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# *Warp Characteristics of Bulk Commodity Suspensions:* American Steel Foundries SSRM Truck

## Part 3 of 3

**by Ken Rownd and Corey Pasta**

**Summary**

The American Steel Foundries' Super Service Ride Master (SSRM) suspension in new condition under a loaded car has more warp resistance than a conventional truck with frame bracing (Frame Brace™), as demonstrated by the 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 SSRM truck has less warp resistance than the Frame Brace™ truck, but substantially more resistance than a conventional truck.

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 SSRM have been combined with elastomeric pedestal pads to reduce lateral curving forces and rolling resistance. Experience by the industry 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.

A conventional truck and three improved truck prototypes were examined in this warp test series. High warp restraint for a truck with the SSRM suspension is a result of the design of the friction shoes and spring group. 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) documents tests with the Frame Brace™ truck and the American Steel Foundries SSRM truck. The conventional truck has low warp restraint. The Frame Brace™ truck provides adequate warp restraint to ensure long-term pedestal pad life. Warp tests for service worn improved suspensions are needed.

This TD ends the reporting by TTCI of the warp resistant tests performed on improved trucks. The first two TDs are TD 03-023 and TD 03-024. The Mechanical Research Committee has guided this research.

TTCI Transportation Technology Center, Inc.

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- Mechanical
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## INTRODUCTION AND CONCLUSIONS

TTCI performed a test series to determine warp resistance characteristics of a conventional truck and three improved trucks. This TD summarizes results for the conventional truck with frame bracing (Frame Brace™) and the American Steel Foundries SSRM truck. These two trucks are variably damped, meaning 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:

Compared to the conventional truck:

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

Adding the pedestal pads to the SSRM truck:

- Increases loaded car warp stiffness by 14 percent and decreases damping by 33 percent.
- Reduces empty car warp stiffness by 36 percent and decreases damping by 13 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 damping is reduced 25 percent.

Comparing SSRM to the Frame Brace™ with primary pads (0.001 radian = milliradian):

- SSRM loaded car warp stiffness is 91 percent more and warp damping is 81 percent more.
- SSRM loaded car warp moment at 5 mrads is 1,838 in-kips while Frame Brace™ moment is 981 in-kips.
- SSRM empty car warp stiffness is 68 percent less and warp damping is 77 percent more.
- SSRM empty car warp moment at 10 mrads warp is 606 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 rely on elastomeric pedestal pads between the side frame and bearing adapter to reduce curving forces and rolling resistance. Figure 1 is the elastomeric pedestal pad in a truck with a SSRM suspension.

**Figure 1: Elastomeric Pedestal Pad in SSRM Suspension**

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.

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 primary pads survive in railroad service? (2) At how many miles 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.

### 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 primary pad) and side frame and from friction between the shoes, 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 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. Force was measured by load cells attached to actuators. 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 tested, 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).

## SSRM Suspension

The SSRM suspension is a 110-ton service design. The suspension was part of a truck design tested with and without elastomeric pedestal pads.

The spring group was seven D5 outer and five D5 inner coils with two 5062 inner and two 5063 inner control springs. This truck is variable damped, having damping proportional to spring-nest travel.

The SSRM suspension has a wider friction shoe than the Frame Brace™ truck. It has a tapered shoe (Figure 1) to provide additional truck squaring and damping.

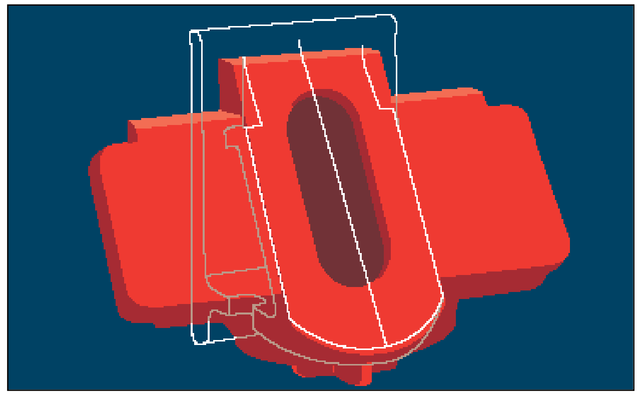

Figure 1: SSRM Shoe

## Conventional Truck with Frame Brace™

A conventional truck from Standard Car Truck Company was equipped with frame bracing to increase warp stiffness. The 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 the empty car results from this test. The general result is that the Frame Brace™ and SSRM suspension 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.

The SSRM 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 are included and dynamic vertical loads are included in the test.

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

| | SSRM | | Frame Brace™ | |
|---|---|---|---|---|
| | No Pads | Pads | No Pads | Pads |
| **Tests with 2.0 Hz vertical input** | | | | |
| Stiffness* | 59.3 | 37.8 | 85.0 | 117.0 |
| Damping** | 262.0 | 228.2 | 172.0 | 129.0 |
| Moment @ 10 mrad** | 855.0 | 606.0 | 1,020.0 | 1,300.0 |
| **Tests with no vertical input** | | | | |
| Stiffness* | 124.0 | 151.0 | 77.5 | 108.0 |
| Damping** | 346.0 | 281.0 | 209.0 | 183.0 |
| Moment @ 10 mrad** | 1,590.0 | 1,790.0 | 984.0 | 1,250.0 |
| * in-kips/mrad | | ** in-kips | | |

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Figure 3 compares empty car warp response for the truck with SSRM suspension and the 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.

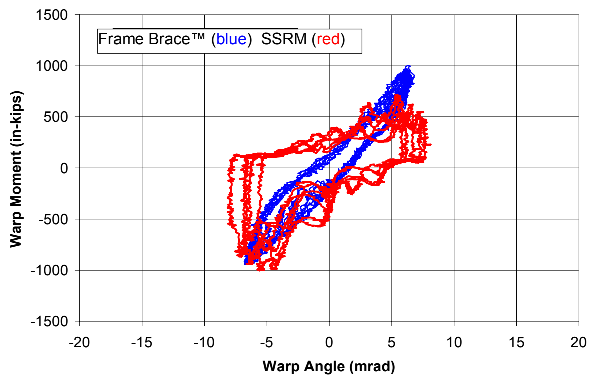


**Figure 3: Empty Car Truck Warp Response with Dynamic Vertical Loads Applied**

## Loaded Car Testing

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

Table 2 summarizes the loaded car results from this test. The general result is that the truck with the SSRM suspension 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: Loaded Warp Stiffness and Damping**

| | SSRM | | Frame Brace™ | |
|---|---|---|---|---|
| | No Pads | Pads | No Pads | Pads |
| **Tests with 0.5 Hz vertical input** | | | | |
| Stiffness* | 199.0 | 227.0 | 111.0 | 119.0 |
| Damping** | 1,040.0 | 702.0 | 479.0 | 387.0 |
| Moment @ 5 mrad** | 2,034.0 | 1,838.0 | 1,030.0 | 981.0 |
| **Tests with no vertical input** | | | | |
| Stiffness* | 184.0 | 243.0 | 113.0 | 124.0 |
| Damping** | 975.0 | 727.0 | 469.0 | 327.0 |
| Moment @ 5 mrad** | 1,893.0 | 1,942.0 | 1,030.0 | 950.0 |
| * inch-kips/mrad | | | **inch-kips | |

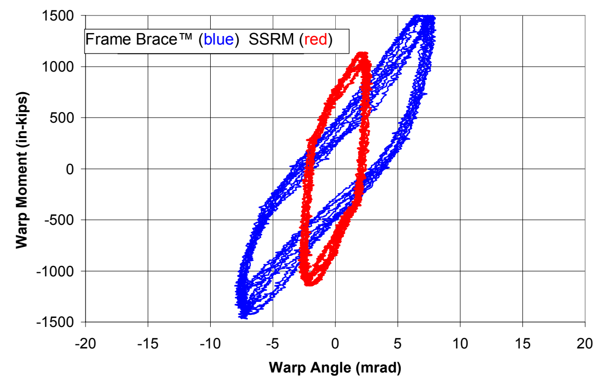


**Figure 4: Loaded Car Truck Warp Response with Dynamic Vertical Loads Applied**

## SUMMARY

The SSRM 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 and TD 03-024 for Parts 1 and 2 of this warp test series.