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Dynamometer Testing of Tread Conditioning Brake Shoes

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Summary

Transportation Technology Center, Inc. (TTCI) evaluated the performance of two types of tread conditioning (TC) brake shoes and standard high friction composition (HFC) brake shoes using a dynamometer and wheels with machined flat spots. One type of TC brake shoe was not statistically different from the HFC shoes in terms of brake shoe wear, wheel wear near the flat spots, or nominal wheel wear at locations not near the flat spots. The other type of TC brake shoe produced statistically higher brake shoe wear and no statistical difference in wheel wear compared to the other shoes tested. One anomalous individual TC brake shoe (of the three shoes of this type that were tested) experienced more brake shoe wear and more wheel wear near the flat spot for reasons not obviously related to the testing parameters.

Tread conditioning brake shoes are marketed as a way to increase wheel life and brake shoe life. Some, but not all, previous revenue service tests conducted by railroads and car owners have supported these claims. Dynamometer testing was conducted because it removes many of the variables that can influence revenue service tests.

Portions of an Association of American Railroads (AAR) specification were used to construct a test matrix of stop tests and grade braking tests for each of nine paired brake shoes and wheels. Each wheel was trued on a wheel lathe, then subjected to approximately 200 service miles under a loaded car to cold work the tread surface and wear down the machining marks prior to testing. Each brake shoe was machined to match its mate wheel radius and tread taper prior to testing.

TTCI tested these TC brake shoes as part of the AAR Strategic Research Initiatives Program on improved brake system performance.



INTRODUCTION

Transportation Technology Center, Inc. (TTCI) conducted laboratory dynamometer tests on two types of tread conditioning (TC) brake shoes to evaluate the brake shoe wear and the ability of the brake shoes to affect the geometry of 3-inch long flat spots in the wheels. Standard high friction composition (HFC) brake shoes served as the test control group.

BACKGROUND

TC brake shoes are often marketed as a way for car owners to improve the service life of not only the brake shoes, but also wheelsets, by reducing the impact loads caused by tread running surface irregularities. TC shoes are colored red for simple identification in comparison to standard HFC brake shoes.

TTCI conducted a survey¹ of railroads' and car owners' revenue service tests involving TC brake shoes and found that wheelset life improvement was reported in five of the six tests. The sixth test found improved brake shoe life, but did not find improvements in the life of wheelsets for either of two different types of TC brake shoes. One test that evaluated wheel wear did not find a large effect due to brake shoe type.

Revenue service testing presents challenges in terms of understanding, controlling, and quantifying all of the relevant variables that influence the results. Because of this, TTCI was asked to conduct laboratory dynamometer tests to evaluate the relative performance of TC brake shoes in comparison to HFC shoes.

MATERIAL PREPARATION

An Association of American Railroads (AAR) member railroad donated five freshly trued wheelsets for this test. TTCI installed these wheelsets under loaded hopper cars and ran them on tracks at Transportation Technology Center (TTC) for approximately 100 miles to cold work the tread surface of the wheels. A 3-inch long flat spot then was created in the tread surface near the tapeline of each of the 10 wheels using a hand grinder and a template that referenced the front rim face of the wheel. The loaded cars with the test wheelsets were again pulled for approximately 100 miles to cold work the edges of the flat spots. After cold working, the flat spot depths ranged from a minimum of 0.075 inches to a maximum of 0.090 inches. Each wheel then was demounted from the axle and nine of the wheels were selected for the hub modifications necessary to mount them on TTCI's dynamometer. In this manner, each test wheel was assured a nearly identical post-truing service history on the tread surface. Cold working the treads near the flat spots was intended to

provide more realistic test conditions by removing undue influence from either unhardened material or the machining marks left during the wheel truing operation. Figure 1 shows an example of a wheel prepared for testing on the dynamometer.

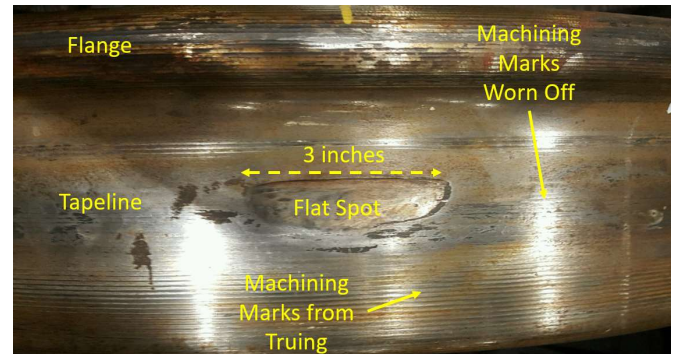


Figure 1. Flat spot on a wheel immediately prior to testing

Nine brake shoes were used in the testing: three HFC shoes (HFC1, HFC2, HFC3), three TC shoes from one manufacturer (TCA1, TCA2, TCA3), and three TC shoes from another manufacturer (TCB1, TCB2, TCB3). Each shoe was matched up with a specific wheel for testing and machined with a concave radius to match the exact convex radius of its mate wheel. Because the dynamometer is designed to apply brake shoe force perpendicular to the axle using a non-tapered brake head, a 1:20 lateral taper was machined on the brake shoes to match the wheel tread taper and provide nearly conformal contact between the brake shoe and the wheel at the start of the test.

DYNAMOMETER TESTING

AAR specification M-997² describes how to conduct grade braking and stop testing of tread conditioning brake shoes on a dynamometer. Portions of this specification were used as building blocks to create a test matrix. Each shoe/wheel combination was exposed to one complete cycle of the “5.0 Brake Shoe Wear-In” grade braking and stop tests. No additional cycles of the wear-in were conducted regardless of whether or not at least 95 percent of the brake shoe was found to be bearing on the wheel after the first cycle. Recall that each brake shoe was machined to produce nearly conformal contact with the wheel prior to testing. Next, each shoe/wheel combination was tested according to the “6.0 Grade Test Series,” “8.0 Light Braking-Stop Test Series,” “9.0 Heavy Braking-Stop Test Series,” and “12.0 Heavy Grade Brake Test Requirements” in sequential order. These four sections of the M-997 specification were repeated a total of eight times per shoe/wheel combination. Tables 1 and 2 detail

the total grade braking and stop tests experienced by each shoe/wheel combination.

Table 1. Grade braking tests conducted per brake shoe

Test Quantity	Duration per Test (minutes)	Simulated Vehicle Speed (mph)	Brake Shoe Normal Force (pounds)
9	45	20	1,450
8	45	20	2,250

Table 2. Stop tests conducted per brake shoe

Test Quantity	Initial Simulated Vehicle Speed (mph)	Brake Shoe Normal Force (pounds)
5	80	4,000
5	80	2,000
24	60	1,500
24	40	1,500
24	80	6,020
24	60	6,020

Data collection included brake shoe thickness measurements at eight locations covering the left, right, top, and bottom of the shoe and transverse wheel profiles at the following circumferential locations relative to the center of the flat spot: 0 inches, +/- 6 inches, +/- 12 inches, and 180 degrees away. This data was collected for each shoe/wheel combination prior to any testing, after every other cycle of the heavy grade tests, and after all testing was completed.

RESULTS

Brake shoe wear was quantified as the average difference between the initial readings and final readings for each of the each brake shoe thickness measurement locations. Wear was reasonably uniform across the surface of each brake shoe. Nominal wheel wear was calculated 4 inches from the back of flange (just beyond the field side edge of the flat spot) using the average of the vertical differences between each set of initial and final wheel profiles. Profiles taken at the center of the flat spot were excluded from this calculation.

The ability of the brake shoe to affect the geometry of wheel tread surface irregularities was quantified by the amount of discernable wear on the wheel near the flat spot. Figure 2 shows an example of a groove that was worn into the wheel tread by the brake shoe during testing. The groove effectively reduces the depth of the flat spot in comparison to the nearby tread surface – or the local radial runout is reduced. This wear pattern was observed

for every shoe/wheel combination tested. By overlaying the initial and final transverse wheel profiles measured at a location 6 inches beyond the flat spot in the direction of rotation, the relative reduction in local radial runout was calculated. Figure 3 visually describes this process.

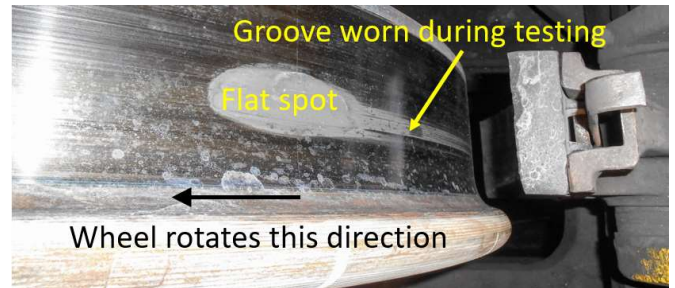


Figure 2. Residual brake shoe material accumulates in a groove in the wheel tread adjacent to the flat spot

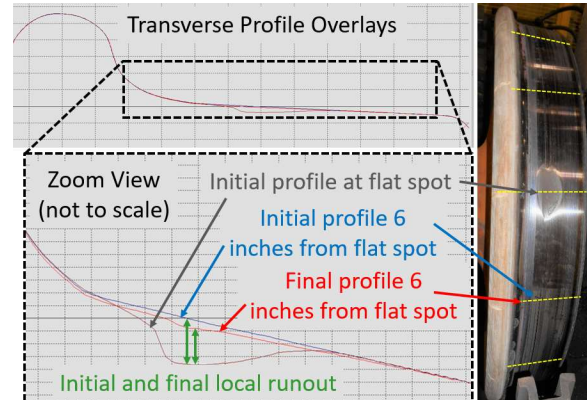


Figure 3. Local radial runout reduction

Table 3 shows the brake shoe wear and wheel wear results. Based on relationships previously documented,³ the approximate estimated reduction in impact load resulting from the reduction of radial runout is also included in this table. Figure 4 shows statistical testing results. The brake shoe wear of the HFC and TCB shoes were not statistically different, but the TCA brake shoes had more wear than the other types. Neither the nominal wheel wear nor the reduction in local radial runout was statistically different between any of the shoe types.

For the TCA1 shoe/wheel combination, all the friction material was worn away at the conclusion of the testing. The high wear rate of this particular brake shoe was consistent throughout the testing. Review of the relevant testing parameters and measurements (including brake shoe normal force, simulated vehicle speed, simulated vehicle weight, and wheel temperature) did not reveal a cause for the anomalous performance of TCA1. This shoe/wheel combination also produced the largest reduction in local radial runout, though the nominal wheel wear was similar to the other shoe/wheel combinations.

Table 3. Test results

Brake Shoe / Wheel Combination	Brake Shoe Wear (inch)	Nominal Wheel Wear (inch)	Reduction in Local Radial Runout (inch)	Estimated Reduction in Impact Load (kip)
HFC1	0.708	0.003	0.010	7
HFC2*	0.459	0.004	0.010	7
HFC3	0.411	0.004	0.007	5
TCA1	1.588	0.003	0.018	13
TCA2	0.783	0.004	0.009	6
TCA3**	0.806	0.003	0.008	6
TCB1	0.500	0.004	0.007	5
TCB2	0.408	0.003	0.004	3
TCB3**	0.477	0.005	0.009	6

* Due to a software issue in the dynamometer control system, the brake shoe forces were approximately 230 lbs. lower than intended for the first 41 of 123 total brake applications for HFC2 tests. The results are not discarded because of the relatively small discrepancy in brake shoe force and the small sample size used in this testing.

** Class D wheels were matched with TCA3 and TCB3, all other wheels were Class C

The anti-fade properties of TC shoes allow for a higher coefficient of friction than HFC shoes during extended braking applications. Therefore, because the simulated vehicle speed and brake shoe force were held constant during the grade braking tests, more work was performed by TC shoes than HFC shoes. In that sense, the HFC shoes have an unfair advantage regarding brake shoe wear comparisons in this type of test. However, the revenue service brake shoe wear for HFC and TC shoes also would be subject to this same phenomenon. A locomotive engineer would make the necessary brake application to control speed on a long grade and this will provide a similar brake shoe force to all brake shoes in the train, regardless of type.

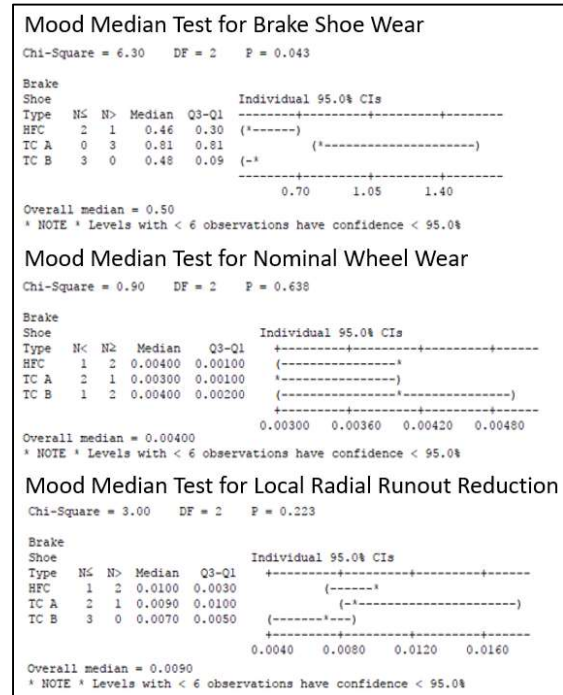


Figure 4. Mood median hypothesis test results for brake shoe wear, nominal wheel wear, and reduction in local radial runout

CONCLUSION

Laboratory dynamometer testing showed no statistical difference in the nominal wheel wear or local radial runout reduction near a 3-inch flat spot for the any of the types of brake shoes. Brake shoe wear was statistically higher for the TCA brake shoe type in comparison to the HFC and TCB brake shoes. One shoe/wheel combination (TCA1) produced higher amounts of brake shoe wear and reduction in local radial runout for reasons not obviously related to the testing parameters.

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