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Evaluating Brake Effectiveness:
Piston Travel vs. Wheel Temperature

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Summary

For a train that is en route between locations more than 1,000 miles apart, brake system effectiveness is currently being evaluated with a visual verification of piston travel. Analyzing wheel temperatures during braking is an alternative method to evaluate the effectiveness of a brake system. Transportation Technology Center, Inc. (TTCI) conducted static brake shoe force tests and wheel temperature tests to illustrate the benefits of wheel temperature analysis.

TTCI measured static brake shoe forces and drag braking wheel temperatures for the following three brake rigging configurations:

- Fully functional condition
- Missing the connection pin between the live lever and the pull rod on the A-end truck
- Missing the connection pin between the live lever and the brake beam on the A-end truck

As expected, removing connection pins from the A-end live lever results in minimal brake shoe forces and much lower drag braking temperatures at the wheels of the A-end truck while the piston travel remains in an acceptable condition.

In a revenue service application, analyzing the wheel temperatures produced by this test car would have identified a problem with the brake effectiveness in the test configurations with the missing connection pins and may have also identified a minor issue with brake cylinder leakage by comparing the average wheel temperature of this car to average wheel temperatures of other cars in the train.

This work was conducted as part of the Association of American Railroads' Strategic Research Initiatives Program on improved brake system performance.

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INTRODUCTION

The visual verification of brake cylinder piston travel has long been the most basic method of assessing brake system health in railcars. The introduction of wayside wheel temperature measurement devices provides an opportunity to assess brake system health using an alternate technique. Wheel temperatures during braking provide a more direct way to evaluate the effectiveness of a brake system compared to a visual verification of piston travel. TTCI conducted static brake shoe force and wheel temperature tests to illustrate the value of assessing brake system condition using wheel temperatures rather than piston travel. This work was conducted as part of the Association of American Railroads' (AAR) Strategic Research Initiatives Program on improved brake system performance.

BACKGROUND

Maintaining dependable braking on railcars is essential for the safe operation and control of trains. Brake systems have been designed to function in a reliable way with minimal required maintenance.

Brake shoes are pressed against the wheels through a system of rods and levers in the brake rigging. The brake cylinder piston provides the input force to the brake rigging. When the brakes are applied, the brake cylinder is pressurized from the fixed volume of the auxiliary reservoir. The brake cylinder piston extends (and will remain extended) when there is sufficient pressure in the cylinder to overcome the retraction spring. This typically requires less than 5 psi.

Short piston travel results in a smaller total volume of the auxiliary reservoir/brake cylinder and a higher brake force. Conversely, long piston travel results in a larger total volume of the auxiliary reservoir/brake cylinder and a lower brake force. Thus, for optimal brake performance, the brake rigging needs to be maintained in a way that produces the desired piston travel measurement. Figure 1 shows a piston travel measurement.

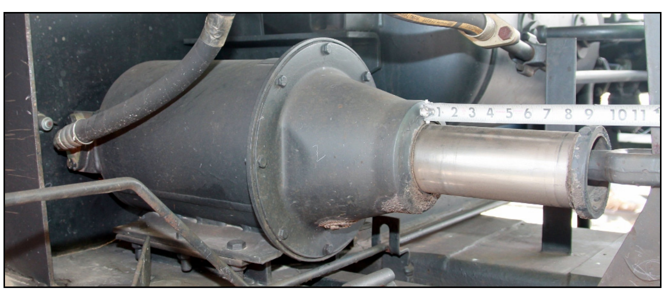

Figure 1. Piston Travel Measurement

The Federal Railroad Administration's (FRA) *Code of Federal Regulations* states that "A car's air brake is not considered effective if it is not capable of producing its nominally designed retarding force or if its piston travel exceeds:

(1) 10½ inches for cars equipped with nominal 12-inch stroke brake cylinders; or
(2) The piston travel limit indicated on the stencil, sticker, or badge plate for that brake cylinder."[1]

The automatic slack adjuster is designed to maintain piston travel in an acceptable range despite the normal fluctuations that the rigging must accommodate over the life of the car including:

- Brake shoe wear
- Wheel wear
- Pin and pin hole wear

Slack adjusters can also maintain piston travel in an acceptable range when there is a problem with the brake rigging. For example, a missing connection pin in the rigging can result in little or no brake shoe force at some locations in the car, yet the piston will extend and the piston travel can be in the acceptable range. Figure 2 shows data from the AAR Car Repair Billing database[2] regarding repairs to brake rigging connection pins due to Why Made Code 3 "Missing." More than 20,000 incidents of missing pins are reported to this database in an average year.

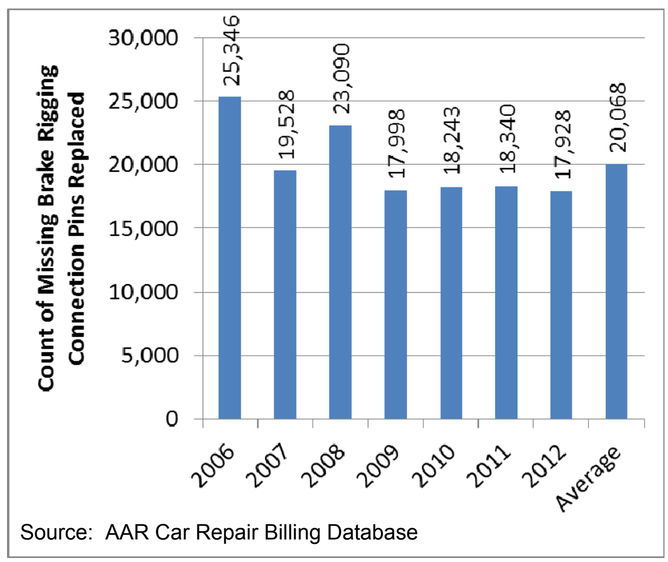

Figure 2. Missing Brake Rigging Pins

The friction between the brake shoe and the wheel produces the retarding force necessary to control train speed on long descents and produces heat at the wheel tread surface that conducts into the wheel rim and plate. Heating of wheels during brake applications has been studied in the past, both in the laboratory and in revenue service.[3,4]

TEST PROCEDURE

TTCI personnel selected a car with typical body mounted brake rigging for this test. The car was brought into the shop and outfitted with commercially available static brake shoe force transducers. A pressure regulator was plumbed directly into the brake cylinder and connected to house air to maintain accurate control of the brake cylinder pressure and eliminate the need to recharge the reservoir before each brake application. Forces were recorded at each brake shoe location after applying 25 psi brake cylinder pressure and 50 psi brake cylinder pressure. These pressures were selected to represent a light brake application common during long grade descents (25 psi, resulting from a 10 psi reduction of train line pressure) and the expected brake cylinder pressure during the Class I Brake Test (50 psi, resulting from a 20 psi reduction of the train line pressure).

After recording the brake shoe forces with the rigging in fully functional condition, the rigging was altered to find conditions in which the brake shoe forces were substantially reduced while the piston travel remained in the acceptable range (6 to 9 inches). Poor lever angularity produced some reduction in brake shoe forces, but removing connection pins produced the most noticeable change. Figure 3 shows a diagram of the brake rigging used in the test.

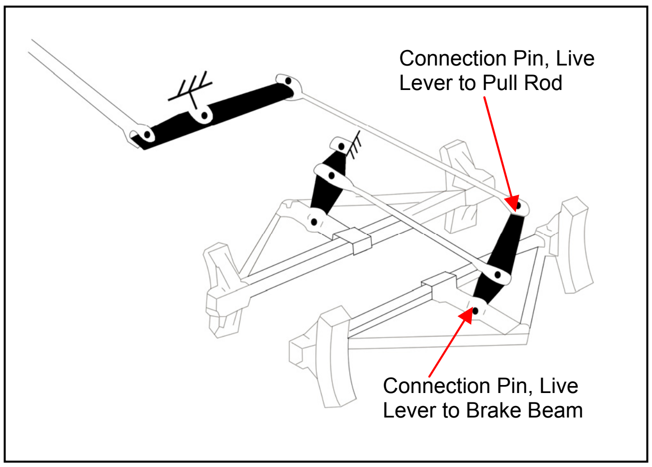

Figure 3. Brake Rigging Diagram

Following the static brake shoe force testing, the pressure regulator was removed, the original plumbing reconnected, and new brake shoes were installed. The car was pulled around the 2.7-mile-long High Tonnage Loop (HTL) at the Transportation Technology Center. A commercially available wayside wheel temperature detector is installed on the HTL and wheel temperatures were recorded each lap. For each test series with a different rigging configuration, the car was pulled at 20 mph for 8 laps of the HTL totaling 21.6 miles in just over an hour. A pressure gauge was connected to the brake cylinder pressure tap immediately before and after the 8 laps to measure starting and ending brake cylinder pressure. The brakes were applied to produce a starting brake cylinder pressure of 25 psi +/- 1 psi.

Before and after each test series, a 20-psi train-line brake application was made and the piston travel was verified to be within the required limits. The wheels were allowed to cool to within 30 degrees of ambient temperature between each test series.

RESULTS

Figure 4 shows the static brake shoe force results for three brake rigging configurations:

- Fully functional condition
- Missing the connection pin between the live lever and the pull rod on the A-end truck
- Missing the connection pin between the live lever and the brake beam on the A-end truck

The average brake shoe forces are highest for the fully functional rigging condition. Removing connection pins from the A-end live lever results in minimal brake shoe forces at the wheels of the A-end truck.

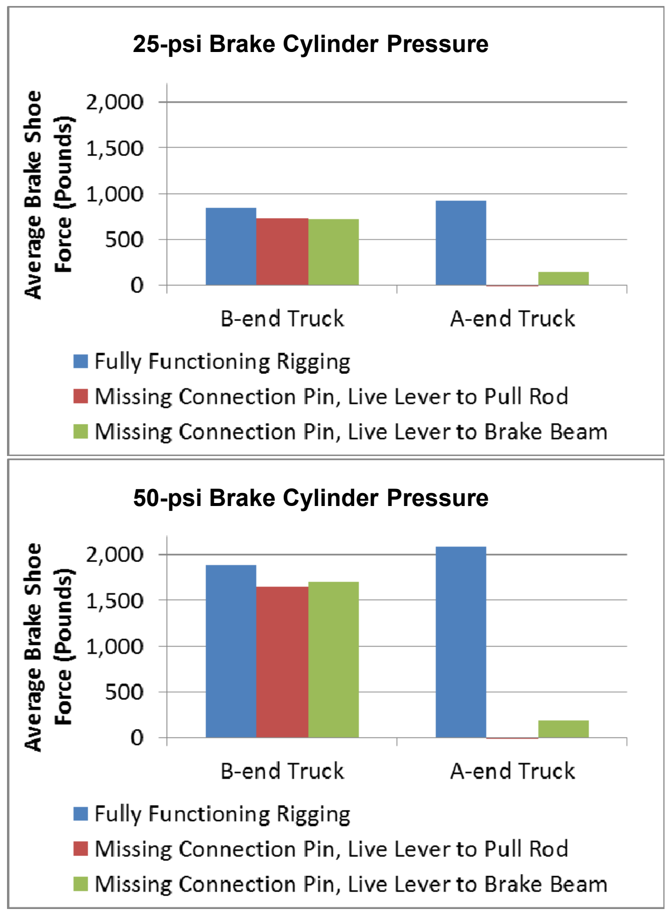

Figure 4. Static Brake Shoe Forces

Figure 5 shows the wheel temperature data for the same configurations. The values shown are degrees Fahrenheit above ambient temperature. As expected, based on the brake shoe force results, the following can be seen from the wheel temperatures:

- The average wheel temperatures for the B-end truck are similar regardless of rigging configuration

- The average wheel temperature for the A-end truck is much warmer for the case of the fully functional rigging compared to the configurations with missing connection pins

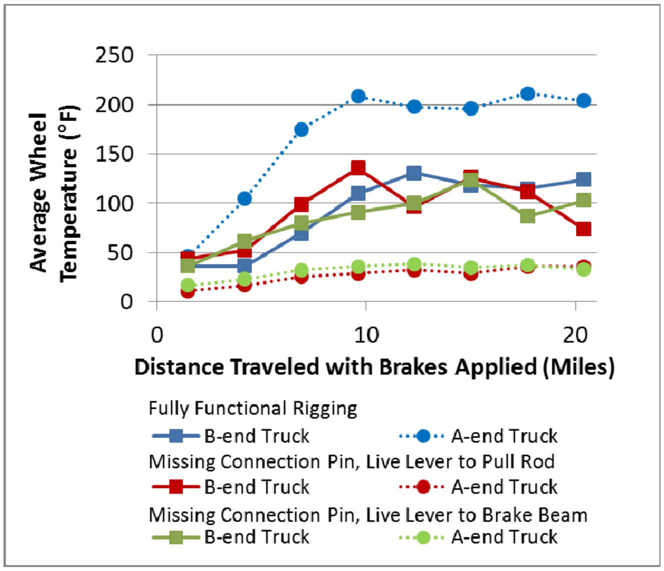

Figure 5. Wheel Temperatures

In addition to the wheel temperature results that were expected based on the shoe force testing, Figure 5 shows two other results. First, the wheel temperatures were cooler than expected. Although the brake cylinder pressure measured 25 psi at the start of each test series, a combination of leaking air and wearing brake shoes reduced the brake cylinder pressure down to 10 psi for each configuration by the time the cylinder pressure measurement was taken following the eight laps. If this change in cylinder pressure were attributed solely to leakage, the rate of air loss would be approximately 15 psi per hour or 1/4 psi per minute, well below the 1 psi per minute leakage rate needed to fail the Single Car Air Brake Test.[5]

The second result observed during the testing was the difference in wheel temperatures between the A- and the B-end trucks in the case of fully functional rigging. Brake shoe force testing showed only slightly larger shoe forces on the A-end truck compared to the B-end truck, which alone could not account for the magnitude of temperature difference. Although this issue was not fully investigated, it may have been at least partially due to friction in the rigging. The car used for testing was more than 40 years old and may have had significant friction in the rigging between the slack adjuster near the B-end of the car and the rigging at the A-end of the car. In this case, a leaking brake cylinder would tend to cause more reduction in the brake shoe force on the B-end wheels compared to the A-end wheels.

In a revenue service application, analyzing the wheel temperatures produced by this test car would have identified a problem with the brake effectiveness in the test configurations with the missing connection pins and may have also identified the issue with the brake cylinder leakage by comparing the average wheel temperature of this car to average wheel temperatures of other cars in the train.

CONCLUSION

Analyzing wheel temperatures is an alternative method for assessing brake system effectiveness on a train that is en route from one location to another.

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