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Top Chord Buckling of an Instrumented Coal Car

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Summary

In March 2008, Transportation Technology Center, Inc. conducted an on-track test using an instrumented aluminum coal car on the Precision Test Track (PTT) at the Transportation Technology Center, Pueblo, Colorado.

This test was performed originally as part of a research effort to develop an instrumented freight car for identifying and monitoring track geometry conditions that are adverse to vehicle performance.¹ As an unplanned outcome, the top chords of this car buckled when the test car was running over a perturbation zone that generated large vertical carbody bouncing responses at 60 mph. This *Technology Digest* summarizes the test results and findings related to the top cord buckling event.

Based on these test results, the allowable train operating speed was determined to be 50 mph for track that has geometry deviations similar to the pitch-and-bounce perturbations on the PTT. This would correspond to the following critical vehicle response levels: 20,000 psi for top chord compressive stress, 1 inch for vertical suspension displacement, 0.75 g (acceleration) for vertical carbody acceleration, and 250,000 pounds for bolster load. The pitch-and-bounce perturbation zone consists of 10 repeated 0.75-inch in-phase variations of cross-level spaced at 39-foot intervals.

The car was also operated over a twist-and-roll perturbation zone, which consists of 10 repeated 0.75-inch out-of-phase cross level variations at 39-foot intervals. The testing speeds on both zones were 20, 30, 40, 50 and 60 mph. Vehicle responses recorded over the twist-and-roll perturbations at those speeds were significantly below the critical levels given above.

The work presented here was funded under the Association of American Railroads' Strategic Research Initiatives Program.



INTRODUCTION

Top chords of some aluminum coal hopper cars that are structural members of the carbody can buckle when cars are fully loaded and subjected to large dynamic vertical forces due to vehicle/track interaction. In general, top chords are subjected to compressive stress, when the carbody bends upward as a result of vertical wheel loads generated under both ends of the carbody. Higher vertical wheel loads cause higher carbody bending, which in turn generates higher compressive stress on the top chords. When compressive stress exceeds the buckling strength of a top chord, buckling can occur.

Top chord buckling has been a problem for railroads transporting coal, especially in the western part of the United States. The western railroads and the AAR have made progress on identifying the causes of top cord buckling and have developed remedies to address the problem.² However, no actual vehicle response data was ever recorded during and immediately before an actual top cord buckling incident.

In March 2008, TTCI conducted an on-track test using an instrumented coal car on the PTT located at TTC. The objective of the test was to examine vehicle responses to known track geometry deviations using a variety of on-board transducers. As an unplanned outcome, the top chords of this car buckled when the test car was running over a perturbation zone that generated large vertical carbody bouncing responses at 60 mph. This Technology Digest summarizes the test results and findings related to the top cord buckling event.

TEST TRACK AND TEST CAR

The test was conducted on the PTT. This track includes three different engineered perturbation zones: twist and roll, pitch and bounce, and yaw and sway. The first two zones are located in a section of tangent track, each consisting of 10 repeated vertical perturbations at 39-foot intervals. The deviations are 0.75-inch peak to peak. However, the deviations are out-of-phase between the two rails in the twist and roll zone, whereas they are in-phase in the pitch and bounce zone. Figure 1 illustrates the twist and roll and pitch and bounce perturbation zones. The yaw and sway zone on the PTT contains repeated lateral deviations with wide gage in a curve, but was not used in this test, because the buckling event occurred prior to the planned runs on the yaw and sway zone.

The test car was an aluminum coal hopper built in 1994 (see Figure 2). Truck center spacing was 40 feet, and truck type was ride-control. The car was loaded with sand and gravel to a gross weight close to 286,000 pounds. This car was fully instrumented with a number of transducers to capture various vehicle responses due to track geometry.¹

The test was conducted at five different speeds of 20, 30, 40, 50 and 60 mph. At each speed, the test train ran through the twist and roll and pitch and bounce zones without stopping.

This test was done as part of a research effort to develop an instrumented freight car for identifying and monitoring track geometry conditions that are adverse to vehicle performance.

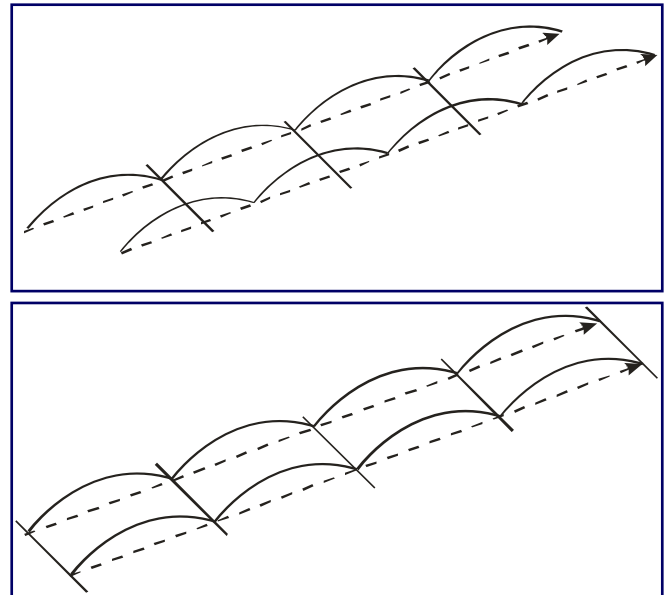


Figure 1. Twist and Roll and Pitch and Bounce Test Zones



Figure 2. Instrumented Coal Car

TOP CHORD BUCKLING

The test was conducted in the sequence of 20, 30, 40, 50, and 60 mph over the twist and roll and pitch and bounce perturbation zones. At the final speed of 60 mph, however, the test car experienced large bouncing responses in the pitch and bounce test zone. The top chords of the test car buckled, spring nests bottomed out, and the wheels bounced up to touch the carbody at 60 mph. The test was then terminated, because the test car was determined to be out of normal operational condition. Figure 3 shows the top chords buckled on both sides of the carbody.



Figure 3. Buckled Top Chords

TEST RESULTS AND DISCUSSION

Because the test car was fully instrumented, vehicle responses, including top chord compression stress, vertical and lateral carbody accelerations, vertical side frame acceleration, vertical and lateral suspension displacements, and bolster load, were all recorded during and immediately before the unplanned top chord buckling event. The following provides a discussion of test results obtained.

Pitch and Bounce Zone

Figure 4 shows the bolster load (time history) recorded at 50 and 60 mph, respectively, over the pitch and bounce zone. As illustrated, at each speed, the bolster load measurement captured vehicle responses due to the 10 track perturbations. At 50 mph, the maximum bolster load recorded was 220,000 pounds, as compared to the static bolster load of 125,000 pounds. At 60 mph, the maximum load recorded was 420,000 pounds, approximately three times the static load. The minimum bolster load recorded at 60 mph was essential zero, indicating that the carbody was bouncing off of the center plate.

Figure 5 shows the top chord compressive stress recorded at 50 and 60 mph, respectively (on both sides of the carbody). Similar to the bolster loads, there was a large increase of compressive stress measured between the 50 and 60 mph tests. At 50 mph, the maximum compressive stress measured was 20,000 psi, whereas at 60 mph the maximum stress measured was 60,000 psi.

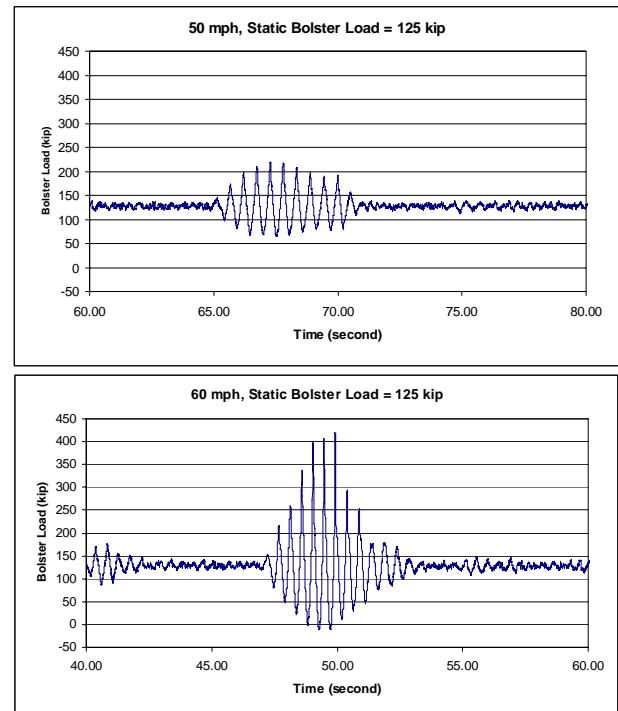


Figure 4. Bolster Load at 50 and 60 mph

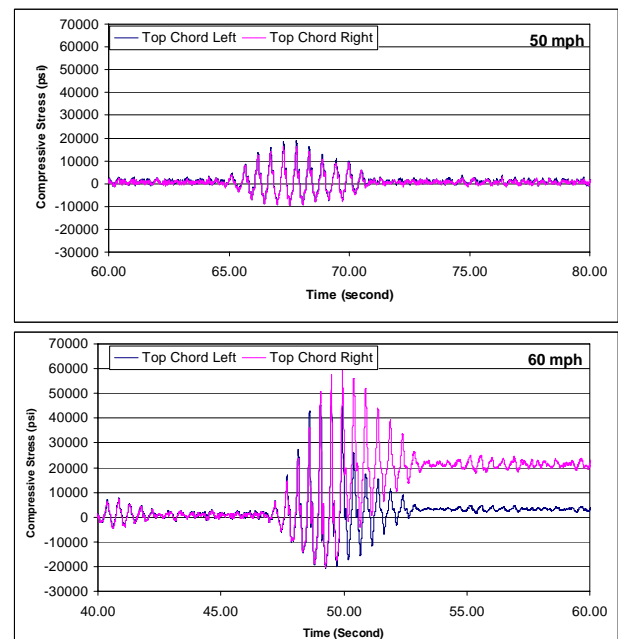


Figure 5. Top Chord Compressive Stress at 50 and 60 mph

In addition, the data included in Figure 5 indicated plastic deformation of the top chords (see Figure 3) due to buckling at 60 mph, as residual stress was left on either side (more on the right side) after the test car went through the pitch and bounce test zone.

Figure 6 shows a summary of maximum responses at five speeds from several measurements obtained on the test car (top chord stress, spring nest displacement, and vertical carbody acceleration). On the top plot, the estimated buckling strength of top chord is also included.² As shown, at 60 mph, the compressive stress generated at either side of the carbody was significantly greater than the estimated buckling strength.

The test results show (Figure 6) that the allowable speed should be 50 mph to prevent top chord buckling due to the pitch and bounce track perturbations, which would correspond to the following critical vehicle response levels: 20,000 psi for top chord stress, 1 inch for vertical suspension displacement, and 0.75 g for vertical carbody acceleration.

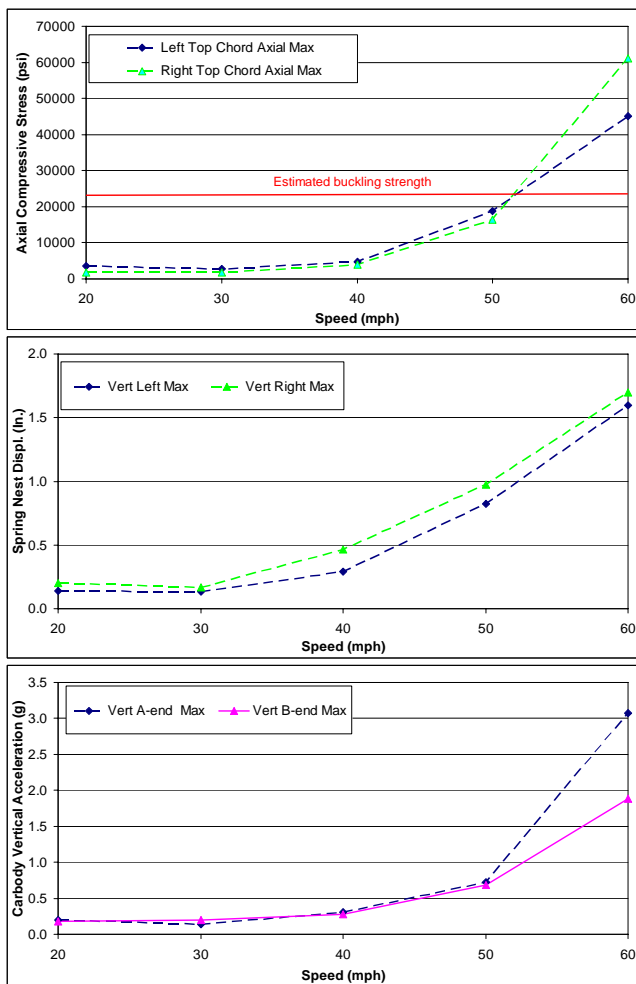


Figure 6. Vehicle Responses Recorded from 20 mph to 60 mph over the Pitch and Bounce Test Zone

Twist and Roll Zone

Figure 7 shows a summary of maximum vehicle responses measured from 20 mph to 60 mph over the twist and roll test zone. Compared to the pitch and bounce test zone (Figure 6), the twist and roll track perturbation caused much lower vehicle responses at higher speeds in terms of the parameters measured.

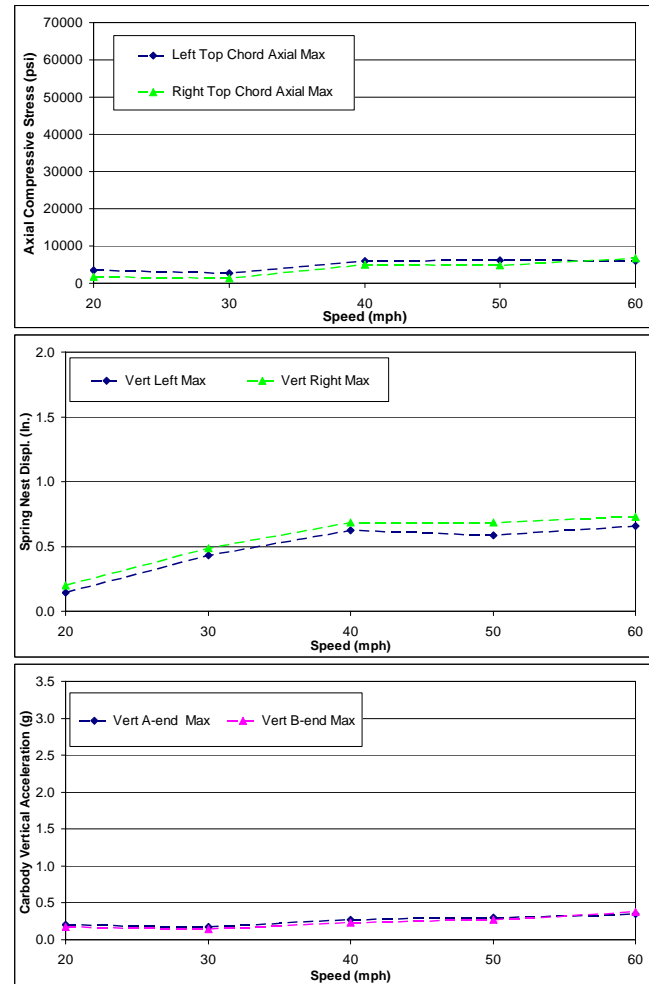


Figure 7. Vehicle Responses Recorded from 20 mph to 60 mph over the Twist and Roll Test Zone

REFERENCES

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2. Koch, Kevin. October 2005. "Measurement of Coal Hopper Top Chord Strain Environment, 286,000-pound Gross Rail Load Service," Research Summary RS-05-006, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.

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