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## ***Warp Characteristics of Worn Bulk Commodity Suspensions: M-976-Type Trucks*** by Ken Rownd and Russell Walker

### **Summary**

The railroad industry has adopted a new interchange standard for cars in 286,000-pound gross rail load (GRL) service. The AAR standard — S-286 — requires truck performance per a new AAR specification, *M-976 Truck Performance Specification for Rail Cars*. Five new truck designs have met the M-976 specification. Each design relies in part on high warp restraint between bolster and side frame to improve curving and high-speed stability. In these five designs, the amount of warp restraint will change as wear in the friction snubbing surfaces occurs.

This Technology Digest reports warp restraint measured for a simulated worn-out M-976-type truck and for two suspensions of the same design moderately worn in railroad service. The moderately worn suspensions retained acceptable levels of warp restraint. The simulated worn out suspension has low restraint similar to that found in unworn conventional truck designs.

Adopted in 2002, M-976 requires dynamic performance not achievable by traditional bulk suspensions. The specification became a certification requirement for 286,000-pound GRL interchange service in 2004 to allow time to implement new suspension designs.

Warp restraint for the five truck types approved through the M-976 process relies on modified or larger friction dampers. High warp restraint will improve curving and high-speed stability performance.

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.

Successful M-976 suspensions (to date) include elastomeric pedestal pads to reduce lateral curving forces and rolling resistance. Industry experience shows that suspensions with high warp resistance will allow these pads to survive and that the same pads applied to conventional suspensions can quickly fail. 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.

The AAR Mechanical Research Committee has guided this research.



## INTRODUCTION AND CONCLUSIONS

TTCI performed a test series to determine warp resistance characteristics of a truck design certified for 286,000-pound interchange service and this same design in worn condition. The trucks tested were variably damped, meaning that damping is proportional to vertical loads.

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A new industry truck performance specification M-976 requires better suspension performance than traditional trucks 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.

The five trucks approved through the M-976 certification process rely on the design of the friction snubbing elements to achieve high warp restraint. The amount of warp restraint will change as wear in the friction snubbing surfaces occurs.

The worn conditions tested, as characterized by wedge rise, were 0.235-inch rise, 0.375-inch rise, and 1-inch rise. The first two are moderately worn trucks from revenue service. These are not the same specimen tested in the new condition. The 1-inch wedge rise test used the new truck with load springs shimmed to simulate the wedge rise for a completely worn out truck.

Tests of moderately worn M-976-type trucks demonstrate significant warp restraint has been retained. When considering these results, remember that a reduction in warp moment for a given warp angle means warp restraint has been reduced.

Comparing the moderately worn and new trucks:

- Significant warp restraint is retained. Although warp stiffness values are reduced compared to a new truck, warp restraint is still high compared to conventional heavy-duty suspension.
- Loaded car warp stiffness was reduced 44 percent, and warp damping increased 8 percent for the truck with 0.235-inch wedge rise.
- Loaded car warp stiffness was reduced 54 percent, and warp damping increased 32 percent for the truck with 0.375-inch wedge rise.
- Loaded car warp moment at 5 milliradians (mrads) was reduced 24 percent for the 0.235-inch rise truck and 21 percent for the 0.375-inch rise truck.

- Empty car warp stiffness was reduced 4 percent, and warp damping increased by 22 percent for the 0.235-inch rise truck.
- Empty car warp stiffness was increased 4 percent, and warp damping increased by 41 percent for the 0.375-inch rise truck.
- Empty car warp moment at 10 mrads was increased 5 percent for the 0.235-inch rise truck and 16 percent for the 0.375-inch rise truck.

Comparing a (simulated) worn out and new truck:

- The truck shimmed to represent a worn out truck had reduced warp restraint as expected.
- The simulated worn-out truck had warp restraint similar to that measured for unworn conventional suspensions.
- Loaded car warp stiffness was reduced 44 percent, and warp damping decreased 31 percent.
- Loaded car warp moment at 5 mrads was reduced 39 percent.
- Empty car warp stiffness was reduced 30 percent and warp damping decreased 27 percent.
- Empty car warp moment at 10 mrads was reduced 41 percent.

## BACKGROUND

A strategic research initiative to solicit and evaluate improved trucks for bulk commodity service was conducted from 1999 to 2001. Most successful prototypes rely 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 in a prototype bulk truck.



Figure 1: Elastomeric Pedestal Pad in GRL M-976-type Suspension

In 2002, the Equipment Engineering Committee adopted a new interchange standard for 286,000-pound gross rail load cars called S-286. The S-286 standard requires truck performance not achievable with conventional suspensions. The truck performance specification is called M-976.

Most prototypes offered to meet the new specification rely on friction wedges to generate warp restraint and have good dynamic performance when the trucks are in nearly new condition. Two questions have been raised concerning the new designs: (1) Will the primary pads survive in railroad service? (2) After 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 primary 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.

**TEST SETUP**

Warp stiffness and warp 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 a thrust bearing between the carbody and truck center plate. Independent rotating wheels minimized wheel rail resistance.

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 2 shows the warp test setup.

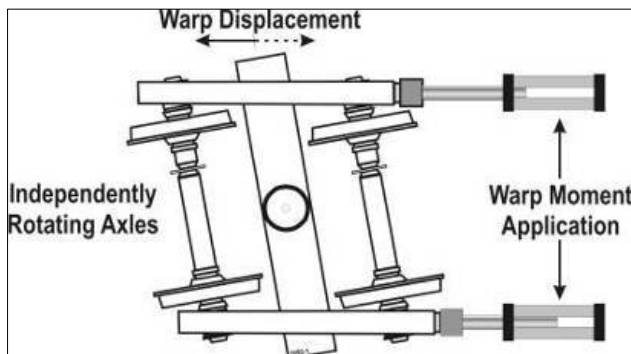


Figure 2: Warp Test Setup

**Warp and Vertical Force Inputs**

Warp tests were conducted in the presence of static vertical load, and with additional dynamic vertical forces applied. Preliminary tests 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 8,000-pound wheel loads. This is the unloaded flatcar condition. Actual empty car wheel loads 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 loads were simulated at 35,500 pounds (284,000 pounds for 4 axles).

Truck warp stiffness for the M-976-type design tested here 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. The 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.

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

**Empty Car Testing**

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

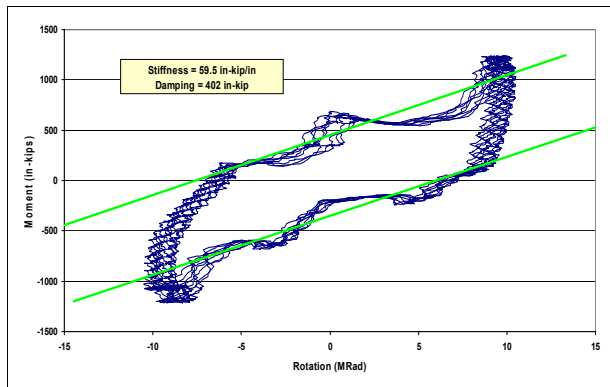
Table 1 summarizes the empty car results from this test. The general result is that the moderately worn trucks still have substantial warp resistance. The warp moment needed to reach 10 mrad warp angle is larger than the moment an empty car could normally generate.

The simulated worn-out truck had warp resistance reduced by more than 70 percent from new condition.

**Table 1: Empty Warp Stiffness and Damping**

	M-976-type truck			
	New	0.235" rise	0.375" rise	1" rise
Stiffness*	57.3	55.0	59.5	17.0
Damping**	285.0	349.0	402.0	76.0
Moment @ 10 mrad**	858.0	899.0	997.0	246.0
* in-kips/mrad	** in-kips			

Figure 3 shows the empty car warp response for the M-976-type suspension with 0.375-inch wedge rise. 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 dynamic vertical input oscillations on the variable damped suspensions.



**Figure 3: Empty Car Truck Warp Response M-976-type truck at 0.375-inch Wedge Rise**

## Loaded Car Testing

Loaded car testing is performed to determine warp resistance in cases where spiral negotiation or roll-response compromises damping provided by the truck suspension. Truck warp in loaded condition will increase forces imparted to the track and increase gage spreading.

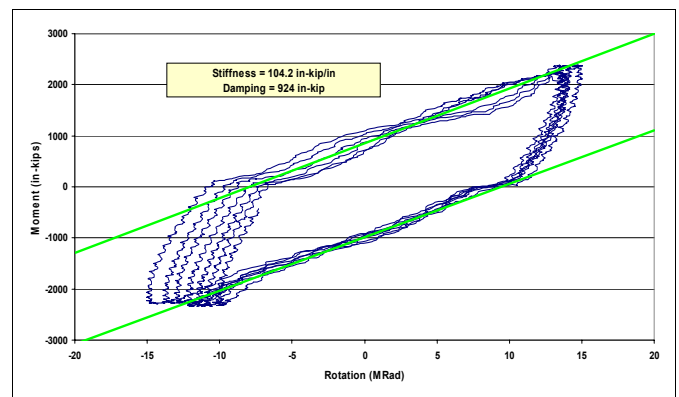
Table 2 summarizes the loaded car results from this test. Significant warp restraint is retained for the moderately worn trucks. The moment required to generate 5 mrad warp angle is still large.

The simulated worn out truck has warp restraint 50 percent reduced compared to the same truck with no wear.

**Table 2: Loaded Warp Stiffness and Damping**

Wedge condition	M-976-type truck			
	New	0.235" rise	0.375" rise	1" rise
Stiffness*	227.0	128.0	104.0	100.0
Damping**	702.0	761.0	924.0	220.0
Moment @ 5 mrad**	1,838.0	1,401.0	1,444.0	720.0
* in-kips/mrad	** in-kips			

Figure 4 shows the warp response for the loaded car test of the M-976-type truck with 0.375-inch wedge rise.



**Figure 4: Loaded Car Truck Warp Response M-976-type truck at 0.375-inch Wedge Rise**

## SUMMARY

The five M-976-type truck designs certified for 286,000-pound GRL interchange service have desirable warp characteristics in new condition. The two moderately worn examples of an M-976-type suspension tested here retained significant warp restraint in railroad service. The test of a simulated worn out truck shows reduced warp restraint with the result similar to that measured for a conventional suspension in new condition.

Sufficient warp restraint will limit gage-spreading derailments, help maintain high-speed stability, and prolong the life of the primary shear pad. The shear pad is needed in these five designs to improve curving performance.

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