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High Performance Wheel Test: 88,000-mile Interim Results

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Summary

Eight types of high performance wheels are being evaluated by Transportation Technology Center, Inc. (TTCI) in a revenue service Union Pacific (UP) Railroad coal train as part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) Program to prevent wheel failures. The SRI is developing and testing high performance wheels to improve the wear and fatigue performance. In 2009, a revenue service test was initiated to quantify the benefits of eight types of high performance wheels paired with composition brake shoes in comparison to AAR Class C wheels paired with composition brake shoes and two types of tread conditioning brake shoes.

TTCI personnel conducted visual inspections of most of the test wheels after approximately 88,000 miles of revenue service. Shells and spalls were further investigated with etchant and surface hardness readings. At this relatively early stage in the test, the high performance wheels are performing similarly to AAR Class C wheels in terms of rolling contact fatigue (RCF) and shelling. The average wheel wear rate is extremely low for all types of wheels. AAR Class C wheels with tread conditioning brake shoe type B (TC-B) are showing more RCF cracks and shelling compared to all other wheel and brake shoe combinations. UP is replacing TC-B brake shoes with type A tread conditioning (TC-A) brake shoes. No safety concerns have been noted with the high performance wheels in the revenue service test.

In addition to the revenue service test, a limited number of wheels are undergoing a durability test in the controlled track environment at Transportation Technology Center (TTC). The operating conditions of the durability test are intended to accelerate RCF damage on the wheels. After approximately 48,000 miles of service at TTC, all of the wheels in the durability test were free of safety concerns and AAR condemnable defects. It is noteworthy that a smaller percentage of high performance wheels in the durability test have shells than compared to AAR Class C wheels. The average wear rates of Type 6 (bainitic) wheels and SRI wheels are higher than the other wheel types in the durability test.

Griffin, Lucchini, OneSteel, Standard Steel, Sumitomo, and Valdunes donated high performance wheels for this project. OneSteel is participating with two steel compositions. The SRI steel wheel is also being tested as part of this program.



INTRODUCTION

As part of the AAR's SRI program to prevent wheel failures, a revenue service test is being conducted on eight types of high performance wheels. The project is developing and demonstrating the benefits of high performance wheel steels, specifically focusing on improvements in resistance to wear and fatigue. The revenue service test is being conducted to quantify the benefits of each type of high performance wheel in comparison to the current standard AAR Class C wheels.

In addition to the revenue service test, a durability test is being conducted at TTC on a smaller sample of each type of wheel. The operating conditions of the durability test are intended to accelerate wear and fatigue damage on the wheels.

Griffin, Lucchini, OneSteel, Standard Steel, Sumitomo, and Valdunes donated high performance wheels for the project. OneSteel is participating with two steel compositions. TTCI's high performance wheel, known as the SRI wheel, is also being tested. With the exception of the SRI wheel, a generic naming convention is used in this *Technology Digest* (TD) to identify each manufacturer's wheels.

BACKGROUND

The testing of the high performance wheels consists of three phases, which overlap to some degree. First, laboratory testing was conducted on each wheel steel including measurements of mechanical properties, microcleanliness, and residual stresses.^{1,2,3} A microstructure evaluation determined that seven of the eight high performance wheel types were comprised of a pearlitic microstructure (similar to AAR Class C), but Type 6 was comprised of a bainitic microstructure. Next, the wheels were installed in loaded cars at TTC and subjected to a drag braking test and are currently involved in a durability test at the Facility for Accelerated Service Testing (FAST).^{4,5} The third phase of testing for the high performance wheels is the revenue service test, which began in August 2009. None of the testing completed to date has indicated any safety concerns related to the high performance wheels.

Steel hopper cars owned by the UP are being used in the revenue service test of the high performance wheels. The light weight of these cars is in the range of 61,000 pounds to 65,000 pounds, and the cars are rated for a gross rail load (GRL) of 286,000 pounds. Build dates on the cars range from 1979 through 1983. Immediately prior to the test, the cars went through a rebuild program consisting of a truck upgrade to AAR M-976 qualified Barber S2-HD-9C split wedge trucks with primary suspension shear pads and D5 spring nest. The cars were equipped with polymer center bowl liners and long travel constant contact side bearings with a nominal 6,000-pound preload. The brake arrangement is a body mounted rod-through-bolster design with the dead levers connected to the bolsters. Slope sheet empty/load devices provide a 50 percent reduction in brake cylinder pressure when the cars are empty.

High friction composition brake shoes (abbreviated as Cmp) were installed on all cars equipped with the high performance wheels and on 16 control cars with AAR Class C wheels. An additional 18 cars are equipped with AAR Class C wheels and one of two types of tread conditioning shoes (called TC-A and

TC-B in this TD). This was done to compare the life of high performance wheels not only to that of AAR Class C wheels with composition brake shoes, but also to the wheel life of AAR Class C wheels with tread conditioning brake shoes. Tread conditioning brake shoes were not paired with any of the high performance wheels to maximize the sample size of the high performance wheels paired with composition brake shoes. Stencils on each test car indicate which shoe type to apply when the shoes are in need of replacement. Additional details regarding the initial test conditions and the test plan have been reported previously.⁶ UP is in the process of replacing all of the TC-B brake shoes with TC-A brake shoes and updating the stencils on the cars to indicate this change.

A durability test of the high performance wheels was begun in 2008 involving three cars loaded to 286,000 pounds that had previously been exposed to high wheel temperatures in a drag brake test.¹ The wheels in these cars provide information about the performance of the wheels in a quasi-normal service environment after thermal abuse. Distributed among the three cars loaded to 286,000 pounds are four AAR Class C wheelsets and one wheelset of each type of high performance wheel. None of the AAR Class C wheelsets in the durability test were new at the beginning of the test. In addition, three cars loaded to 315,000-pounds GRL were equipped with 36-inch diameter high performance wheels and placed in the test train for durability testing. Heavier axle loads affect the fatigue life of a wheel by increasing the stress at the wheel/rail contact patch.

These six cars were placed in the test train at FAST to monitor the performance of the wheels with respect to fatigue, wear, and to identify any potential safety issues. The train at FAST is turned regularly and the direction of travel around the High Tonnage Loop (HTL) (clockwise/counterclockwise) is also varied so that every wheel accumulates approximately equal mileage in the leading and trailing positions of a truck and on the inner and outer rails of the loop. Although the HTL is largely comprised of 5- and 6-degree curves, few wheels are removed from the train for tread damage causes. This is most likely due to the careful control of rail friction, combined with minimal use of train brakes.

INSPECTION PROCEDURES

After 88,000 miles of accumulated revenue service, TTCI personnel visually inspected a total of 566 wheels from the revenue service test train without removing the wheels from the cars. The majority of the wheel tread surface was viewed, excluding where the rail or the brake shoe blocked access to the tread. The inspectors were specifically looking for RCF cracks, shells/spalls, and any indications of wheel sliding. When the visual inspectors identified shells or spalls on a particular wheel, a nondestructive testing technician documented the condition by applying etchant to look for martensite and performed a series of surface hardness tests near the affected area. Post inspection review of the notes, photographs, etching results, and hardness values were used to determine whether the damage on a wheel tread was the result of a sliding event (spalling) or fatigue (shelling).

While the cars in the test train have largely stayed together, not all of the cars with test wheels were present at the inspection site. Accordingly, not every wheel in the test was inspected.

REVENUE SERVICE TEST RESULTS

A wheel slide event that results in a spall is not reflective of the performance of the wheel. Thus, wheels with spalling damage were excluded from further analysis. Wheels without spalls were placed into one of two possible categories: “Shells” or “RCF Cracks or No Visible Damage.” Any wheel with at least one shell with a minor axis (smallest dimension) larger than 1/8 inch (3 mm) was placed in the Shells category. All other wheels without spalls were placed in the RCF Cracks or No Visible Damage category.

Table 1 is a categorized summary of the wheel tread conditions. Figure 1 shows the categorized percentages of unspalled wheels per wheel type. None of the wheels inspected had shells large enough to be deemed condemnable under AAR rules.

Table 1. Revenue Service Test Inspection Results

Wheel Type	Inspected Wheel Count	Spalled Wheel Count	Unspalled Wheel Count	RCF Cracks or No Visible Damage Wheel Count	Shells Wheel Count
1	56	1	55	54	1
2	48	0	48	48	0
3	58	5	53	51	2
4	36	0	36	36	0
5	42	1	41	41	0
6	44	0	44	41	3
7	42	0	42	41	1
SRI	24	2	22	22	0
C, Cmp	96	2	94	90	4
C, TC-A	64	0	64	64	0
C, TC-B	56	3	53	46	7

Data from a wayside wheel profile detector was compared to wheel profile data measured prior to the initiation of the revenue service test in August 2009. In this manner, average wear values of the flange width and tread (flange height) were established for each wheel type. Figure 3 shows the average wear rates categorized by wheel type and brake shoe combination. The flange width measurement is reported at a radial location relative to the worn tread surface, and thus, is somewhat dependent on the shape of the wheel profile.

The average wear rates of the wheels in the revenue service test are extremely low. Wear rates tend to be highest initially, and then lower as the wheels develop profiles that produce conformal contact with the rail.⁷ Although the wear rates for

many of the high performance wheels are higher than AAR Class C wheels at this early stage of the test, the wheel with the highest wear rate (Type 1) would still be projected to have a wear life longer than 500,000 miles. One Type 6 wheelset was removed for thin flange at 40,000 miles; this data is included in Figure 2.

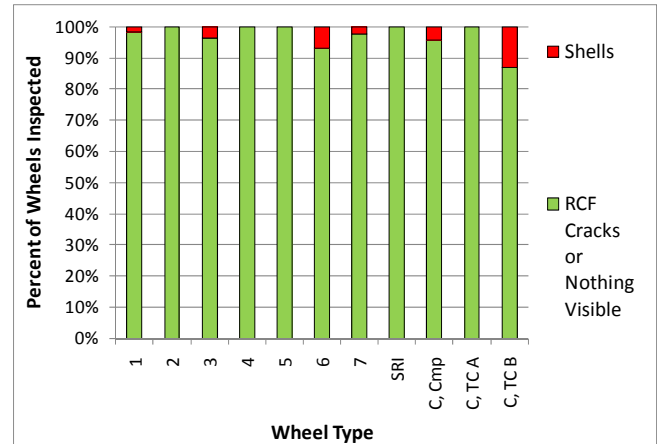


Figure 1. Tread Condition of Wheels in Revenue Service Test

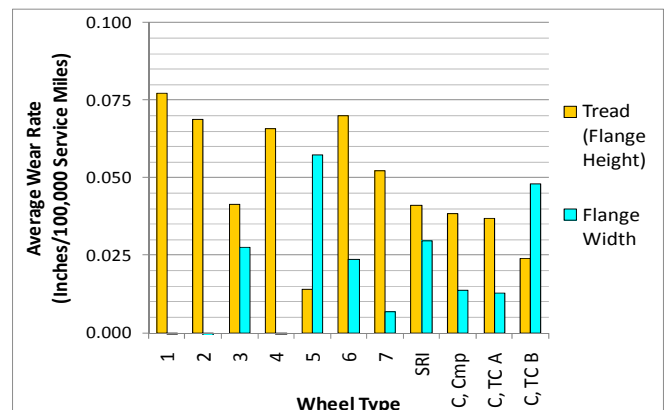


Figure 2. Wear Rate of Wheels in Revenue Service Test

WAYSIDE DETECTOR DATA

Wheel impact load detector (WILD) data for the test cars shows minimal problems with impact loads. Eight wheels from the revenue service test with known spalls have WILD readings in excess of 70,000 pounds. If these or other wheelsets from the test train are removed for cause, they will be set aside for inspection and to ensure that non-AAR Class C wheels do not become mixed with the general wheel population.

DURABILITY TEST RESULTS

TTCI personnel inspected the entire circumference of all 48 wheels in the durability test after 48,000 miles (the SRI wheels have approximately 8,000 fewer miles than the other wheel types). No spalling or evidence of wheel slides was found. Table 2 is a categorized summary of the wheel tread conditions of all of the wheels in the durability test. None of the wheels in the durability test had shells large enough to be deemed condemnable under AAR rules.

Table 2. Durability Test Inspection Results

Wheel Type	Wheel Count	RCF Cracks or No Visible Damage Wheel Count (Percent)	Shells Wheel Count (Percent)
1	6	5 (83%)	1 (17%)
2	6	6 (100%)	0 (0%)
3	4	4 (100%)	0 (0%)
4	4	4 (100%)	0 (0%)
5	4	3 (75%)	1 (25%)
6	6	6 (100%)	0 (0%)
7	6	6 (100%)	0 (0%)
SRI	4	4 (100%)	0 (0%)
AAR Class C	8	5 (50%)	4 (50%)

Both of the shelled high performance wheels are installed under 315,000-pound cars. All of the AAR Class C wheels are installed under 286,000-pound cars. Only two of the 24 wheels under 315,000-pound cars are free of RCF cracks and shells. Nine of the 24 wheels under 286,000-pound cars are free of RCF cracks and shells.

Figure 3 shows the wear rates of the wheels in the durability test based on hand measured wheel profiles. The wear rates are substantially higher for the wheels in the durability test compared to the wheels in the revenue service test. The AAR Class C wheels were not new at the start of the test, and therefore, it is not unexpected that they have more shelling and a reduced wear rate (wheels tend to wear most rapidly at the beginning of their life) compared to the other wheel types. Type 6 wheels (bainitic) show a higher tread wear rate than the other pearlitic wheel steels being tested, but a comparable flange wear rate. The SRI wheels in the durability test have a higher flange wear rate compared to the other wheel types, but a comparable tread wear rate. Results from the durability test should not be considered as significant as the results from the revenue service test, because of the small sample size and unique operating characteristics at FAST.

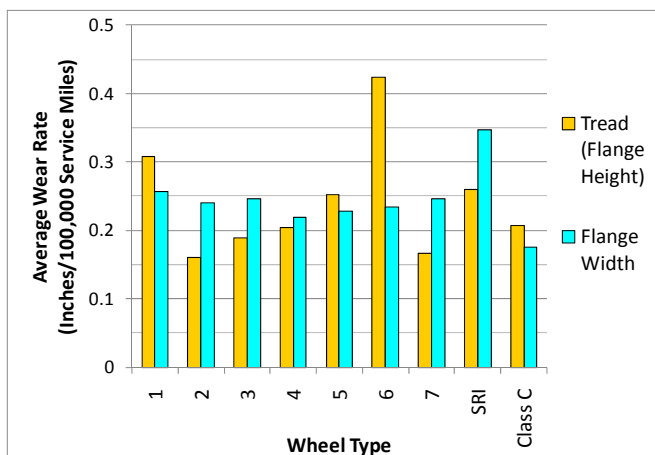


Figure 3. Wear Rate of Wheels in Durability Test

CONCLUSIONS

An inspection of the majority of the wheels involved in the revenue service high performance wheel test after 88,000 miles revealed the following:

- At this early stage in the test, the high performance wheels show similar performance compared to AAR Class C wheels in terms of RCF and shelling.
- The average wheel wear rate is extremely low for all types of wheels.
- AAR Class C wheels with TC-B brake shoes are showing more RCF cracks and shelling compared to all other wheel and brake shoe combinations. UP is replacing TC-B brake shoes with TC-A brake shoes.

After 48,000 miles in the durability test:

- A smaller percentage of high performance wheels have shells than compared to AAR Class C wheels.
- The average wear rates of Type 6 wheels and SRI wheels are higher than the other wheel types.

ACKNOWLEDGEMENTS

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