

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Dynamic Testing of Alternative Brake Beam Designs

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.

Variation in brake shoe force and the resulting wheel temperature variation between individual wheels of a car appear to be drivers of thermal mechanical wheel shelling, and thus the main performance criteria in this evaluation is the distribution of brake shoe normal forces to each wheel in the truck.

The alternative rigging designs in the test are a combination of designs supplied by industry experts and one design built by TTCI. New, standard unit beams from three different manufacturers and service-worn unit beams are also being evaluated for a baseline comparison. All of the alternative brake rigging designs utilized one or more of the following concepts in an attempt to reduce or eliminate the reaction force generated at the unit beam end extension by the brake retarding force: increased length of the unit beam end extensions, four bar linkage, and/or pivoting connection between the brake beam and side frame.

Test results showed the following:

- Both the average brake shoe forces and the variation in brake shoe forces were larger during dynamic testing than static testing.
- When tested dynamically, the swing hanger systems were not able to provide the same level of improvements over unit beams that were observed during static testing.
- One of the base case unit beams produced the lowest average percent shoe force variation of any of the configurations.
- The worn base case unit beams outperformed all but one alternative configuration.
- The different unit beam base cases produced a wide range of performance.
- The link systems appeared to be over-constrained during both the static and dynamic testing, likely due to the geometry of the bent lever rigging.

The brake shoe located at axle 1 left wheel position (position L1) had consistently larger brake shoe forces than the other positions during both the static and dynamic testing, likely due to the torque on the beam from the bent truck lever. Unlike the results from the current test with rod-through-bolster rigging, previous testing of the link system in a rod-under-bolster arrangement showed substantial improvements compared to a base case. For these reasons, additional testing of the alternative rigging designs is underway with a rod-under-bolster rigging arrangement using unbent equal length truck levers.



INTRODUCTION

TTCI has dynamically evaluated eight alternative brake rigging designs 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

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, so 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.

As reported previously, swing hanger systems provide better static distribution of brake shoe forces than unit beams. Composite average shoe force total percent variation was between 34 and 51 percent lower for the swing hanger configurations compared to the composite average for the new base case configurations. Transducer design was observed to influence the distribution of brake shoe forces during static testing.⁴

BRAKE BEAMS

In general, 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. An exception to this was configuration 9, which required the use of its own truck, levers, and push rod. Four base-case unit beam configurations were evaluated as well as eight 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

All of the alternative brake rigging designs utilized one or more of the following concepts in an attempt to reduce or eliminate the reaction force generated at the unit beam end extension by the brake retarding force:

- Increased length of the unit beam end extensions (configurations 2, 3, and 5)
- Four bar linkage (configurations 4, 5, 6, and 9)
- Pivot connection between the brake beam and side frame (configurations 6, 7, 8, and 9)

Table 1. Test Configuration Details

| Configuration Name | Unit Beam End Extensions | Four Bar Linkage | Connection to Side Frame |
|--|--------------------------|------------------|--------------------------|
| 1A. Base Case A | Standard | No | Slide |
| 1B. Base Case B | Standard | No | Slide |
| 1C. Base Case C | Standard | No | Slide |
| 1W. Base Case Worn | Standard | No | Slide |
| 2. Modified Unit Beams | Extended | No | Slide |
| 3. Long Extensions | Extended | No | Slide |
| 4. Unit Beams with Link | Standard | Link System | Slide |
| 5. Modified Beams with Link | Extended | Link System | Slide |
| 6. Swing Hanger with Link | None | Link System | Pivot |
| 7. Swing Hanger | None | No | Pivot |
| 8. Swing Hanger with Nubs | Nubs | No | Pivot |
| 9A. Swing Hanger with Guides | None | Yes | Pivot |
| 9B. Swing Hanger with Guides, A and B Trucks | None | Yes | Pivot |

DYNAMIC TESTING

Each brake configuration was tested dynamically by applying and releasing the brakes while the car was in motion. The test vehicle was a new aluminum 110-ton coal gondola equipped with AAR M-976 approved trucks and typical foundation brake rigging; i.e., rod-through-bolster push rods connected to bent brake levers of unequal length. 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 test vehicle’s original truck and brake rigging were left in place for all testing except configuration 9B in which the special truck and brake rigging associated with configuration 9 were installed at both ends of the car. Each system was tested with an AAR M-976 truck and many systems were also tested with a standard 3-piece truck.

Brake shoe forces were recorded at each of the four brake shoes in the B-end truck using an instrumented brake shoes system 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. Figure 1 shows one of the instrumented brake shoes. 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.

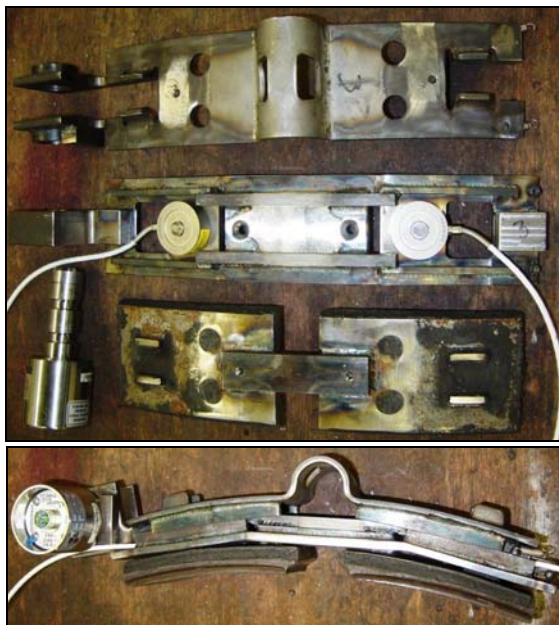


Figure 1. Instrumented Brake Shoe (Top: Disassembled Top View, Bottom: Assembled Side View)

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 |

RESULTS

The average brake shoe forces measured during dynamic testing were larger than those measured during static tests. Figure 2 shows the average brake shoe forces for each configuration.

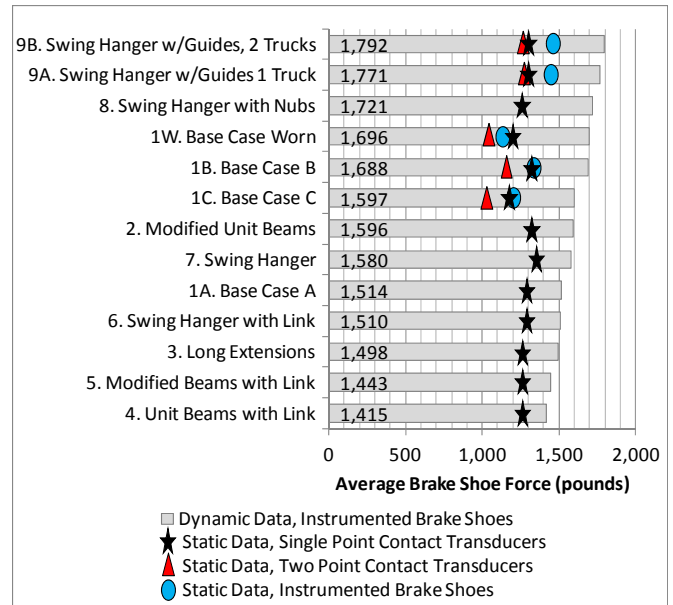


Figure 2. Average Brake Shoe Forces per Configuration

Position L1 had consistently larger brake shoe forces than the other positions during both the static and dynamic testing. Figure 3 shows the average brake shoe force measured dynamically at each wheel position. This is likely due to the torque on the beam from the bent truck lever, as Figure 4 illustrates.

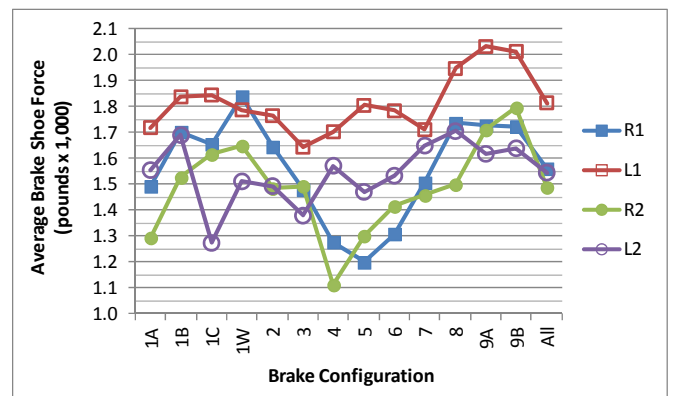


Figure 3. Average Brake Shoe Forces Measured during Dynamic Testing

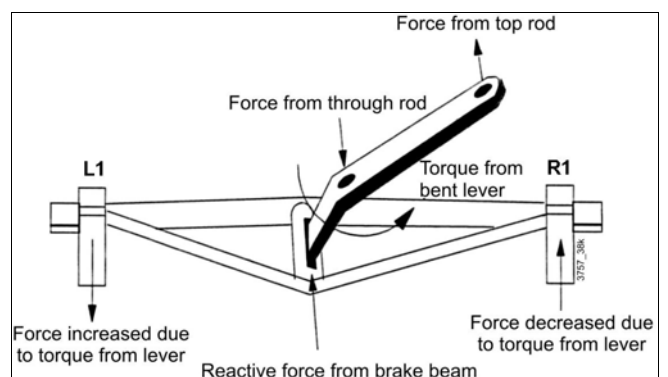


Figure 4. Effect of Bent Truck Levers

Figure 5 shows composite results in terms of the percent shoe force variation between the four instrumented brake shoes in the B-end truck. Although AAR M-976 trucks provide a large benefit for link systems and swing hangers, truck style was not a major factor for unit beams. Brake shoe force variation was large in all cases. On average, the unit beams performed nearly as well or better than the link systems and the swing hangers.

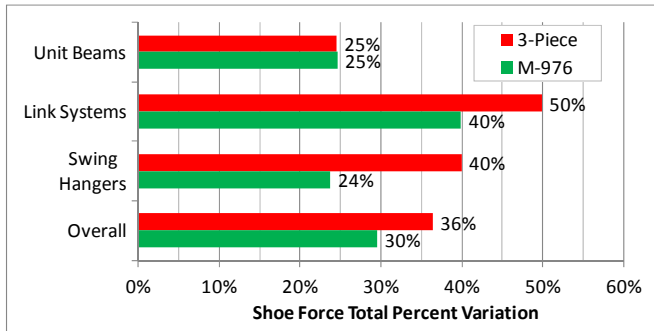


Figure 5. Percent Variation Grouped by Design Type

Figure 6 shows percent shoe force variation results for each configuration. In most cases, variation in shoe forces was much larger dynamically than statically.

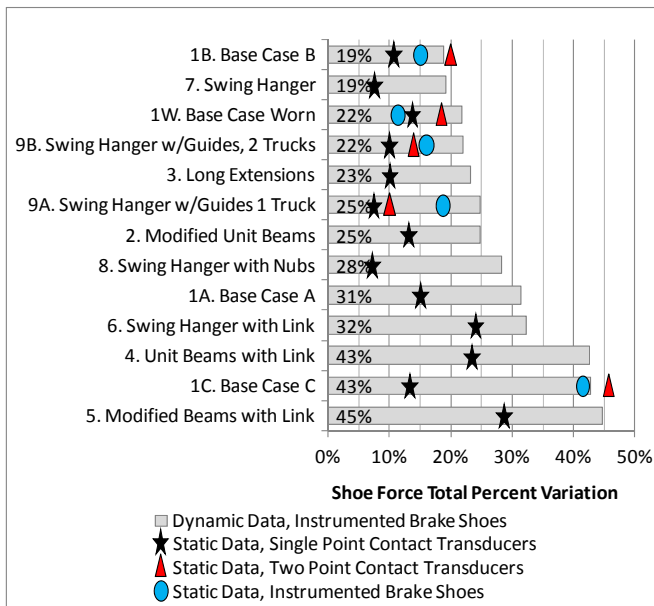


Figure 6. Percent Variation per Configuration

It should also be noted that configuration 3 (unit beams with long extensions) jammed in the unit guides on several occasions producing an undesirable situation with very high brake shoe forces.

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 7 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.

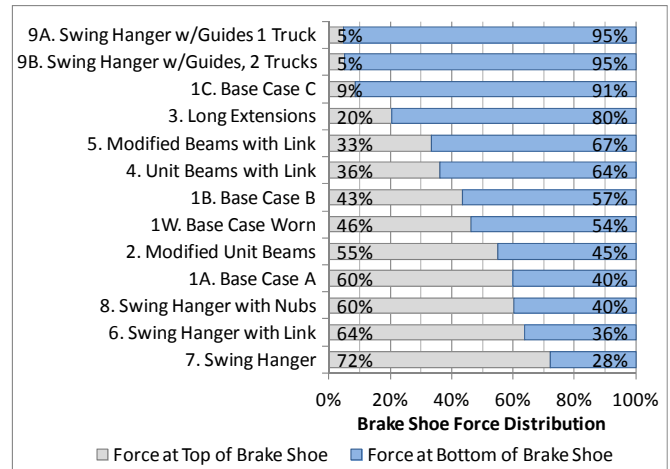


Figure 7. Top/Bottom Brake Shoe Force Distribution

CONCLUSIONS

Dynamic evaluations of alternative brake rigging designs showed that one of the base case unit beams (1B) produced the lowest average percent shoe force variation of any of the configurations. Additionally, the worn base case unit beams (1W) outperformed all but one alternative configuration (7, Swing Hanger). The different unit beam base cases produced a wide range of performance. When tested dynamically, the swing hanger systems were not able to provide the same level of improvements over unit beams that were observed during static testing. The link systems appeared to be over-constrained during both the static and dynamic testing, likely due to the geometry of the bent lever rigging. Both the average brake shoe forces and the variation in brake shoe forces were larger during dynamic testing than static testing.

FUTURE WORK

TTCI is in the process of conducting additional testing with a rod-under-bolster rigging arrangement using unbent equal length truck levers.

ACKNOWLEDGEMENTS

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