST

Warp damping comes from friction between the bearing adapter (or primary pad) and side frame, and from friction between the wedges, side frame, and bolster.

Test Setup

Warp stiffness and damping were measured for each truck. Single trucks were tested under one end of a specially equipped flatcar. This flatcar enabled static weight changes and connection for hydraulic actuators configured to apply dynamic vertical loads while warping the trucks with longitudinal actuators.

Center plate resistance was minimized by installing a thrust bearing between the car body and truck center plate. Independent rotating wheels minimized wheel rail resistance.

Figure 1 shows the test setup. Warping forces were applied to each side frame. Force was measured by load cells attached to actuators. Displacement was measured between the side frames and the truck bolster.

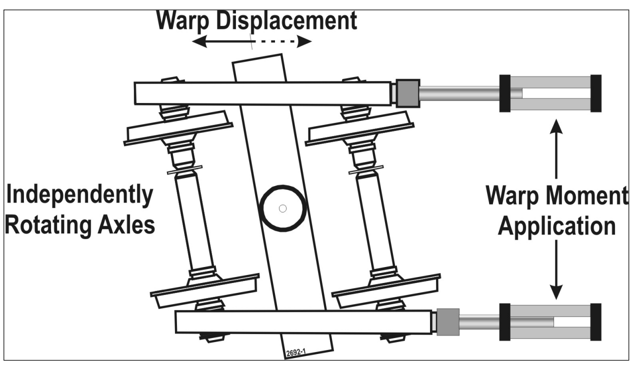

Figure 1: Line Drawing of Warp Test Setup

Warp and Vertical Force Inputs

Warp tests were conducted in the presence of static vertical load. Additional tests were performed with dynamic vertical forces applied. Preliminary operations were performed to ensure that hard stops and excessive force would not be encountered during data runs. Warp moment applications were at 0.2 cycles per second (Hz).

For empty car tests, dynamic vertical loads were applied at 2.0 Hz with peak-to-peak amplitude of 0.2 inch to represent motions that might reduce warp damping during onset of high-speed instability.

For loaded car tests, the dynamic vertical load application was at 0.5 Hz with peak-to-peak amplitude of 0.2 inch to represent motions associated with roll or body twist in curve entry.

The empty car, as tested, had 8000-pound wheel weights. This is the unloaded flatcar condition; actual empty car weights could be as low as 5,600 pounds for some car types. Thus, empty car warp stiffness and damping are slightly over estimated. The loaded car wheel weights were simulated at 35,500 pounds (284,000 pounds).

Trucks Tested

Four trucks were tested. This TD reports on the results for the base truck and the same truck with Frame Brace™ applied.

Base Truck

The base was a 125-ton service Standard Car Truck S2-HD. The truck was tested with the thicker Lord Corporation (LC) pads and with the thinner pads now being offered for bulk trucks. The thin pad had 23 percent less warp stiffness than the thick pad in the loaded car test. Empty car differences were negligible.

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
- Six B-298 intermediate coils in parallel

Base Truck with Frame Brace™

The base truck was equipped with a Frame Brace™ to increase warp stiffness.

Empty Car Testing

Empty car testing is performed to determine the warp resistance where onset of high-speed stability could compromise the damping by friction wedge. High-speed instability can quickly fatigue the primary pad and wear out truck frictional components.

Table 1 summarizes the empty car results from this test. The general result is that the Frame Brace™ dramatically increases warp stiffness and increases warp damping by more than 50 percent. Therefore, the moment required to warp the truck (with pads) 10 mrads is increased by 1,138 percent.

Figure 2 compares empty car warp response for the base and Frame Brace™ truck with dynamic vertical loads applied. Warp stiffness was computed as the average slope of the upper and lower segments around 0-mrad warp angle. Warp damping was computed as half the distance between these segments at 0-mrad warp angle. Line waviness is due to the effect of oscillating vertical load input on the variable damped suspensions.

Table 1: Empty Warp Stiffness and Damping

	Base		Frame Brace™	
	No Pads	Pads	No Pads	Pads
Tests with 2.0 Hz vertical input				
Stiffness*	3.0	2.6	85.0	117.0
Damping**	113.0	79.0	172.0	129.0
Moment @ 10mrad**	140.0	105.0	1,020.0	1,300.0
Tests with no vertical input				
Stiffness*	4.3	1.5	77.5	108.0
Damping**	140.0	82.5	209.0	183.0
Moment @ 10 mrad**	182.0	95.0	984.0	1,250.0
* inch-kips/mrad	** inch-kips			

Table 2. Loaded Warp Stiffness and Damping

	Base		Frame Brace™	
	No Pads	Pads	No Pads	Pads
Tests with 0.5 Hz vertical input				
Stiffness*	22.0	12.8	111.0	119.0
Damping**	424.0	251.0	479.0	387.0
Moment @ 5 mrad**	530.0	315.0	1,030.0	981.0
Tests with no vertical input				
Stiffness*	26.3	14.3	113.0	124.0
Damping**	438.0	240.0	469.0	327.0
Moment @ 5 mrad**	580.0	310.0	1,030.0	950.0
* inch-kips/mrad	**inch-kips			

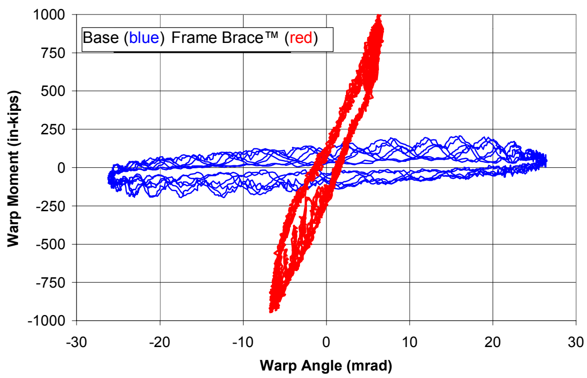

Figure 2: Empty Car Truck Warp Response with Dynamic Vertical Loads Applied

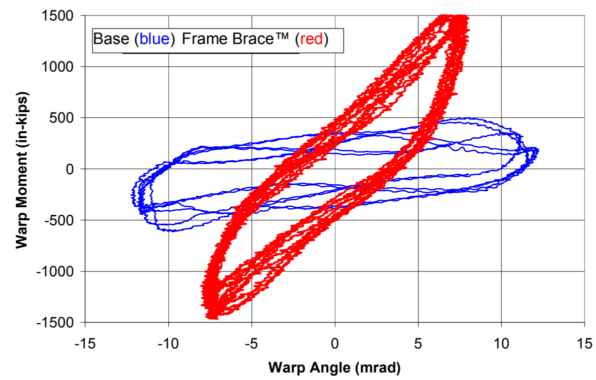

Figure 3: Loaded Car Truck Warp Response with Dynamic Vertical Loads Applied

Loaded Car Testing

Loaded car testing is performed to determine warp resistance in cases where spiral negotiation or roll-response compromises damping by friction wedges.

Table 2 summarizes loaded car results from this test. The general result is that the Frame Brace™ increases warp stiffness dramatically. Warp damping is increased by more than 35 percent for cases with elastomeric pedestal pads. Therefore, the moment required to warp the truck (with pads) 5 mrads is increased by 211 percent.

Figure 3 compares warp response for loaded car tests with elastomeric pedestal pads and dynamic vertical loads applied.

SUMMARY

Elastomeric pedestal pads are used in trucks to improve dynamic performance and to decrease the stress state of the railroads. This TD shows why they last longer in Frame Brace™ trucks compared to conventional trucks. Conventional suspensions have very low warp resistance leading to early pedestal pad failure. This is consistent with railroad experience. Elastomeric pedestal pads will reduce fuel consumption, track maintenance, and wheel and rail wear as long as they maintain their design characteristics.

Increased warp restraint will limit gage-spreading derailments and help maintain high-speed stability. Since warp damping relies on friction, this desirable characteristic may decrease over time, especially for the conventional truck. Parts 2 and 3 of this TD series will compare improved suspension designs to the Frame Brace™.