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Alternative Brake Beam Performance with Rod-Under-Bolster Rigging

Scott Cummings

Summary

Eight types of alternative brake rigging are being evaluated by Transportation Technology Center, Inc. (TTCI) as part of the Association of American Railroads' Strategic Research Initiatives Program to improve brake performance. Wheel and brake shoe replacement costs could potentially be reduced through the use of improved brake rigging that reduces the variation in brake shoe force to each wheel in the truck and reduces tapered brake shoe wear. In addition to testing alternative brake rigging designs, TTCI is evaluating new unit beams from three different manufacturers and service-worn unit beams for a baseline comparison.

Static and dynamic evaluations of alternative brake rigging designs using two different foundation rigging styles (rod-through-bolster and rod-under-bolster) showed the following:

- None of the alternative brake systems reduced brake shoe force variation compared to the best base case unit beam configurations.
- The rod-under-bolster arrangement produced less force variation between brake shoe locations for the majority of systems tested.
- While static tests performed with single point contact transducers can provide reasonable estimates of the average brake shoe force of a car in motion, this form of testing far under predicts dynamic variation in shoe forces between brake shoe locations.

As expected, the link system performed much better in the rod-under-bolster arrangement with unbent truck levers of equal length compared to the rod-through-bolster arrangement in which it was over-constrained and difficult to install.

This *Technology Digest* focuses specifically on the performance of three of the alternative brake rigging designs and the base case unit beams when installed in a car with a rod-under-bolster arrangement. The change in brake arrangement from rod-through-bolster to rod-under-bolster also required the use of a different truck, and therefore changes in unit guide geometry. Although most of the alternative brake rigging designs produced less force variation in the rod-through-bolster arrangement as expected, two of the designs produced more force variation, indicating that the side frame unit guide geometry may play a larger role in brake shoe force variation and brake shoe top/bottom force distribution than anticipated and should be investigated further.



INTRODUCTION

TTCI has statically and dynamically evaluated three alternative brake rigging designs in a car with rod-through-bolster foundation brake rigging as part of the Association of American Railroads’ (AAR) Strategic Research Initiatives Program for improved brake performance. New, standard unit beams from three different manufacturers and service-worn unit beams were also tested for a baseline comparison.

Performance criteria for the brake systems are:

1. Evenly distributed brake shoe normal force at each wheel in the truck to reduce variation in wheel temperatures.
2. Well distributed top and bottom contact between the brake shoes and the wheel to promote even shoe wear.

BACKGROUND

Wheel and brake shoe replacement costs could potentially be reduced through the use of improved brake rigging. Eliminating wheel temperature variation between individual wheels of a car could reduce the number of wheels subject to thermal mechanical shelling by a factor of eight.¹ Wheel temperature depends on brake shoe force among other factors; thus reducing brake shoe force variation could produce wheel life benefits. The brake retarding force and the associated reaction force at the connection between the unit brake beam and the side frame are not colinear, and therefore generate a torque that acts to pitch the beam.² Brake beam pitch (sometimes referred to as droop) results in uneven brake shoe wear. A study of nearly 4,000 brake shoes noted that 75 percent of the shoes had significantly more wear on the top of the brake shoe compared to the bottom.³ Tapered shoe wear results in premature brake shoe removal and wasted maintenance funds.

Each brake configuration consisted of two brake beams. The same car, truck, live and dead levers, push rod, and wheelsets were used when testing each configuration. Four base case unit beam configurations were evaluated as well as three alternative brake rigging designs. The base case configurations were composed of brand-new unit beams from three different manufacturers plus a set of heavily worn unit brake beams. Heavily worn nonmetallic brake beam wear liners were used for the worn base case. New, nonmetallic brake beam wear liners were installed for all other unit beam configurations. Table 1 lists relevant details about the various configurations. Photos of the configurations have been published previously.⁴

Table 1. Test Configuration Details

Configuration Name	Four Bar Linkage	Connection to Side Frame
1A. Base Case A	No	Slide
1B. Base Case B	No	Slide
1C. Base Case C	No	Slide
1W. Base Case Worn	No	Slide
4. Unit Beams with Link	Link System	Slide
6. Swing Hanger with Link	Link System	Pivot
7. Swing Hanger	No	Pivot

The alternative brake rigging designs utilized either a four bar linkage (configuration 4), a pivot connection between the brake beam and side frame (configuration 7), or both (configuration 6) in an attempt to reduce or eliminate the reaction force generated at the unit beam end extension by the brake retarding force. The same brake beams were used for configurations 1A and 4 and for configurations 6 and 7 with the key difference being the addition or removal of the link system.

The alternative brake rigging designs were previously tested statically⁴ and dynamically⁵ using a car with a typical rod-through-bolster arrangement requiring rod-through-bolster push rods connected to bent brake levers of unequal length. This type of brake rigging produces two undesirable conditions: a yaw torque on the beam from the bend in the truck levers as well as lateral forces on the brake beams.

The test vehicle used for the current testing was a steel 100-ton hopper equipped with basic 3-piece trucks and rod-under-bolster foundation rigging with unbent truck levers of equal lengths. This type of rigging should greatly reduce the yaw torque and lateral forces on the brake beams. The car was in the loaded condition during all testing. Data was collected at the B-end of the car where the alternative brake configurations were installed. The number of alternative systems tested in the rod-under-bolster system was paired down from the full list of alternative systems to provide a cost-effective means of identifying performance trends.

STATIC TESTING

After installing each brake configuration in the test car, the brakes were cycled several times to allow for proper slack adjuster position. The brake piston travel was measured to verify appropriate adjustment prior to each test series. Compressed air was piped directly into the brake cylinder and applied in five discrete increments: 10-, 20-, 40-, 60-, and 80-psi to cover the range from minimum service brake applications to emergency brake applications. Forces were recorded at each of the four brake shoes in the test truck before and after tapping all of the pins in the brake rigging. Commercially available brake shoe force transducers that contact the wheel with only a single small “button” of a load cell located at the center of the brake head were used for the static testing.

The AAR static shoe force test requires brake systems have no more than +/- 12.5 percent shoe force variation with a full service application. Based on this criteria, all of the configurations tested met AAR standards (total percent variation is the absolute value of negative variation plus positive variation, effectively allowing a 25 percent total variation at 65-psi brake cylinder pressure).

Figure 1 shows the static shoe force results after tapping the pins in terms of total percent variation based on the results from the single point contact brake shoe force transducers. With the exception of the worn base case (configuration 1W) at 10 psi, all of the brake systems performed well during the static testing and showed much less dependence on the brake

cylinder pressure as compared to the static results with the rod-through-bolster arrangement. In the rod-through-bolster arrangement, the link system was difficult to install, implying that the system was over-constrained. This was confirmed during testing based on poor average brake shoe forces and force variation. However, in the rod-under-bolster arrangement, the link system was easily installed and did not negatively influence the results.

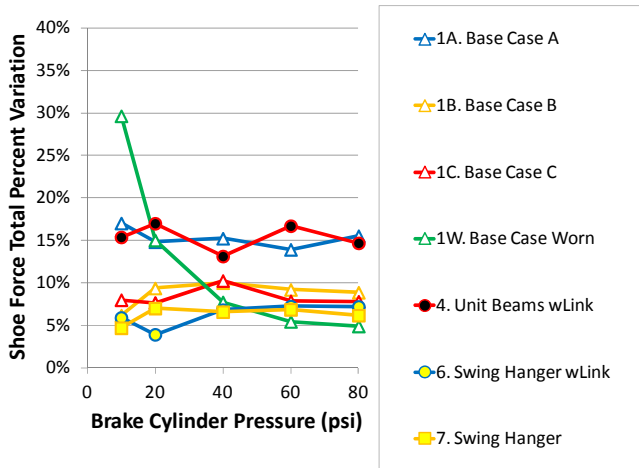


Figure 1. Static Brake Shoe Forces and Force Variation per Configuration

DYNAMIC TESTING

Each brake configuration was tested dynamically by applying and releasing the brakes while the car was in motion. Brake shoe forces were recorded at each of the four brake shoes in the B-end truck using instrumented brake shoes developed by TTCI. Two miniature load cells are embedded in each brake shoe between a layer of standard high friction composition brake shoe material and a standard brake shoe backing plate. A slotted pin joint carries the shear forces associated with the brake retarding force. In addition to the total brake shoe normal force, the instrumented brake shoes can provide data about the top-to-bottom force distribution at each shoe location.

All dynamic tests were conducted at the Transportation Technology Center, Pueblo, Colo., on 7½-, 10-, and 12-degree curves and adjacent tangent zones. Special gage and cross-level perturbations are present in the 10-degree curve and were useful during this testing to provide dynamic truck motions. Pressurized air was piped directly into the test vehicle’s brake cylinder. Brake cylinder applications and releases of 30 psi were made in curves and tangents. This level of braking would approximate a 12-psi brake pipe pressure reduction and was intended to represent a moderately heavy revenue service grade brake scenario. Test speed was restricted to 12 mph to minimize heat into the wheels and wear of the instrumented brake shoe friction material. For each configuration, data was collected during five movements through each curve. Table 2 describes the details of the test movements.

Table 2. Test Movement Details

Push or Pull	Lead End of Test Vehicle	Brake Applications
Pull	B	Apply in curve, release in curve
Push	A	Apply in curve, release in curve
Pull	B	Apply in tangent, release in curve
Pull	B	Apply in curve, release in tangent
Pull	B	Apply in tangent, negotiate curve, release in tangent

Testing with the rod-through-bolster arrangement showed the average brake shoe forces measured during dynamic testing were larger than those measured during static tests. This was not typically the case with the rod-under-bolster testing. Figure 2 shows the average brake shoe forces for each configuration as measured statically and dynamically with the rod-under-bolster arrangement as well as the average brake shoe forces measured dynamically with the rod-through-bolster arrangement for comparison purposes.

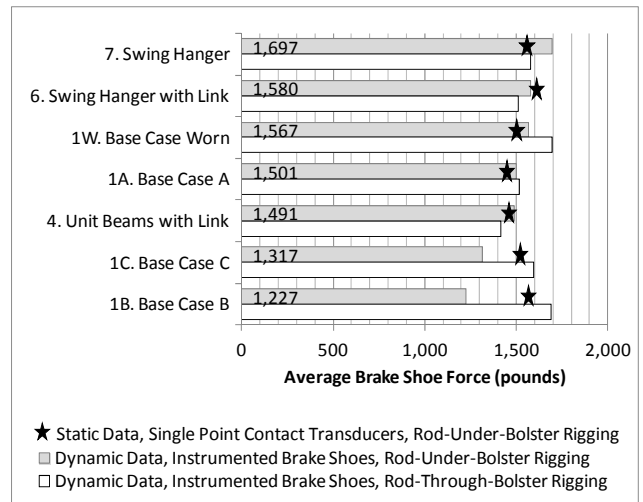


Figure 2. Average Brake Shoe Forces per Configuration

No individual brake shoe location had consistently larger or smaller brake shoe forces than the other positions during testing with the rod-under-bolster arrangement. Figure 3 shows the average brake shoe force measured dynamically at each wheel position.

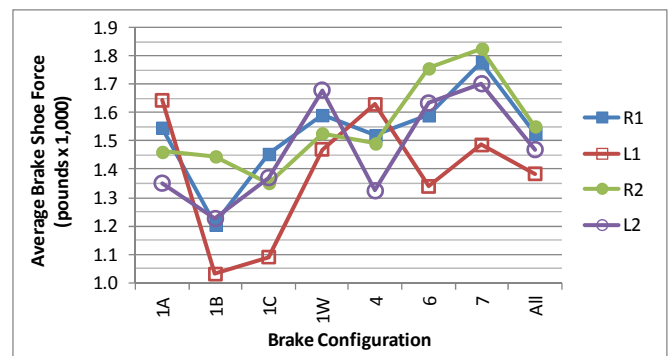


Figure 3. Average Brake Shoe Forces Measured during Dynamic Testing

Figure 4 shows the percent shoe force variation results for each configuration measured statically and dynamically with the rod-under-bolster arrangement and dynamically with the rod-through-bolster arrangement for comparison purposes. Variation in shoe forces was much larger dynamically than statically. Although five of the seven brake systems showed reduced shoe force variation in the rod-under-bolster-arrangement, this was not the case for the swing hanger (configuration 7) or the base case B (configuration 1B). In fact, configuration 1B is indicative of the complex interactions between the brake beams and the side frame unit guides, because this configuration produced the lowest percent shoe force variation in the rod-through-bolster arrangement and the highest percent variation in the rod-under-bolster arrangement. This change in performance may be due as much to differences in the geometry of the side frame unit guides as to the arrangement of the push rod and design of the truck levers.

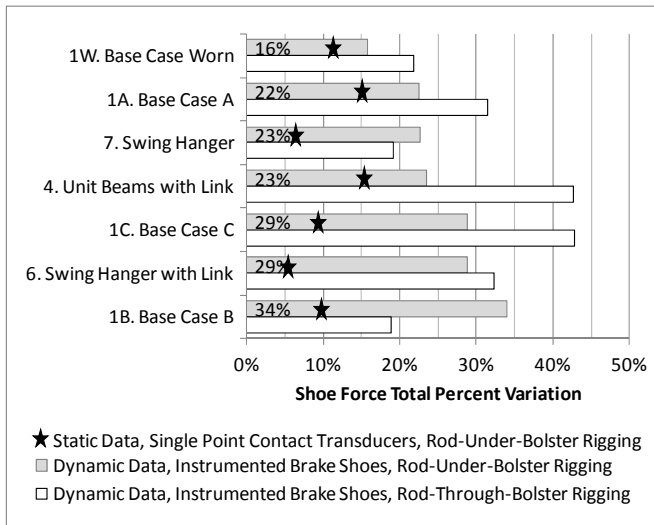


Figure 4. Percent Variation per Configuration

The distribution of force between the top and bottom of a brake shoe should be a good indicator of initial brake shoe wear distribution. Figure 5 shows the average top/bottom distribution of brake shoe forces for each configuration. Larger forces at the top of the brake shoe should lead to faster initial brake shoe wear at the top of the shoe, and vice versa. The distribution of forces on individual brake shoes was skewed toward the top of the brake shoe for the rod-under-bolster testing compared to the rod-through-testing. The average angle of the unit guides was 14.3 degrees in the rod-under-bolster truck and 13.9 degrees in the rod-through-bolster truck, which should tend to skew the top/bottom brake shoe force more toward the bottom of the shoe in the rod-under-bolster truck. However, the average vertical gap of the unit guides was wider in the rod-under-bolster truck by 0.07 inch which, combined with a typical 4.75-inch-long unit beam end extension, could translate into an increased beam droop of 0.8 degrees. This would more than offset the 0.4 degree difference in unit guide angle and could help explain the increased distribution of force at the top of the brake shoe.

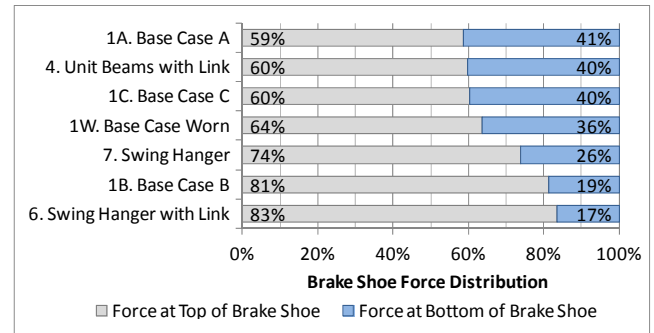


Figure 5. Top/Bottom Brake Shoe Force Distribution

CONCLUSIONS

Static and dynamic evaluations of alternative brake rigging designs using two different foundation rigging styles (rod-through-bolster and rod-under-bolster) showed the following:

- None of the alternative brake systems reduced brake shoe force variation compared to the best base case configurations regardless of the brake arrangement.
- The rod-under-bolster arrangement produced less force variation between brake shoe locations for five of the seven systems tested.
- While static tests performed with single point contact transducers can provide reasonable estimates of the average brake shoe force of a car in motion, this form of testing far under predicts dynamic variation in shoe forces between brake shoe locations.
- The link system performed much better in the rod-under-bolster arrangement compared to the rod-through-bolster arrangement in which it was over-constrained and difficult to install.
- Side frame unit guide geometry may play a larger role in brake shoe force variation and brake shoe top/bottom force distribution than anticipated and should be investigated further.

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