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High Performance Wheel Test: 223,000-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 testing high performance wheels designed 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 41 percent of the test wheels after approximately 223,000 miles of revenue service. Twenty-three percent of the inspected AAR Class C wheels paired with high friction composition brake shoes have medium sized shells. This is a substantially higher percentage than any other combination in the test with the exception of Type 7 wheels (22 percent).

In addition to the UP train revenue service test, a limited number of wheels are undergoing a durability test in the controlled track environment of the Facility for Accelerated Service Testing (FAST) at Transportation Technology Center (TTC). After approximately 89,000 miles of service at TTC, all of the Type 1, Type 6, and SRI wheels have been removed for cause. One wheelset each of Types 4 and 5 have also been removed for cause.

Shattered rim cracks have been found in three out of six Type 6 wheels and three out of four SRI wheels from the durability test at FAST. With this information, UP opted to remove all of the Type 6 wheels and SRI wheels from the revenue service test and send them to TTCI for further investigation. The investigation of the shattered rim wheels is an ongoing effort as of the time of this *Technology Digest* publication.

Griffin, Lucchini RS, 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.

Two types of high performance wheels (1 and 5) will be further evaluated in a Canadian National Railway unit coal train beginning in late 2012. Accelerated results are expected from that test from a combination of high traction forces, braking demands, and cold weather conditions.

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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 objective is to develop and demonstrate the benefits of high performance wheel steels, specifically focusing on improvements in resistance to wear and fatigue. The revenue service test is designed 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 RS, 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] 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).[2] The third phase of testing for the high performance wheels is the revenue service test, which began in August 2009.[3]

Steel hopper cars built in the early 1980s and 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. Immediately prior to the test, the cars went through a rebuild program including a truck upgrade to AAR M-976 qualified trucks and long travel constant contact side bearings.

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. During the rebuild in 2009, an additional 18 cars were 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.[3] In 2011, UP replaced all of the TC-B brake shoes with TC-A brake shoes and updated the stencils on the cars to indicate this change.

Five cars equipped with high performance wheelsets are operating in a durability test at FAST to monitor the performance of the wheels with respect to fatigue and wear and to identify any potential safety issues. Two of the cars are loaded to 286,000 pounds, and the other three cars are loaded to 315,000 pounds. All five cars are equipped with non-M976 3-piece trucks. 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.

REVENUE SERVICE TEST

After 223,000 miles of accumulated revenue service operation, TTCI personnel visually inspected a total of 270 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 rolling contact fatigue (RCF) cracks, shells/spalls, and any indications of wheel sliding. Post inspection review of the notes, photographs, and any etching results and/or hardness readings collected during previous inspections were used to determine whether the damage on a wheel tread was the result of a sliding event (spalling) or fatigue (shelling).

Many of the cars that started in the test train have been pulled out for various reasons. At the time of the inspection, 34 of the original 83 cars involved in the test remained in the same train. The other 49 cars had been scattered among different trains. Accordingly, not every wheel in the test was inspected, because not all of the cars with test wheels were present at the inspection site.

Shortly after the inspection of the wheels in the revenue service cars, cracks were discovered in three of the Type 6 wheels and three SRI wheels involved in the FAST durability test. Based on this development, UP decided to remove all of the Type 6 and SRI wheelsets from the revenue service cars and send them to TTCI for investigation. Additional details of the cracks in the Type 6 and SRI wheels are described in the following section.

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 five possible categories:

- "Medium Shells" — at least one shell with a minor axis (smallest dimension) larger than 1/8 inch

- "Small Shells" — visible shells, but none with a minor axis of 1/8 inch or larger
- "Large RCF Cracks" — visible RCF cracks ≥ 3/4 inch
- "Small RCF Cracks" — visible RCF cracks < 3/4 inch
- "Excellent Condition" — no visible shells or RCF cracks

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. TTCI personnel collected wheel profile data on 171 wheels during the inspection to facilitate wear evaluations between the different wheel types. Figure 2 shows the wheel wear rates of these 171 wheels. Note the sample size for Type 4 is quite small for both the visual inspection and the wear analysis, because of the small number of cars with this wheel type that have stayed with the train.

All non-AAR Class C wheels removed for cause are set aside for inspection and to ensure that non-AAR Class C wheels do not become mixed with the general wheel population. A total of 12 high performance wheelsets and eight AAR Class C wheelsets had been removed from the train for cause through June 2012. Table 2 lists details about the wheelsets removed from service prior to the inspection at 223,000 miles.

Table 1. Revenue Service Test Inspection Results

Wheel Type	Inspected	Wear Data Recorded	Spalled	Unspalled	Medium Shells	Small Shells	Large RCF Cracks	Small RCF Cracks	Excellent Condition
1	22	12	0	22	0	3	3	1	17
2	16	16	0	16	0	0	2	0	14
3	34	21	0	34	3	0	2	0	29
4	8	4	0	8	0	0	0	1	7
5	16	12	0	16	1	0	1	1	13
6	44	26	0	44	2	3	5	6	28
7	18	10	0	18	4	1	1	2	10
SRI	16	12	0	16	1	0	3	1	11
C, Cmp	22	14	0	22	5	1	1	1	14
C, TC-A	40	28	0	40	0	3	13	1	23
C, TC-B	32	16	0	32	2	6	3	4	17

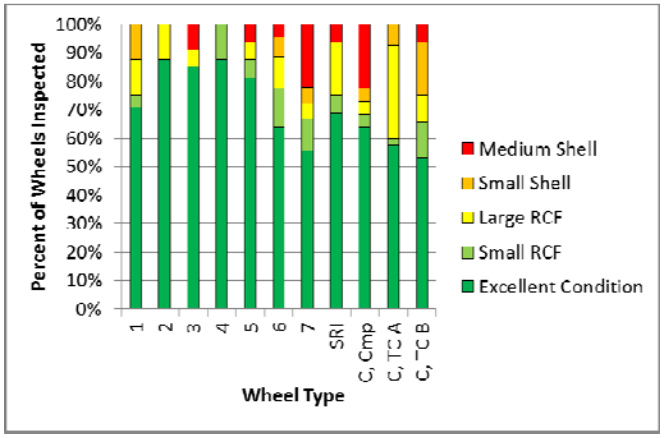

Figure 1. Tread Condition of Inspected Wheels in Revenue Service Test

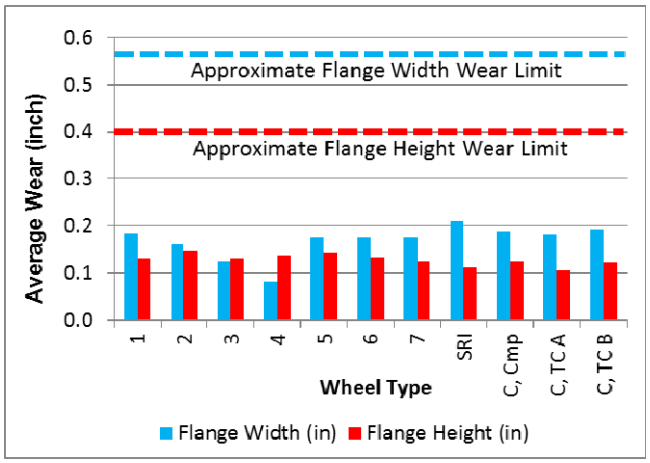

Figure 2. Wear of Inspected Wheels in Revenue Service Test

Table 2. Wheelsets Removed through May 2012

Type	Date	Mileage	Removal Code	Comments
6	6/10	40,000	60 – thin flange	
2	8/10	60,000	11 – removed in good condition	Hot bearing
5	3/11	75,000	75 – shelling	Spalls
5	3/11	75,000	61 –impact load	Spalls
C, Cmp	7/11	148,000	65 –impact load	
C, Cmp	7/11	148,000	25 – owner request	Impact > 90,000 pounds
6	10/11	170,000	61 – impact load	Spalls
C, TC-B	10/11	173,000	65 – impact load	
3	10/11	152,000	65 – impact load	Spalls
3	10/11	152,000	65 – impact load	Spalls
C, TC-B	11/11	185,000	65 – impact load	Spalls
5	2/12	160,000	65 – impact load	Spalls
4	2/12	100,000	61 – impact load	Spalls
4	2/12	100,000	65 – impact load	
SRI	3/12	158,000	65 – impact load	Spalls
SRI	3/12	162,000	75 – shelling	
C, TC-B	5/12	207,000	65 – impact load	Spalls
C, TC-B	5/12	210,000	61 – impact load	Spalls
C, TC-B	5/12	210,000	61 – impact load	Spalls
C, TC-B	5/12	210,000	25 – owner request	Spalls, Impact > 90,000 pounds

DURABILITY TEST AT FAST

Ten of the 21 high performance wheelsets in the durability test have been removed for cause. All of the Type 1, Type 6, and SRI wheelsets have been removed, as well as one wheelset each of Types 4 and 5. All of the remaining wheels in the durability test are still in acceptable condition with no shells larger than the "Small Shells" category. Table 3 lists some details about the wheelsets removed from the durability test.

As mentioned previously, cracks were discovered in three out of six of the Type 6 wheels and three out of four of the SRI wheels involved in the FAST durability test. All of the Type 6 wheels were removed for other causes, and the subsurface cracks were identified with ultrasonic methods after observing substantial metal flow from the tread surface toward the front rim face and the presence of deep shells. Upon sectioning the cracked wheels and exposing the crack surfaces, concentric fatigue rings were found.

Table 3. Wheelsets Removed from Durability Test

Type	Date	Mileage	Car Load (pounds)	Comments
5	10/11	68,000	315,000	Shells, high impact loads
1	1/12	73,000	315,000	Shells, high impact loads
1	2/12	76,000	315,000	Shells, high impact loads
1	2/12	73,000	286,000	Out of round, high impact loads
6	4/12	81,000	315,000	High flange, shells, shattered rim
4	4/12	82,000	286,000	Out of round, high impact loads
6	6/12	88,000	315,000	Shells, shattered rim crack
6	7/12	89,000	286,000	High flange, shells, shattered rim
SRI	8/12	86,000	315,000	Shattered rim
SRI	9/12	80,000	286,000	Shattered rim

The cracks in the SRI wheels are oriented parallel to the tread surface, as is the case with most shattered rims. The cracks found in the Type 6 wheels are oriented approximately 45 degrees from the tread surface. Scanning electron microscopy of one Type 6 wheel found no evidence of inclusions in the microstructure at the fatigue origin, whereas shattered rims typically originate at a large inclusion. Large impact loads are also thought to be a necessary condition for the initiation of typical shattered rim cracks, but none of the cracked wheels produced impact loads exceeding 70,000 pounds. However, operating conditions at FAST include a variety of track experiments that can expose the wheels to impact loads from running surface discontinuities one or more times per lap (2.7 miles). Substantial material flow on the wheel tread at the front rim face was found on the Type 6 wheelsets from the FAST durability test. Figure 3 shows an example of the material removed from one of these wheels. The Type 6 wheelsets from the revenue service test do not show material flow of this nature. The investigation of the shattered rim wheels continues.

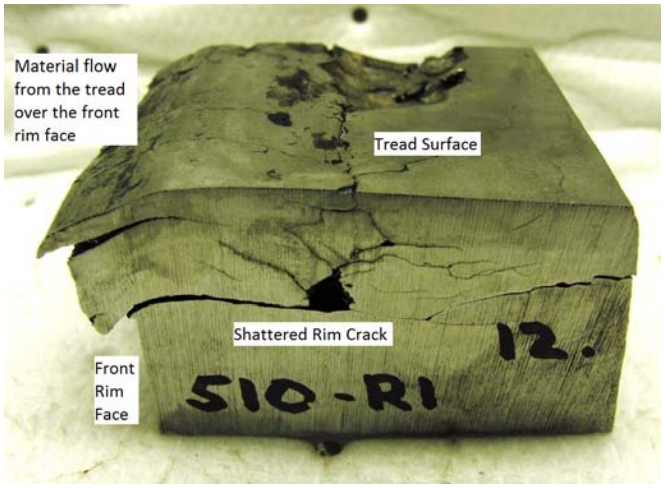

Figure 3. Section from a Type 6 Wheel Removed from the Durability Test

CONCLUSIONS

An inspection of 41 percent of the wheels involved in the revenue service high performance wheel test after 223,000 miles revealed the following:

- Twenty-three percent of the AAR Class C wheels paired with high friction composition brake shoes have medium sized shells. This is a substantially higher percentage than any other combination in the test with the exception of Type 7 wheels (22 percent).
- Thirteen out of the 20 wheelsets removed prior to the most recent inspection had spalling damage from wheel slides, as documented during previous inspections.

After 89,000 miles in the durability test at FAST:

- All of the Type 1, Type 6, and SRI wheels have been removed for cause. One wheelset each of Types 4 and 5 have also been removed for cause. The remaining wheelsets in the test remain in acceptable condition.

Type 6 and SRI wheels:

- Shattered rim cracks have been found in three out of six Type 6 wheels and three out of four SRI wheels from the durability test at FAST.
- UP opted to remove all of the Type 6 and SRI wheels from the revenue service test and send them to TTCI for further investigation.
- The metal flow from the tread to the front rim face was substantial on the Type 6 wheels that developed shattered rim cracks. Flow of this type has not been observed on any of the revenue service Type 6 wheels.

ACKNOWLEDGEMENTS

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