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Characteristics of Long Service, Warp Stiffened Trucks

by John Tunna and Russell Walker

Summary

Laboratory test results from four warp-stiffened trucks with approximately 500,000 miles of service life show that their warp stiffness and damping have reduced since they were new.

However, the warp stiffness and damping of all four worn trucks were greater than that for a typical, un-warp stiffened 3-piece truck when new. It is important that trucks have sufficient warp stiffness throughout their operational life to:

- Prevent high-speed instability
- Reduce angles of attack while curving
- Avoid high wheel and rail-wear rates

Transportation Technology Center, Inc. conducted laboratory tests to determine the warp characteristics of four trucks that had completed approximately 500,000 miles in coal service. The trucks were a S-2-C design equipped with constant-contact side bearings. They had split wedges with variable damping.

The only notable observation from inspecting the trucks was that they all had cracked center-plate liners. The center-plate liners were removed for the tests, so they would not affect the measured warp characteristics. Average wedge rises were found to be 0.5 inch, which is not unexpected.

The standard warp characterization test was performed on the trucks. In this test, static and dynamic vertical forces are applied to simulate carbody movement, while equal and opposite longitudinal forces are applied to the side frames. The rotation of the bolster is measured with displacement transducers. The test produces a graph of warp moment plotted against warp displacement. From this graph, the truck's warp damping and stiffness can be calculated.

Some variation was found in the warp characteristics of the four trucks, but no more than would be expected given such a small sample size. Also, the warp damping and stiffness were higher when the trucks were under load compared to the empty condition.

The reduced warp stiffness of the worn trucks suggests that they may be prone to high-speed instability if installed under a lightweight carbody.

However, under the coal car, when equipped with constant-contact side-bearings, they still have sufficient warp stiffness to prevent high-speed instability in service.

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INTRODUCTION

The standard laboratory test has been used to characterize the warp stiffness and damping of several 3-piece truck designs. Characteristics have been determined for a range of truck types including those stiffened with split wedges, wide wedges, and Frame Brace™ .[1,2,3] Warp stiffening is necessary to prevent rotation between the bolster and side frames of 3-piece trucks.

These earlier tests were performed on trucks in new condition. From the previous tests, it was recommended that trucks in a worn condition be tested to determine the change in warp characteristics with service. This digest gives the test results from four trucks with approximately 500,000 miles of service. The characteristics are compared with the earlier results for new trucks.[1,2,3]

TEST TRUCKS

The four trucks that were tested were all S-2-C designs with standard-travel, constant-contact side bearings. They had been under two coal cars that had completed 543,000 and 474,000 miles of service. The trucks were warp-stiffened with split wedges (see Figure 1) since new.

Figure 1. Split Wedges on Test Trucks

The spring nest configuration for all trucks was seven D5 outer coils and six D5 inner coils with double control coils providing variable damping. There were no primary suspension pads at the pedestals.

Both trucks were inspected for defects and measured for wear. The only noteworthy observation was that all bolster center-plate liners were cracked (see Figure 2). This would have affected the trucks' rotational resistance but not their warp characteristics.

The gib measurements and side-bearing heights were all within acceptable limits.

The warp displacement of the trucks at rest under an empty car on straight track varied between 0.9 and 2.9 milliradians (mrad), and the inter-axle yaw displacements varied between 0.6 and 1.7 mrad.

Table 1 lists the wedge height for each spring nest. These measurements were also made with the car empty.

Figure 2. Example of Cracked Center-Plate Liner

Table 1. Measured Wedge Heights

Car	Spring Nest	Wedge Height (inch)
UP35668	AR	0.18
	AL	0.59
	BR	0.21
	BL	0.38
UP35683	AR	0.00
	AL	-0.09
	BR	0.51
	BL	0.54

The zero and small negative wedge heights for the "A" truck on car UP35683 were the result of new side frame wear plates being fitted to the truck in January 2000. It was noted that the clearance between side frame columns was tight on this truck. That may have caused the wedges to sit lower in the bolster pockets than normal. Assuming that the wedge heights for the other trucks were zero when new, the values in Table 1 give the wedge rises after approximately 500,000 service miles.

Assuming that the average unit coal car travels 62,000 miles each year, service life for these trucks would have been about 8 years, during which they would have been into workshops a few times for maintenance. The maintenance, for example, may have included wheel re-profiling, but apart from the repair noted above, did not include reconditioning of the major suspension components, such as springs and wedges.

WARP CHARACTERIZATION TEST

The trucks were tested in the laboratory by applying an equal and opposite longitudinal forces to the side frames. These loads were cycled at 0.2 Hz. The truck was placed under a flatcar equipped with a low friction bearing at the center-pivot. Axles equipped with independently rotating wheels were installed in the trucks to eliminate the effect of friction between the wheels and rails. The constant-contact side bearings were also removed for the tests. Thus, the warp stiffness and damping measured was only that provided by the spring nests, friction wedges, and pedestals.

Static vertical forces were applied to simulate both empty and loaded conditions. A dynamic vertical force was applied at 2 Hz to give a displacement of ±0.2 inch. This dynamic force simulates the carbody bouncing on the spring nest and overcomes some of the friction between the wedges and side frame columns.

Warp rotation was measured with displacement transducers fixed to both ends of the bolster. The tests were performed by controlling the warp force. The maximum force applied to each side frame was 15 kip for the empty car test and 25 kip for the loaded car test.

TEST RESULTS

A typical test result is shown in Figure 3. This hysteresis loop is a result of the warp damping and stiffness in the truck. Between -20 and 20 mrad, the force/displacement characteristic is reasonably linear. In this range, the friction wedges are sliding on the bolster and side frame, and the stiffness is provided by the vertical displacement of the control coils and the torsional rotation of the spring nest.

As the displacement increases, the force/displacement relationship becomes non-linear. This is due to various clearances closing up providing stiffer load paths leading to higher warp moment.

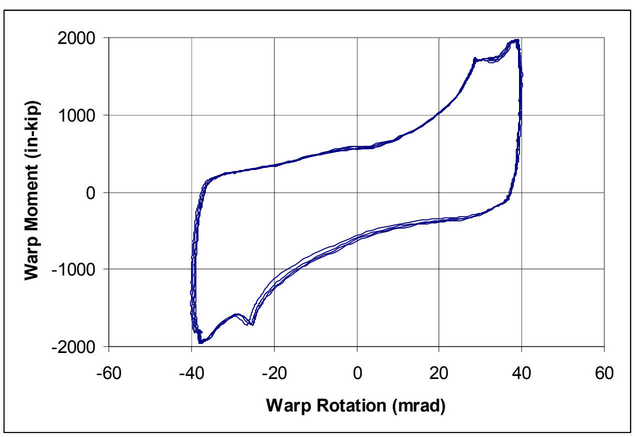

Figure 3. Warp Characteristic for UP35668A Loaded Car Test

Thus, the slope of the hysteresis loop as it passes through zero displacement is a measure of the warp stiffness, and the applied moment at zero displacement is a measure of the warp damping.

When the force is released at the maximum displacement (40 mrad in this example) there is no initial warp displacement due to the friction wedges locking in the bolster pockets. When the applied warp moment reverses sufficiently, the wedges break lose and the linear stiffness from the control coils is once again observed.

The warp stiffness and damping test results for all four trucks are shown in Table 2 for the empty car condition and Table 3 for the loaded car condition.

Table 2. Empty Car Warp Test Results

Truck	Warp Stiffness (in-kip/mrad)	Warp Damping (in-kip)	Moment @ 10-mrad Warp
UP35668 A	9.6	231	327
UP35668 B	11.4	111	225
UP35683 A	7.6	140	216
UP35683 B	18.8	197	385

Table 3. Loaded Car Warp Test Results

Truck	Warp Stiffness (in-kip/mrad)	Warp Damping (in-kip)	Moment @ 5-mrad Warp
UP35668 A	16.3	624	706
UP35668 B	69.2	767	1113
UP35683 A	35.5	561	739
UP35683 B	52.0	573	833

These results show that warp stiffness and damping are higher when the car is loaded. This is expected because in the loaded condition there is more force in the control coils. Thus, when the wedges are not sliding there is a greater normal force, and hence friction, to overcome. The warp stiffness is higher in the loaded condition because of the increased torsional stiffness of the spring nest when it is compressed.

The warp moment required to achieve a specified warp displacement is a useful way of combing the stiffness and damping characteristics. The average 10-mrad warp moment in the empty car condition is 288 in-kip with a standard deviation of 82 in-kip. In the loaded car condition, the average 5-mrad warp moment is 848 in-kip with a standard deviation of 185 in-kip. The variation in measured warp characteristics between the trucks was not statistically significant.

These results are compared with previous results from standard and warp stiffened trucks in Figures 4 and 5.[12,3] Both figures show the average and range of results for S-2-C truck designs.

Although the S-2-C trucks are not directly comparable to the previous trucks that were tested, it is expected they would have had similar warp characteristics to the S-2-E and Super Service Ride Master (SSRM) trucks when new.

The figures also show that the combined warp stiffness and damping of the worn S-2-C trucks with split wedges is less than that for the other warp stiffened trucks when the other trucks were new. However, the combined stiffness and damping for the worn S-2-C trucks is greater than that for the conventional, un-warp stiffened S-2-HD truck when new. Even the softest worn S-2-C truck with split wedges was stiffer than the new S-2-HD truck.

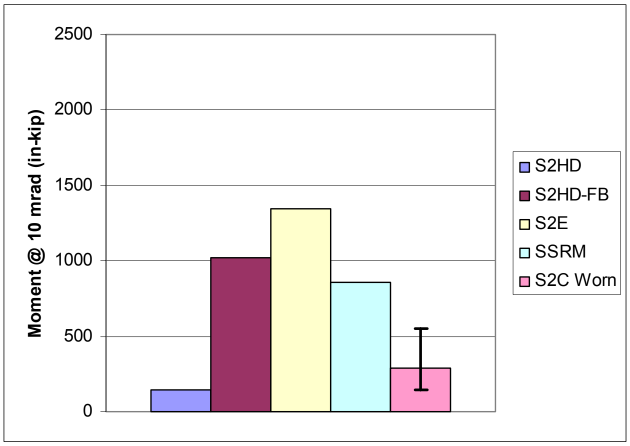

Figure 4. Comparison of Empty Car Results

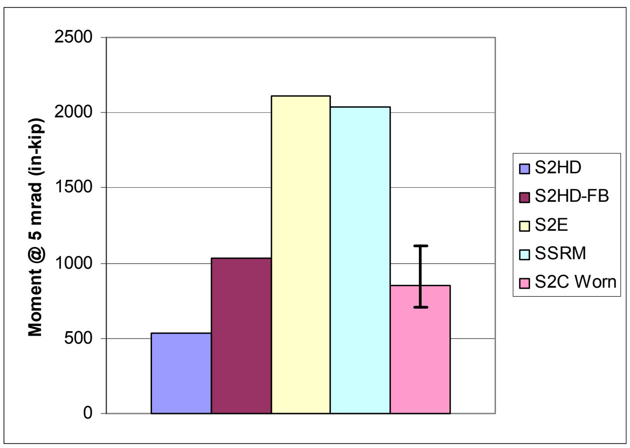

Figure 5. Comparison of Loaded Car Results

Figure 6 shows a performance envelope for a theoretical lightweight car. The typical range of warp stiffness for warp-stiffened trucks in new condition is 60 to 100 in-kip/mrad. Thus, the S-2-C trucks equipped with split wedges should have been in region C of the performance envelope when new.

The test results reported here show that the warp stiffness for the worn S-2-C trucks with warp stiffening is less than 20 in-kip/mrad. If these trucks were under a lightweight carbody with low rotational resistance, it is possible that they would have crossed the stability performance boundary and would be prone to high-speed instability in service when the cars were empty.

However, when used with the 67,000-pound coal car, equipped with constant-contact side bearings, the worn trucks are expected to have acceptable high-speed stability performance in service. Even with the loss of warp stiffness resulting from 500,000 miles of service operation, there is sufficient remaining warp stiffness to prevent the trucks from being unstable when operating at high speeds.

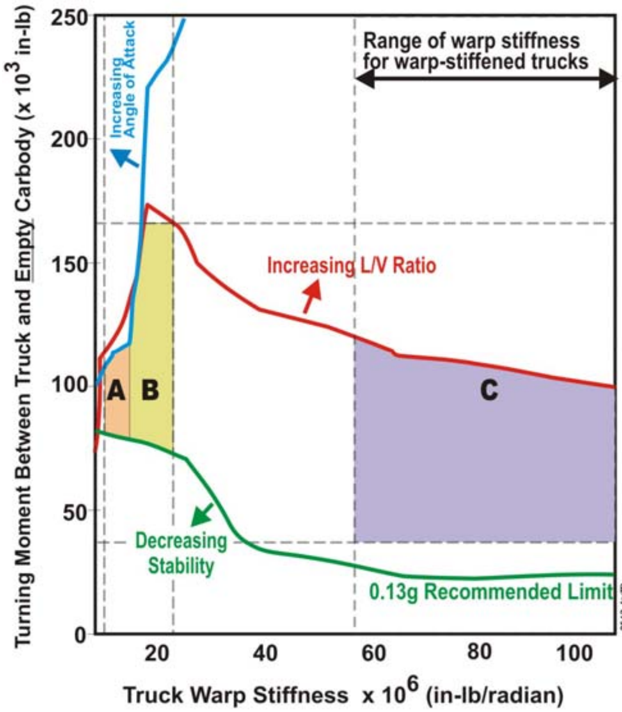

Figure 6. Performance Envelope for a Lightweight Car

CONCLUSIONS

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