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Warp Characteristics of Bulk Commodity Suspensions: Standard Car Truck Company S2E Truck

Part 2 of 3

by Ken Rownd and Corey Pasta

Summary

The Standard Car Truck Company S2E suspension in new condition under a loaded car has more warp resistance than a conventional truck with frame bracing (Frame Brace™), as demonstrated by Transportation Technology Center, Inc. Experience industry wide shows that the Frame Brace™ truck has adequate warp restraint. 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. Under an empty car, the S2E truck has less warp resistance than the Frame Brace™ truck, but substantially more resistance than a conventional suspension.

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

In 2002, a new truck performance specification, *M-976 Truck Performance Specification for Rail Cars*, was adopted for 286,000-pound cars. Specification M-976 requires dynamic performance not achievable by traditional bulk suspensions.

Several potential M-976 suspensions, including the S2E design, rely on elastomeric pedestal pads to reduce lateral curving forces and rolling resistance. Experience by the industry demonstrates suspensions with high warp resistance will allow these pads to survive and that the same pads applied to conventional suspensions can quickly fail.

A conventional truck and three improved truck prototypes were examined in this warp test series. High warp restraint for the S2E truck is a result of changes to the friction wedge design. Long-term dynamic performance and warp restraint will be dependent on the wear life of the wedges and the integrity of the elastomeric pedestal pads.

This *Technology Digest* (TD) compares the results of tests with the Frame Brace™ truck and Standard Car Truck Company's S2E truck. A conventional truck has low warp restraint. Warp tests for service worn improved suspensions are needed.

This TD is Part 2 of 3 of the warp test series. The first TD 03-023 compares a conventional truck and the same truck with a Frame Brace™. The Mechanical Research Committee has guided this research.

Suggested Distribution:

- ❑ Mechanical
- ❑ Planning & Analysis

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 conventional truck with frame bracing (Frame Brace™) and the Standard Car Truck Company S2E truck. These two trucks have damping 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, increase track maintenance costs, and frequently exhibit high-speed instability. The results were as follows:

Compared to the conventional truck

- All stiffness and damping values for S2E and Frame Brace™ trucks are large.

Adding the pedestal pads to the S2E truck:

- Reduces loaded car warp stiffness by 24 percent and damping by 29 percent.
- Reduces empty car warp stiffness by 53 percent and damping by 49 percent.

Adding the pads to the Frame Brace™ truck:

- Increases loaded car warp stiffness 7 percent and decreases warp damping 19 percent.
- Increases empty car warp stiffness 38 percent and reduces warp damping 25 percent.

Comparing S2E to the Frame Brace™ with elastomeric pedestal pads (0.001 radian = milliradian):

- S2E loaded car warp stiffness is 97 percent more and warp damping is 59 percent more.
- S2E loaded car warp moment at 5 mrads is 1,880 in-kips while the Frame Brace™ warp moment is 981 in-kips
- S2E empty car warp stiffness is 62 percent less and warp damping is 56 percent more.
- S2E empty car warp moment at 10 mrads warp is 651 in-kips while the Frame Brace™ moment is 1,300 in-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 an elastomeric pedestal pad above the axle in a S2E truck.

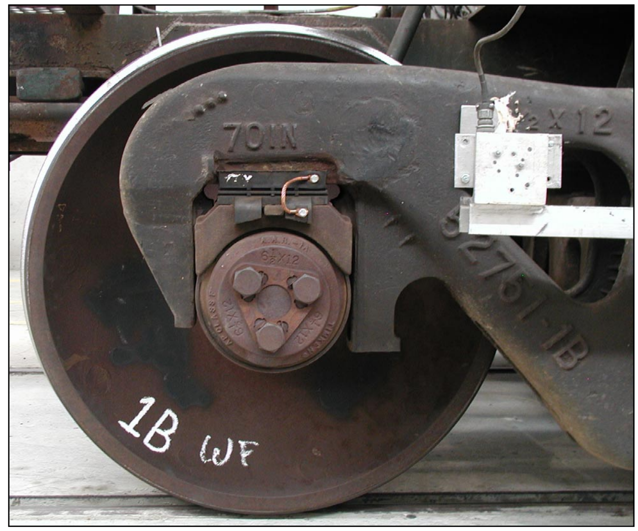

Figure 1: Pedestal Pad on S2E Truck

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

The S2E truck relies on friction wedges to generate warp restraint. This truck has good dynamic performance when the trucks are in nearly new condition. Two issues have been raised concerning new designs with elastomeric pedestal pads: (1) Will the 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 elastomeric pedestal 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?

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.

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

TEST SETUP

Warp stiffness and damping was 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 a thrust bearing between the car body and truck center plate. Independent rotating wheels minimized wheel rail resistance.

Warping forces were applied to each side frame. Load cells attached to actuators measured force. Displacement was measured between the side frames and the truck bolster.

Warp and Vertical Force Inputs

Warp tests were conducted in the presence of static vertical load and with additional 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 simulated, had 8,000-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).

Standard Car Truck Company S2E Truck

The S2E tested was a 110-ton service Standard Car Truck design. The suspension was tested with and without elastomeric pedestal pads.

The spring group was seven D5 outer and seven D5 inner with two B-353 and two B-354 control springs. This truck has damping proportional to spring-nest travel.

The S2E has a split-friction-wedge design that provides additional truck squaring and damping. Figure 2 shows the split wedge. The inclined surfaces of the split wedges are angled to maintain spacing

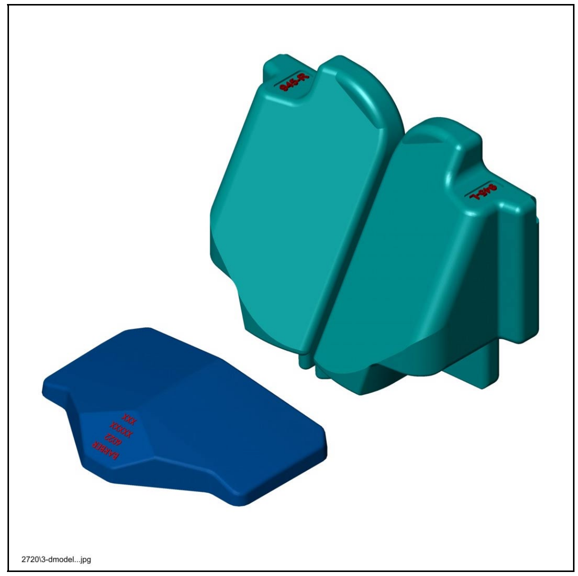

Figure 2. S2E Split Wedge Drawing

Conventional Truck with Frame Brace™

A conventional truck from Standard Car Truck Company was equipped with frame bracing to increase warp stiffness. This conventional truck was a S2HD for 125-ton service.

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 elastomeric pedestal pad and wear out truck frictional components.

Table 1 summarizes empty car results from this test. The general result is that the Frame Brace™ and S2E trucks have substantial warp resistance. The warp moment needed to reach 10 mrad warp angle is larger than the moment an empty car could normally generate.

Table 1. Empty Warp Stiffness and Damping

	S2E		Frame Brace™	
	No Pads	Pads	No Pads	Pads
Tests with 2.0 Hz vertical input				
Stiffness*	95.4	45.0	85.0	117.0
Damping**	392.0	201.0	172.0	129.0
Moment @ 10 mrad**	1,346.0	651.0	1,020.0	1,300.0
Tests with no vertical input				
Stiffness*	203.0	154.0	77.5	108.0
Damping**	673.0	477.0	209.0	183.0
Moment @ 10 mrad**	2,700.0	2,020.0	984.0	1,250.0
* in-kips/mrad		** in-kips		

The S2E warp damping is larger than the Frame Brace™ damping when both are in new condition. The warp stiffness is less than the Frame Brace™ stiffness when elastomeric pedestal pads and dynamic vertical loads are included.

Figure 3 compares empty car warp response for the S2E and Frame Brace™ truck with dynamic vertical loads applied. Warp stiffness is the average slope of the upper and lower segments around zero-mrad warp angle. Warp damping was computed as half the distance between these segments. Line waviness is due to the effect of vertical input oscillations on the variable damped suspensions.

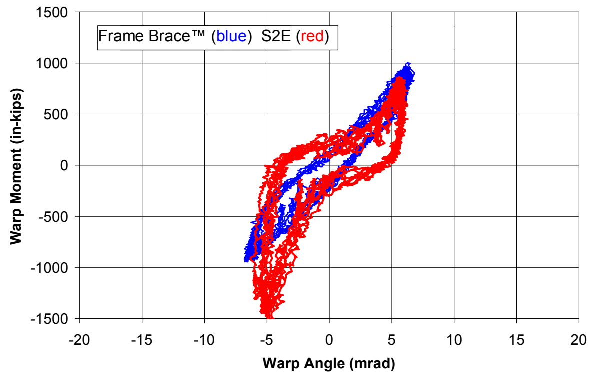

Figure 3: Empty Car Truck Warp Response with Dynamic Vertical Loads Applied

Loaded Car Testing

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

Table 2 summarizes the loaded car results from this test. The general result is that the S2E has more warp stiffness and damping than the Frame Brace™ truck. The moment required to generate 5 mrad warp angle is very large for either truck design.

Figure 4 compares warp response for loaded car tests with elastomeric pedestal pads and dynamic vertical loads applied.

Table 2. Lateral Warp Stiffness and Damping

	S2E		Frame Brace™	
	No Pads	**Pads**	**No Pads**	**Pads**
Tests with 0.5 Hz vertical input				
Stiffness*	266.0	234.0	111.0	119.0
Damping**	780.0	615.0	479.0	387.0
Moment @ 5 mrad**	2,131.0	1,880	1,030.0	981.0
Tests with no vertical input				
Stiffness*	388.0	367.0	113.0	124.0
Damping**	928.0	726.0	469.0	327.0
Moment @ 5 mrad**	2,871.0	2,562.0	1,030.0	950.0
* in-kips/mrad		** in-kips		

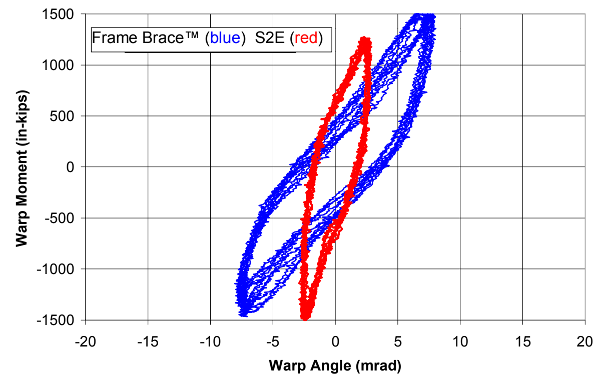

Figure 4: Loaded-Car Truck Warp Response with Dynamic Vertical Loads Applied

SUMMARY

The S2E truck in new condition has desirable warp characteristics. Increased warp restraint will limit gage-spreading derailments and help maintain high-speed stability. Since warp damping relies on friction, this desirable characteristic will decrease with truck wear. Examination of the worn truck warp characteristic is needed.

See TD 03-023, Part 1 of 3, of this warp test series.