TTCI TRANSPORTATION TECHNOLOGY CENTER, INC. TECHNOLOGY DIGEST

AUGUST 2021 TD21-022

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

Revenue Service Test of Cars with Disabled Brakes: Final Results

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Key Findings:

- Typical wheel shelling from RCF can and does occur independent of heating from tread braking.
- Neither the well cars, nor the coal hopper cars showed statistical differences in wheelset survival based on the condition of the brakes.
- The effect of braking on the wear rates of the well car wheels was inconclusive due to the data scatter and small sample sizes, but the coal car wheels did not show any wear penalty from tread braking.
- Despite the application of the coal car brakes dozens of times per trip, it is not clear that the wheel temperatures were high enough to influence wear or shelling.
- No accidents, incidents, or injuries occurred due to operating these eight cars with disabled brakes for more than three years in otherwise normal service.

TTCI investigated the effects of tread braking on wheel wear and tread damage by monitoring the performance of three articulated five-unit well cars and five coal hopper cars with disabled brakes operating in otherwise normal revenue service conditions for more than three years. The Federal Railroad Administration (FRA) granted an enforcement discretion allowing these eight cars to operate in revenue service with disabled brakes until July 2020 as part of this test.[1] The trains moving these cars were required to contain enough cars to maintain at least 95 percent operational brakes—a requirement that provided sufficient safety precautions as evidenced by the fact that no accidents, incidents, or injuries were incurred due to the disabling of the brakes. The test was conducted as part of the Association of American Railroads' (AAR) Strategic Research Initiatives program and included appropriate control groups so the performance of the groups could be identified with and without braking.

Wheel wear and tread surface damage have long been thought to be influenced by the abrasive contact and heat developed through tread braking. Thermal mechanical shelling (TMS) is the acceleration of near-surface rolling contact fatigue (RCF) damage on wheel treads due to elevated wheel temperatures. It has been hypothesized that tread braking can have a negative influence on wheel wear rates and can initiate undesirable wear patterns.[2] The revenue service test mentioned in this *Technology Digest* allowed a focused investigation on the effects of tread braking, though it is difficult to quantify and control all the interacting variables in a revenue service environment. The results reported here provide important insight into the effects of tread braking for the particular service environments being evaluated, but the results do not cover the full range of operating environments in North American freight service.

Although the influence of tread braking on wheel performance was not found to be significant in the service environments studied, the concepts of TMS and brake-induced wheel wear may still be relevant in other operational environments. For example, recent laboratory twin-disc tests showed that, for relatively low traction ratios, the number of cycles required to develop RCF damage varied inversely with temperature even for temperatures as low as 300°F.[3] It was not clear if the wheels in the tested coal cars with fully functioning brakes reached even these moderate temperatures.

TEST CARS

Articulated intermodal well cars allowed for an ideal comparison between the wheels in the D truck with disabled brakes and the wheels in the E truck with fully functioning brakes; the mileage and routing were identical within each car and the load conditions were similar. Figure 1 shows that each of these cars was equipped with two handbrakes: one that activated the brakes on the B and C trucks and one that activated the brakes on the F and A trucks. The test wheels in the D and E trucks were not affected by the handbrake applications. The well cars used in this test operated on their normal routes, typically in Canada. New 38-inch wheelsets were installed in the D and E trucks of these cars for this test. The three well cars re-entered service and began their test in October 2016.

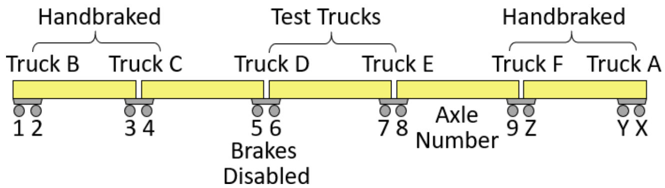

Figure 1. Five-unit articulated intermodal well car nomenclature

A total of 10 coal hopper cars were also used to evaluate the effects of tread braking. Five of these cars had disabled brakes, and the other five cars had fully functioning brakes to act as a control group. Each of the 10 test cars received new 36-inch wheelsets at the start of the test. These cars had a typical light weight of 49,200 pounds and a gross rail load capacity of 286,000 pounds. They were equipped with M-976 trucks, body-mounted brake rigging, and high-friction composition brake shoes. The coal cars began service testing in early July 2017 and operated on a standard route between Wyoming and Georgia. Additional details regarding the test cars as well as background and motivations for the testing have been described previously.[4]

WHEEL LIFE

Table 1 shows details regarding the removal of the well car test wheelsets. By the time 245,000 service miles had accumulated, all six of the wheelsets in the trucks with disabled brakes and five of six wheelsets in the trucks with normal braking had been removed for wheel-related causes. The car owner stated that the mileages for these wheelset removals were shorter than typically expected. Further investigation regarding the lifespan of these wheelsets was beyond the scope of this effort.

Table 2 shows the details regarding removal of the coal car test wheelsets. After 252,000 service miles, 3 of the 20 wheelsets in cars with disabled brakes and 5 of the 20 wheelsets in cars with normal brakes had been removed for wheel-related causes. Two additional wheelsets were removed for bearing- related causes and all four wheelsets from a test car with normal braking were removed at the owner's request for an issue unrelated to this test.

Table 1. Wheelset removals, well cars braked (red), not braked (blue)

Car	Axle	Braked	AAR Removal Cause*	Date	Mileage
148	8	Yes	WILD 90+	3/5/17	53,000
759	8	Yes	WILD 90+	3/24/17	50,000
919	7	Yes	WILD 90+	6/6/17	77,000
148	6	No	WILD 80+	6/16/17	72,000
759	5	No	WILD 90+	12/22/17	137,000
759	6	No	WILD 90+	1/19/18	146,000
759	7	Yes	WILD 90+	1/19/18	146,000
919	5	No	WILD 90+	1/19/18	136,000
148	5	No	Scrape, dent, or gouge	2/27/18	143,000
919	8	Yes	WILD 90+	11/30/18	215,000
919	6	No	WILD 90+	2/9/19	245,000

* WILD 80+: High impact wheel from 80 kips to less than 90 kips; WILD 90+: High impact wheel 90 kips or greater.

Table 2. Wheelset removals, coal cars braked (red), not braked (blue)

Car	Axle	Braked	AAR Removal Cause*	Date	Mileage
155	4	Yes	ABD	7/20/18	94,000
134	3	No	WILD 90+	1/16/19	140,000
157	1	Yes	Owner's request	1/16/19	140,000
157	2	Yes	Owner's request	1/16/19	140,000
157	3	Yes	Owner's request	1/16/19	140,000
157	4	Yes	Owner's request	1/16/19	140,000
162	2	Yes	WILD 90+	1/16/19	140,000
158	1	No	ABD	3/11/19	151,000
158	2	No	WILD 90+	3/11/19	151,000
155	1	Yes	WILD 90+	4/25/19	157,000
162	1	Yes	WILD 80+	12/19/19	214,000
243	1	Yes	WILD 80+	12/19/19	214,000
195	1	Yes	WILD 90+	3/12/20	239,000
215	2	No	WILD 90+	4/27/20	252,000

* WILD 80+: High impact wheel from 80 kips to less than 90 kips; WILD 90+: High impact wheel 90 kips or greater; ABD: Acoustic Bearing Detector Level-1, verified by hand roll.

Wheelset survival analyses were conducted for the well cars and the coal cars. Each wheel was individually classified as a "failure" or "right censored." A "failure" meant it was billed due to a wheel-related cause while "right censored" indicated it was removed for any other reason or it remained in service. Neither the well cars nor the coal cars showed statistical differences in wheelset survival based on the status of the brakes.

WHEEL WEAR

Wheel transverse profile measurements were collected with a Miniprof instrument during inspections and overlaid with the associated profile data that was collected at the test initiation to determine wheel wear. The wheel profile area loss was then calculated for each wheel and separated into flange wear and tread wear. For the well car wheels, statistical comparisons were hindered by small sample sizes, inconsistent service mileages between the cars when measurements were collected, and relatively short wheel lives. In contrast, the coal cars traveled together in the same train, allowing for simultaneous car inspections that produced much larger sample sizes at common mileages. For the final inspection at 263,000 miles, wear data from the wheels in axle position 1 of the coal cars with disabled brakes were excluded from the analysis because all five of the wheelsets in axle position 1 of the coal cars with normal braking had already been removed, therefore no wear data was available. The wheels in axle position 1 generally showed slightly more wear than average due to the cars being oriented with the B-end leading more than 60 percent of the time during the first two years of the test.

Figure 2 shows the average profile area loss as a function of service mileage. There was not a discernible wear penalty from tread braking for the coal cars. It is more difficult to draw conclusions from the well cars, but tread wear and resulting total wear may indicate some influence from tread braking. The well car wheels had a noticeably higher wear rate (roughly twice as high or greater) than the coal car wheels regardless of brake status.

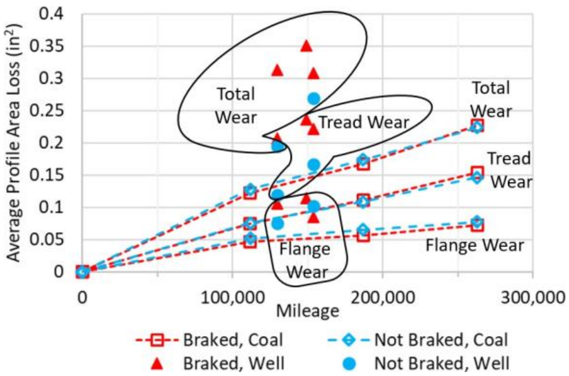

Figure 2. Wear area loss results for coal hopper cars and well cars separated by wheel flange and tread

Figure 3 shows the average wheel wear in terms of flange height and flange width. These results show that relatively little wear had accumulated on the coal car wheels after 263,000 service miles, further confirming no wear penalty from tread braking. Once again, the well car wheels exhibited a higher wear rate than the coal car wheels, but it is difficult to confidently point to a consistent difference in wear rates between the braked and unbraked well car wheels.

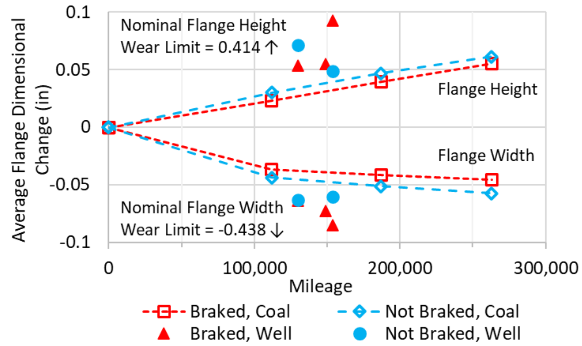

Figure 3. Flange height and width wear results for test cars

TREAD DAMAGE INVESTIGATIONS

Various combinations of visual evaluations, ultrasonic testing, magnetic particle inspection, optical microscopy, and metallurgical analysis were conducted on four of the wheelsets removed from one well car with disabled brakes and two coal cars with disabled brakes. Figure 4 shows two examples of the tread damage found on these wheelsets.

Figure 4. Photographs of RCF tread surface damage on two wheels removed from different cars with disabled brakes

Figure 5 shows an image of near-surface RCF cracking in a cross section of one of the wheels as viewed under an optical microscope.

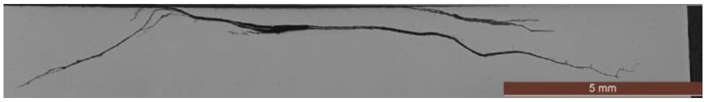

Figure 5. Optical microscopy shows typical RCF near-surface cracking

All of the analyzed wheelsets showed characteristics consistent with typical RCF tread damage observed on wheels in normal revenue service operations and did not give any indication of damage caused by the wheels sliding on the rail.

SERVICE ENVIRONMENT ANALYSIS

Locomotive event recorder files from two eastbound trips with the loaded coal cars were examined for air brake applications. Loaded trains were selected for this analysis because they would be expected to require additional applications of the air brake to control train speeds in comparison to the number of applications needed for empty trains. The first event recorder file covered 615 miles of service and noted 55 air brake applications. The second file pertained to an additional 575 miles and contained 36 applications. Only air brake applications that were initiated at a train speed greater than 15 mph were included in these counts. The average horsepower (hp) of each brake application was estimated based on the reduction in brake pipe pressure and train speed. Figure 6 shows the approximate hp and duration of each application and includes approximate isothermal lines derived from dynamometer data.[5]

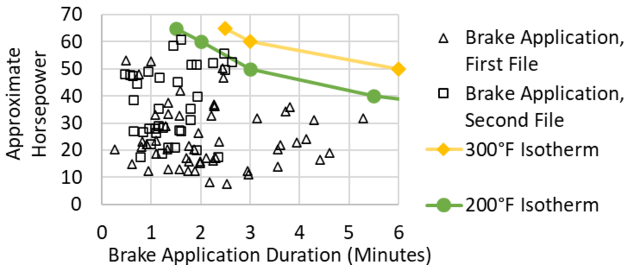

Figure 6. Estimated wheel temperatures

As many as nine of the analyzed applications may have exceeded 50 hp, but only for 3 minutes or less, and therefore, are not expected to have generated wheel temperatures much in excess of 200°F.

An analysis of more than 70,000 individual wayside wheel temperature detector readings from the coal cars involved in this test showed that the majority of the readings occurred while the train brakes were not applied, as evidenced by typical wheel temperature readings of about 30°F above ambient. Temperatures in this range are most likely the result of minor heating due to work at the wheel/rail contact patch. Figure 7 is a histogram of the analyzed wayside wheel temperature data.

There were a small percentage of wheel temperature readings greater than 70°F above ambient, primarily observed on the cars with unmodified brake systems. However, a total of three occurrences were noted in which one wheel in a car with the brakes disabled exceeded 70°F above ambient. Two of these three warm outlier wheels were still in service at the conclusion of the test and the other had been removed in good condition on account of the mate wheel.

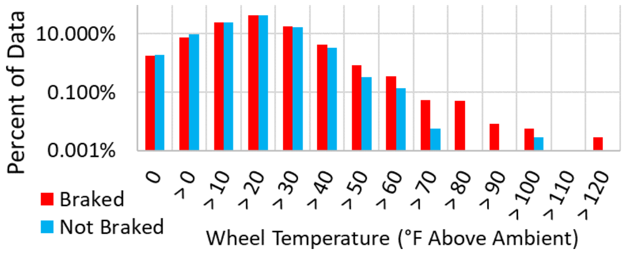

Figure 7. Wheel temperature data histogram

CONCLUSIONS

After more than three years in revenue service, a test of three intermodal well cars and five coal hoppers with disabled brakes has safely concluded. The wheelset survival rates for both car types and the wheel wear rates for the coal cars did not show statistical differences due to brake status. In both car types, typical wheel shelling originating from RCF was found despite a lack of braking.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the cooperative effort of Norfolk Southern Railway, TTX Company, BNSF Railway, Canadian National Railway, and Southern Company. The inspiration for this project and partial funding for the 52 new wheelsets used in the test came from the Wheel Defect Prevention Research Consortium (2016).

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