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Static Testing of Alternative Brake Beam Designs

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Summary

Eight types of alternative brake rigging are being evaluated by Transportation Technology Center, Inc. (TTCI) as part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) 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 substantial 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 designs 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.

Static brake shoe force test results show that the swing hanger configurations (pivoting connection) provide better 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. All of the unit beam designs, including the baseline configurations, performed similarly in these tests, however, the worn baseline configuration showed poor distribution of brake shoe forces under heavy brake applications. Although the link system has performed well in previous TTCI testing, it appeared over-constrained in the current tests using a rod-through-bolster arrangement.

Three styles of brake shoe force transducers were used and results showed that the transducer design can affect the contact conditions between the wheel and brake head and can influence the static distribution of brake shoe forces. The single point contact transducers commonly used in the industry may be underestimating the total percent brake shoe force variation.

The brake rigging designs will be evaluated dynamically by applying the brakes on cars in motion and measuring the brake shoe forces using instrumented brake shoes. Plans also include additional testing with a rod-under-bolster rigging arrangement. If some of the alternative configurations show improvement over the base cases during dynamic testing, revenue service trials are planned.



INTRODUCTION

TTCI has statically evaluated eight alternative brake rigging designs as part of the AAR’s SRI 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

Analysis of wayside wheel temperature data shows that 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 sliding interface between the unit brake beam and the side frame is subject to wear and deformation and is thought to be a significant source of brake shoe force variation. 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. This effect has been explained in detail previously.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.

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. One 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, and Figures 1-5 show the different brake configurations tested.

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	Figure Number
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	1
3. Long Extensions	Extended	No	Slide	2
4. Unit Beams with Link	Standard	Link System	Slide	3
5. Modified Beams with Link	Extended	Link System	Slide	1, 3
6. Swing Hanger with Link	None	Link System	Pivot	3, 4
7. Swing Hanger	None	No	Pivot	4
8. Swing Hanger with Nubs	Nubs	No	Pivot	4
9. Swing Hanger with Guides	None	Yes	Pivot	5



Figure 1. Configurations 2 and 5, Modified Unit Beams (Short Tab Welded to Unit Beam End Extension)



Figure 2. Configuration 3, Long Extensions (4 Inches Added to Side Frame Brackets and Unit Beam End Extensions)



Figure 3. Configurations 4, 5, and 6, Link System (Short Links Located next to Live Lever and Dead Lever)

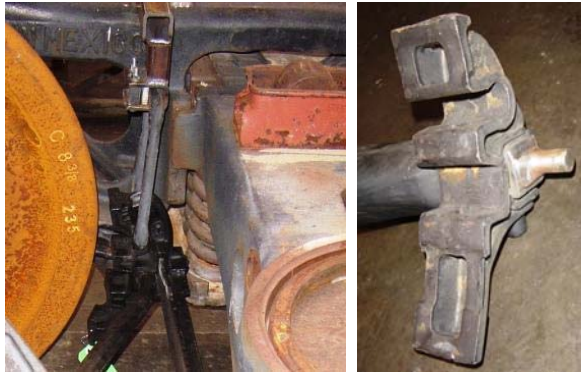


Figure 4. Configurations 6, 7, and 8 Swing Hanger Connection to Side Frame (Left) and Configuration 8, Swing Hanger with Nubs (Right)



Figure 5. Configuration 9, Swing Hanger with Guides

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 before and after tapping all of the pins in the brake rigging.

Brake shoe forces were recorded at each of the four brake shoes in the test truck using 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. Because of this single point of contact, there is no pitch constraint on the brake beam. This may allow for different contact conditions between the brake beam and the side frame compared to a full brake shoe.

To explore the effects of a brake beam with pitch constraint, two additional styles of transducers were used on select configurations. One style is a commercially available brake shoe force transducer system which produces two contact points between the wheel and the brake head at approximately 3-inch circumferential spacing. The design of this system does not transmit any shear forces and would more closely simulate

the beam pitch constraint that is present when normal brake shoes are installed. The third style of transducer used for this testing is an instrumented brake shoe system developed by TCI. The primary purpose of this system is to measure brake shoe forces of cars in motion, and thus the design is not optimized for static measurements. 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 6 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.

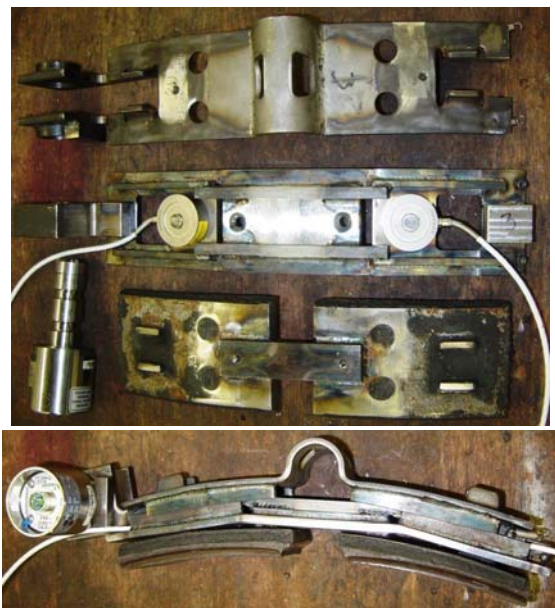


Figure 6. Instrumented Brake Shoe (Top: Disassembled Top View, Bottom: Assembled Side View)

RESULTS

The results of the static shoe force testing show that the percent variation between individual shoe forces within a truck is inversely related to the brake cylinder pressure. 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 criterion, 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). Full-service braking is applied only to slow or stop a train rather than to maintain speed while descending a grade. Lighter brake applications used while descending grades are used for longer durations and produce a higher shoe force percent variation. This is one reason why wheel temperatures have so much variation while descending grades.

Figure 7 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. The swing hanger systems (configurations 7, 8, and 9) produce

the smallest shoe force percent variation over a wide range of brake applications. All of the unit beams in the new condition (configurations 1A, 1B, 1C, 2, and 3) performed similarly in the static testing, although configurations 1B and 3 performed extremely well at 10-psi brake cylinder pressure. The worn base case showed much higher percent variation at 60- and 80-psi brake cylinder pressure compared to the other unit beams. The link system configurations (4, 5, and 6) were outperformed in the static test by the other configurations. Previous static testing of unit beams in a rod-under-bolster brake system with straight brake levers showed improved brake shoe force distribution when the link system was added.⁴ The more complicated geometry of the brake rigging used in this test (rod-through-bolster brake system with bent truck levers) appeared to be over constrained by the links. A number of small modifications were tested in an attempt to improve the performance of the link systems. Figure 7 contains the results of the final link configurations.

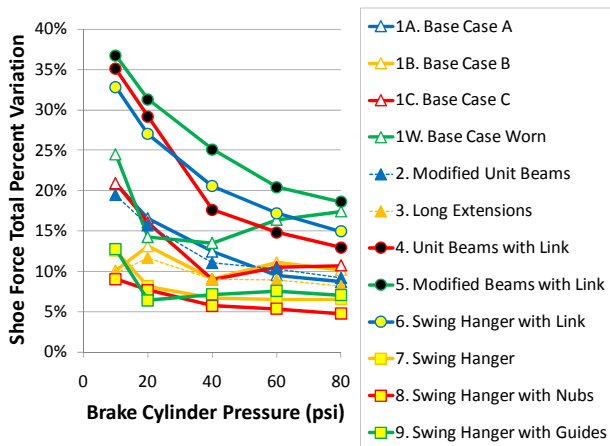


Figure 7. Static Shoe Force Test Results after Tapping Pins

Because the two point contact transducers and the instrumented brake shoes were not available when some of the brake configurations were tested, only five configurations were tested statically with all three transducer styles. Figure 8 shows the composite average shoe force from the five configurations as a function of brake cylinder pressure for each transducer type. The two point contact transducers reported average shoe force values between 65 and 126 pounds less than the single point contact transducers. The instrumented brake shoes reported average values between 32 and 356 pounds greater than the single point contact transducers and between 105 and 482 pounds greater than the two point contact transducers. Each transducer creates different contact conditions between the wheel and brake head, so these results are not unreasonable.

The shoe force total percent variation was much higher with both the two point contact transducers and the instrumented brake shoes compared to the single point contact transducers. Figure 9 shows these results. This is an indication that the single point contact transducers may be underestimating the total percent variation.

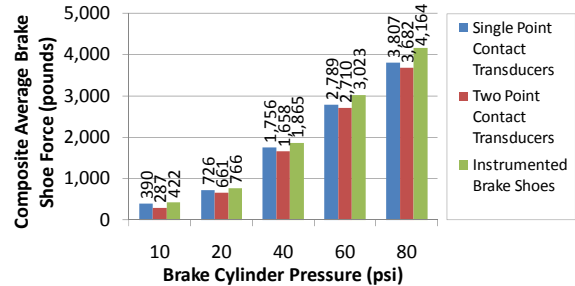


Figure 8. Transducer Comparison: Average Shoe Force

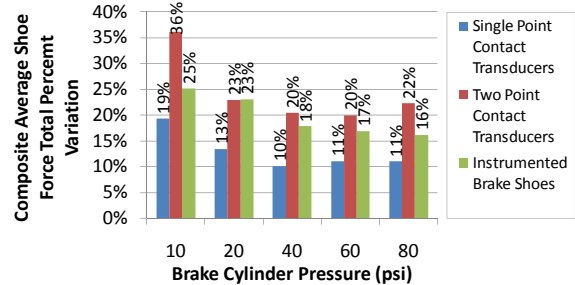


Figure 9. Transducer Comparison: Percent Variation

CONCLUSIONS

Evaluations of eight alternative brake rigging designs showed that 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. Brake shoe force transducer design can affect the contact conditions between the wheel and brake head and can influence the static distribution of brake shoe forces.

FUTURE WORK

TTCI is also evaluating the brake rigging designs dynamically by applying the brakes on cars in motion and measuring the brake shoe forces using the instrumented brake shoes. Plans also include additional testing with a rod-under-bolster rigging arrangement. If some of the alternative configurations show improvement over the base cases during dynamic testing, revenue service trials are planned.

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