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Effects of High In-train Forces on Track Stability

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Key Findings:

- Overall, track displacement was minimal. The maximum tie displacement during a test with loaded cars ranged from -0.08 to +0.12 in. The maximum tie displacement during a test with empty cars ranged from -0.11 to +0.085 in.
- The highest tie peak-to-peak displacement amplitude of 0.15 in. was recorded on tie set No. 3 (tangent) during the test with loaded cars and 0.158 in. during the test with empty cars.
- The influence of increased buff force from 50,000 to 300,000 lbs. on lateral track displacement is minimal.
- After each test of certain buff force, the displacement of the ties did not return to zero, leaving a residual displacement of about 0.02 in. Static test performed under cyclic loading confirmed a residual displacement of 0.02 and 0.03 in on tested ties.
- The fastening system on the WRM loop is not transferring the lateral force to ties as anticipated; thus, the high lateral force may cause the rail-roll and lateral translation prior to the tie movement.

[Transportation Technology Center, Inc. \(TTCI\)](#) designed a program to conduct simulations and tests to record dynamic load data. The goal of this program is to estimate the effects of in-train forces and explore options for minimizing detrimental effects of these forces on track. The primary focus of this research is to evaluate track lateral stability under high lateral wheel/rail forces.

In the summer 2018, TTCI performed dynamic and static tests to determine the effects of high buff force on track. The dynamic tests were performed using a test train comprising four locomotives (two lead and two trail), 15 loaded hoppers, and three test cars. The first test was performed with three fully loaded test cars, and the next test was run with three empty cars. Each train was tested through a range of buff loads. Tests were conducted at low speed (up to 7 mph) and buff forces from 50,000 to 300,000 pounds. The displacements of the ties and rails were monitored using linear variable displacement transducers (LVDTs) located in four sections along the test zone: one set on a 4.5-degree curve, one set on a spiral, and two sets on a tangent track of the wheel rail mechanism (WRM) loop.

This research is being conducted as part of the Association of American Railroads' (AAR) Strategic Research Initiative (SRI) on Vehicle-Track-Interaction (VTI) program.

TEST OVERVIEW

The testing program was designed to determine the relationship between lateral and vertical (L/V) forces due to high buff forces and evaluate the response of track under these forces. The railcar types used in the testing were 53-foot gondolas. The first set of runs was performed with three fully loaded cars, 262,000 lbs. gross rail load (GRL). A second set of test runs was performed with three empty cars.

Each set of tested railcars was placed behind 15 loaded gondolas from the Facility for Accelerated Service Testing (FAST) (315,000 lbs. GRL). The two locomotives pushed the train at a constant speed between 5-7 mph. Two additional helper locomotives, positioned at the leading end of the consist, were used to provide additional retarding force via the independent air brake. The intent was to provide steady state compression load for each test.

The test was repeated on a 4-degree curve and a tangent track and stopped before the 5-degree curve, at MP 99+24 (Figure 1). The location of the wayside measurements is marked on Figure 1.

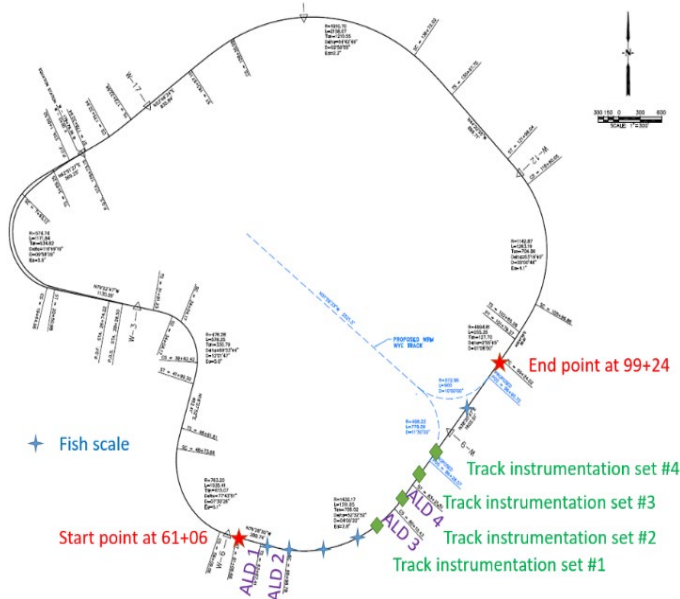


Figure 1. Test location

Each set of vehicles was tested through a range of buff-loads. The high-adhesion locomotives pushed against air-brake application on a number of loaded hoppers to generate steady buff loads. Testing was conducted up to 300,000 pounds buff force.

After each run, the test train backed up to the desired location. The train was stretched on the tangent track to align the couplers before next run to minimize lateral and vertical offset in the load path prior to the application of buff load. Table 1 presents average buff force for each run of test.

During testing the buff force was monitored closely in real time. The onboard data was collected through the entire test zone. The wayside data collection was only in the marked locations.

ON-BOARD MEASUREMENTS

Each tested vehicle was instrumented with string potentiometer to measure the lateral and vertical angles of the couplers relative to their carbodies. Coupler displacement instrumentation was placed on each coupler between Car No. 1 – Car No. 2 and Car No. 2 – Car No. 3. String pots were installed between carbody and coupler to be able to resolve vertical, lateral, and longitudinal coupler displacements. The coupler angularity was monitored with reference to the increasing buff force.

Table 1. Statistical parameters for riveted members

Test	Buff force during test with loaded cars	Buff force during test with empty cars
Run 1	75	50
Run 2	100	100
Run 3	140	125
Run 4	170	135
Run 5	210	170
Run 6	250	200
Run 7	215	250
Run 8	300	285

An instrumented coupler was mounted between the first test car and locomotive to measure buff force. Instrumented wheelsets were used to measure vertical and lateral forces (Figure 2).

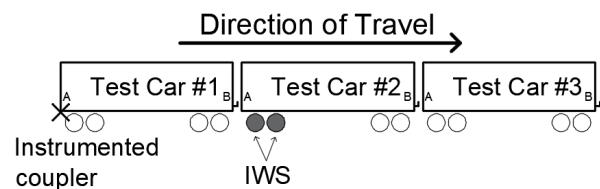


Figure 2. IWS and Instrumented-coupler location

Preliminary modeling suggested that the trailing truck of the center car (car No. 2) was likely to generate the largest lateral forces as a function of increasing buff load. The test results from on-board instrumentation will be reported in another *Technology Digest*.

WAYSIDE MEASUREMENTS

The displacement of the ties and rails was monitored using LVDTs located in four sections along the test zone: one set on a 4.5-degree curve, one set on a spiral, and two sets on a tangent track of the WRM loop (Figure 1). Each set includes one displacement transducer to measure tie lateral displacement and four LVDTs attached to a tie to measure rail-head and rail-base movement (as seen on Figure 3). The LVDTs were located on the field sides of a tie as shown in Figure 3.

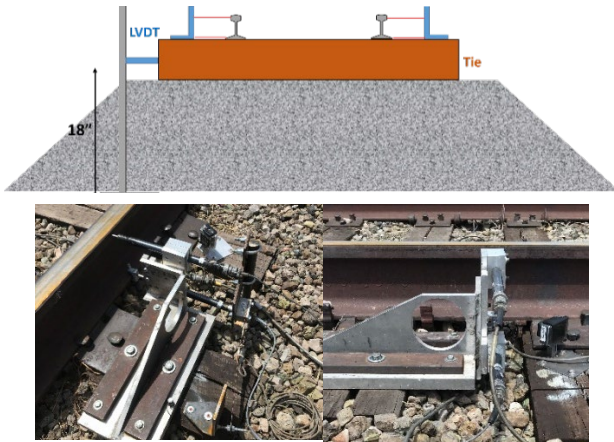


Figure 3. Deflection measurement instrumentation to measure rail and tie lateral displacement

During dynamic testing, higher displacement was recorded on the inside rail and both rails were pushed to the field side which means the gage widened. Figure 4 presents displacement measured during the test with loaded cars under high buff force of 300 kips. The negative displacement corresponds to inside curve movement, and the positive displacement is to outside curve. This example shows that the gage widening was up to 0.2 in. and the tie displacement was only one-third of the displacement of the inside head rail.

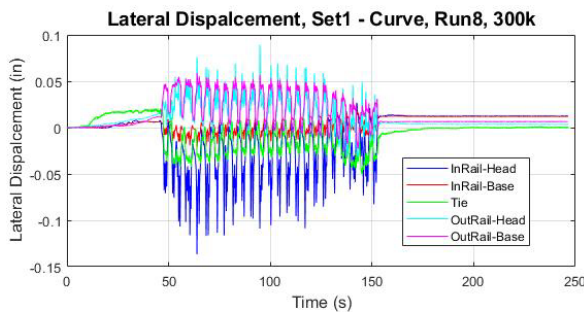


Figure 4. Lateral Displacement of rails and tie (Set 1) under buff force of 300 kips – Test with loaded cars, Run 8

The maximum tie displacement during a test with loaded cars ranged from -0.08 to +0.12 in. The maximum tie displacement during a test with empty cars ranged from -0.11 to +0.085 in. The highest peak-to-peak amplitude (between the variable's extreme values) of 0.15 in. was recorded on tie set No. 3 (tangent) during the test with loaded cars. The amplitude on the same tie was 0.158 in. during the test with empty cars.

It was observed during the dynamic test that the displacement of a rail head was higher than the tie displacement in the curve (Set 1) and the spiral (Set 2). However, the tie displacement was higher than the rail head movement at the two tangent locations (Sets 3 and 4). Figures 5 and 6 present comparison of maximum

lateral displacements recorded on the ties and rails for all consecutive runs. The influence of increased buff force on lateral displacement is minimal. Only small increase of inside rail movement is visible for increased buff force from Run 3 to Run 8. The observation is similar for rail and tie displacements during the tests with loaded cars.

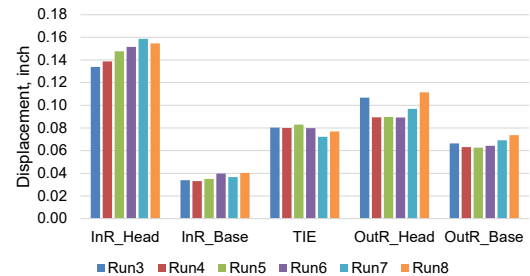


Figure 5. Amplitude of lateral displacement of tie and rails at Set 1 (curve) during the test with empty cars

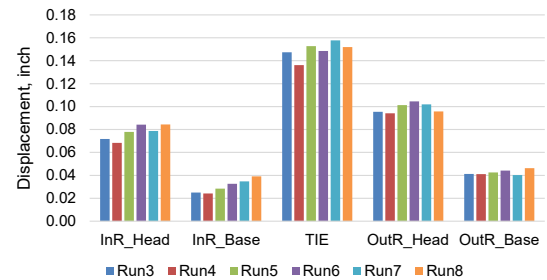


Figure 6. Amplitude of lateral displacement of tie and rails at Set 3 (tangent) during the test with empty cars

Overall, the track displacement was minimal. However, after each test of certain buff force, the displacement of the tie did not return to zero. The examples below present consistent residual displacement of 0.02 in. recorded on the tie located at the 4-degree curve, during the tests with empty cars (Figure 7). In some cases the residual displacement reaches 0.07 inch as presented on Figure 8 (Set 3, Run 5).

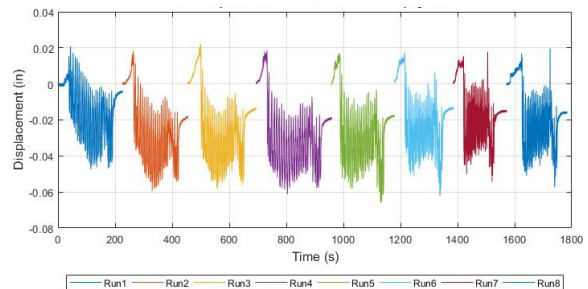


Figure 7. Lateral displacement of tie at Set 1 (curve) during the test with empty cars, all consecutive runs

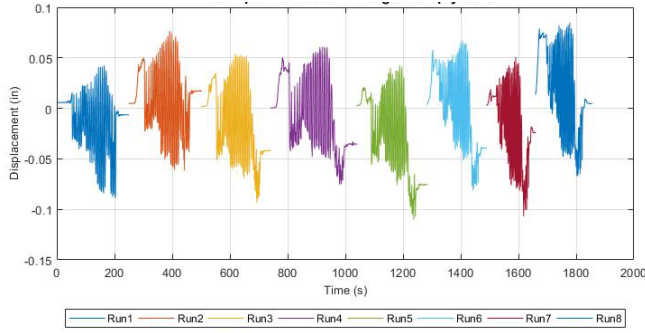


Figure 8. Lateral displacement of tie at Set 3 (tangent) during the test with empty cars, all consecutive runs

TLV TEST RESULTS

To investigate residual displacement of ties further, a track loading vehicle (TLV) test was performed under cyclic loading. Stationary TLV panel shift tests have shown that with the subsequent cycles the residual displacement was measured 0.02 and 0.03 in. During the test vertical wheel load of 10 kips was applied and the lateral force was applied in seven cycles: 10 kips, 15 kips, 20 kips, 25 kips, 30 kips, 35 kips and 37 kips (Figures 9 and 10).

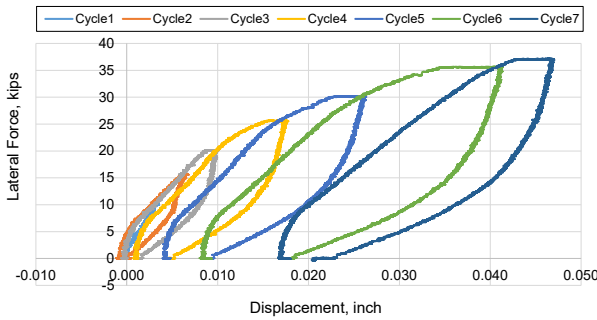


Figure 9. Lateral Tie Displacement under cyclic lateral force and constant vertical wheel force of 10 kips (set 3)

Lateral load-deflection relationships are non-linear but tie deflection was not high enough to cause track stability issue. Previous researchers observed sudden large panel shift at axle L/V ratios near or equal 1.0,¹ however during the test at WRM loop, the highest L/V axle ratio was 1.85 and still the deflection was only up to 0.055 in.

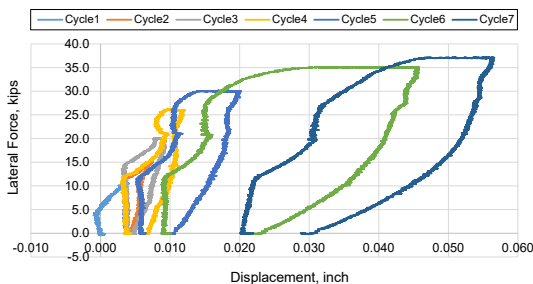


Figure 10. Lateral tie displacement under cyclic lateral force and constant vertical wheel force of 10 kips (set 4)

The TLV measurements revealed that the fastening system (cut spikes) on the WRM loop was not transferring much of the lateral wheel forces to ties. The wheel loads applied were causing more lateral rail movement than lateral tie movement (see plot below).

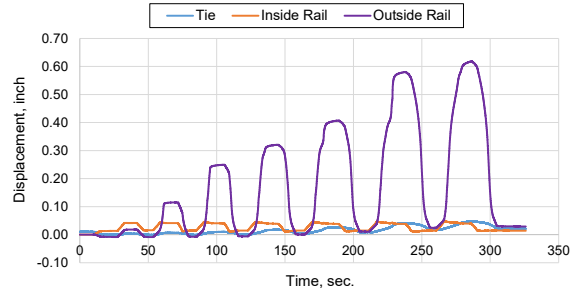


Figure 11. Lateral tie and rail displacement under cyclic lateral force (set 3)

CONCLUSION

Overall, the track displacement during the dynamic tests was minimal and did not produce conditions that could risk a derailment. The highest peak-to-peak amplitude of 0.15 and 0.158 in. was recorded on tie set No. 3 (tangent) during the tests with loaded cars and with empty cars. The influence of increased buff force on lateral tie displacement is minimal. The residual displacement of ties was observed at the level of 0.02 in. Static tests performed under cyclic loading confirmed this tie characteristic. In addition, it was observed that the fastening system on the WRM loop was not transferring much of the lateral wheel forces to ties as expected. With this track characteristic, the high lateral force may cause the rail-roll prior to the lateral tie movement.

References

1. Li D., W. Shust, 1997. "Investigation of Lateral Track Strength and Track Panel Shift using AAR's track loading vehicle." *R-Report-917*, AAR/TTCI, Pueblo, CO.

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