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High Performance Wheel Test: 158,000-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 158,000 miles of revenue service. Shells and spalls were further investigated with etchant and surface hardness readings. At this stage in the test, the majority of wheels are in good condition and the high performance wheels are performing similarly to AAR Class C wheels in terms of rolling contact fatigue (RCF) and shelling. Current wheel wear data is not available, but will be captured in future inspections. Two out of 22 AAR Class C wheelsets paired with high friction composition brake shoes have been removed from service after exhibiting impact loads greater than 90,000 pounds. No other wheelsets have been removed for non spall related tread damage. No safety concerns have been noted with the high performance wheels in the revenue service test.

In addition to the UP train 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 73,000 miles of service at TTC, Type 1 and Type 6 wheels both show higher tread wear rates than the other wheel types, and half of the Type 1 and Type 6 wheels have developed medium sized shells. One Type 5 wheelset was removed due to large impact loads from a shell at 68,200 miles. No safety concerns have been noted with the high performance wheels in the durability test.

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.

Three types of high performance wheels (1, 5, and SRI) will be further evaluated in a Canadian National Railway unit coal train beginning in 2012. Accelerated results are expected from that test due to 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] None of the testing completed to date has indicated any safety concerns related to the high performance wheels.

Steel hopper cars built in the early 1980's 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.

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.[2] The wheels in these cars provide information about the performance of the wheels in a quasi-normal service environment after thermal abuse. Originally, there were four AAR Class C wheelsets distributed among these cars and one wheelset of each type of high performance wheel. The AAR Class C wheelsets in the durability test were not new at the beginning of the test and have been removed. The remaining eight high performance wheelsets were consolidated between two cars. 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 five cars are operating in the test train at FAST to monitor the performance of the wheels with respect to fatigue and wear and to identify any potential safety issues. 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.

INSPECTION PROCEDURES

After 158,000 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 areas. 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).

About half of the cars that started in the test train have been pulled out for various reasons. Forty-six of the original 83 cars involved in the test remain in the same train. The other 37 cars are 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.

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 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 at least 3/4 inch in length
- "Small RCF Cracks" — visible RCF cracks shorter than 3/4 inch in length
- "Excellent Condition" — no visible shells or RCF cracks

Figure 1 shows representative photographs of medium and small shells. Table 1 is a categorized summary of the wheel tread conditions. Figure 2 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. Recent data from a wayside wheel profile detector was not available for analysis. In future inspections, TTCI personnel will take wear measurements during the inspection to facilitate wear evaluations between the different wheel types.

Figure 1. Medium Shells (left) and Small Shells (right) with an Inch Ruler for Size Reference

Table 1. Revenue Service Test Inspection Results

Wheel Type	Inspected	Spalled	Unspalled	Medium Shells	Small Shells	Large RCF Cracks	Small RCF Cracks	Excellent Condition
1	32	0	32	0	7	9	10	6
2	32	1	31	4	2	0	7	18
3	34	0	34	2	7	1	1	23
4	24	2	22	2	2	0	2	16
5	16	0	16	0	3	3	0	10
6	44	3	41	1	8	7	6	19
7	34	0	34	1	3	4	6	20
SRI	16	0	16	1	5	2	1	7
C, Cmp	22	3	19	2	2	1	3	11
C, TC-A	48	0	48	0	9	13	16	10
C, TC-B	64	9	55	10	9	7	12	17

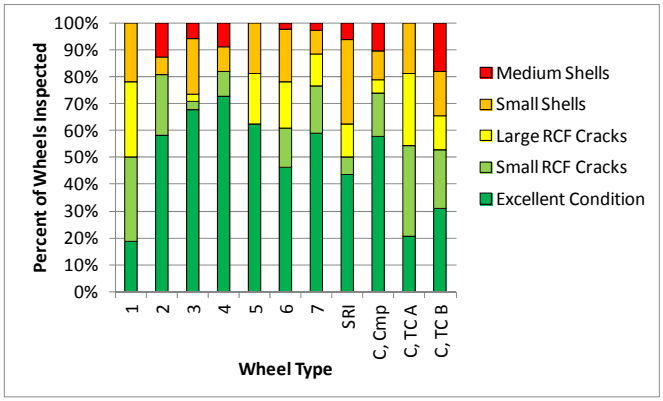

Figure 2. Tread Condition of Wheels in Revenue Service Test

WHEELSET REMOVALS

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. Table 2 lists details about the six wheelsets removed so far. Wheel impact load detector (WILD) data for the test cars shows that an additional 28 of the wheels still in the test have had at least one impact load greater than 70,000 pounds.

Table 2. Wheelsets Removed

Type	Mileage (x 1000)	Removal Code	Comments
6	40	60 – thin flange	
5	75	75 – shelling	Previously documented spalls
5	75	61 –impact load	
2	60	11 – removed in good condition	Hot bearing
C, Cmp	148	65 –impact load	Previously documented shells
C, Cmp	148	25 – owner request	Impact loads > 90,000 pounds

DURABILITY TEST RESULTS

TTCI personnel inspected the entire circumference of all 48 wheels in the durability test after 73,000 miles (the SRI wheels have approximately 8,000 fewer miles than the other wheel types). No spalling or evidence of wheel slides was found. One Type 5 wheelset was removed at 68,200 miles due to a large shell approximately 2.5 inches long by 0.75 inch wide that was producing impact loads of 87,000 pounds. The mate wheel was in excellent condition. Figure 3 shows a photograph of the wheel tread surface.

Figure 3. Shell on Type 5 Wheel

Table 3 is a categorized summary of the wheel tread conditions of all of the wheels in the durability test. Figure 4 shows the categorized percentages per wheel type. Fourteen of the 40 high performance wheels in the durability test have developed small or medium sized shells. Each car in the durability test contains at least one wheel with small or medium sized shells. The two cars loaded to 286,000 pounds GRL have seven wheels with small or medium sized shells, and the three cars loaded to 315,000 pounds GRL also have seven wheels with small or medium sized shells.

Table 3. Durability Test Inspection Results

Wheel Type	Inspected	Medium Shells	Small Shells	Large RCF Cracks	Small RCF Cracks	Excellent Condition
1	6	3	2			1
2	6			4	2	
3	4		1		1	2
4	4		1	2	1	
5	4	1				3
6	6	3	1	1		1
7	6	1		3	1	1
SRI	4		1		1	2

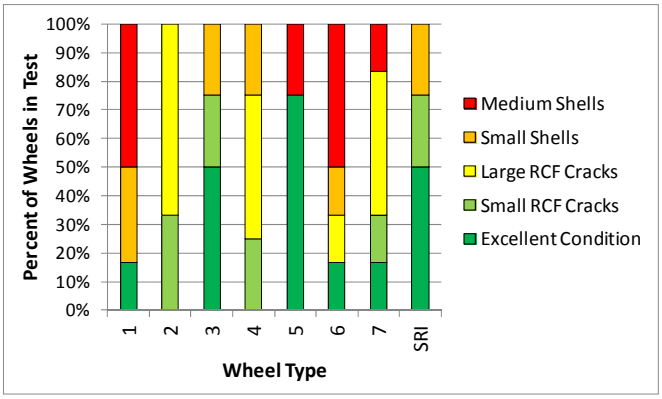

Figure 4. Tread Condition of Wheels in Durability Test

Figure 5 shows the wear rates of the wheels in the durability test based on hand measured wheel profiles. Type 6 wheels (bainitic) show the highest average tread wear rate. The Type 1, Type 5, and SRI wheels show somewhat higher average tread wear rates. Type 2, Type 3, and Type 7 wheels have the lowest average tread wear rates. All wheels show comparable average flange wear rates. 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.

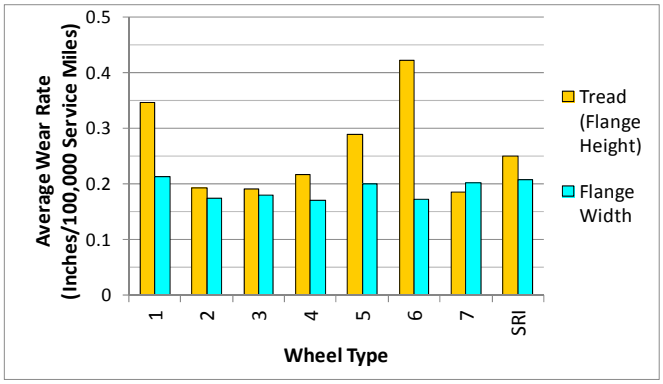

Figure 5. Wear Rate of Wheels in Durability Test

CONCLUSIONS

An inspection of the majority of the wheels involved in the revenue service high performance wheel test after 158,000 miles revealed the following:

- At this stage in the test, the majority of wheels are in good condition, and the high performance wheels show similar performance compared to AAR Class C wheels in terms of RCF and shelling.
- Two out of 22 AAR Class C wheelsets paired with high friction composition brake shoes have been removed from service after exhibiting impact loads greater than 90,000 pounds. No other wheelsets have been removed for non spall related tread damage.

After 73,000 miles in the durability test:

- Type 1 and Type 6 wheels both show higher tread wear rates, and half of the Type 1 and Type 6 wheels have developed medium sized shells.
- One Type 5 wheelset was removed due to large impact loads from a shell at 68,200 miles.

ACKNOWLEDGEMENTS

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