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# Interim Report: Comparison of AAR Class C and High Performance Wheels

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## Summary

Increased resistance to wear and shelling are vital to improving wheel life under increasingly challenging conditions.<sup>1</sup> Under the Association of American Railroads' (AAR) Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI) has been conducting long-term testing of high performance wheels (HPW) in laboratory, accelerated service, and revenue service environments. TTCI proposed material properties for HPWs that would provide superior service over AAR Class C steels. Based on limited testing, statistical analyses of test results do not predict high confidence estimates of life improvement, but the HPWs have had far fewer removals than the AAR Class C wheels.

Six manufacturers supplied HPWs for testing. An additional type designed by TTCI was also supplied. Material properties were tested from each of the wheel types. All of the steels met most of the required properties.

An accelerated test representing the eight wheel types began in 2008 at the Facility for Accelerated Service Testing (FAST) located at the Transportation Technology Center, Pueblo, Colorado. Several types of HPWs experienced shattered rims at FAST and were removed. Currently, two of the original wheel types remain in the test, with an average distance of 140,000 miles traveled. An additional wheel type was added in 2013, and it is displaying good wear and rolling contact fatigue resistance and has accumulated 58,000 miles to date.

In 2009, the test expanded to revenue service on a western United States railroad. The same wheel types used in the accelerated test were placed under cars in a unit coal train. AAR Class C wheels were used as a control group. The number of wheelsets of each type was much greater than those used in the accelerated test. TTCI personnel conducted visual inspections of the wheels semi-annually to assess the tread condition. Eight HPWs and 14 AAR Class C wheelsets have been removed for shelling or high impact wheels. The two HPW wheel types with the fewest removals also show the least wear.

Future testing will use an increased sample size of the best performing types of wheels.



**INTRODUCTION AND BACKGROUND**

In 2007, TTCI began an evaluation of improved wheel steels to determine which properties contribute to improved wear and fatigue performance. AAR Class D wheels were not yet defined or approved when this evaluation began, so the advanced wheel steels were designated HPWs. The laboratory testing data is available in a previous *Technology Digest*.<sup>1</sup>

There are two primary methods to improve mechanical properties of steels: chemistry and heat treatment. Both methods can affect the microstructure. Manufacturers have made many property improvements with the heat treatment and rim quenching of wheels. Chemistry changes can produce large microstructure and property changes, but these alloying elements are usually more expensive than those used for AAR Class C wheels.

Six manufacturers provided seven different wheel types for the FAST and revenue service testing. TTCI also developed an eighth wheel type with high performance wheel chemistry that was produced by two different manufacturers. The two grades were designated SRI and DS-SRI. All of the high performance wheel types were randomized, and each one was given a number to maintain anonymity of results.

**LABORATORY TESTING OF IMPROVED WHEEL STEELS**

In 2008, TTCI used one wheel of each type for independent mechanical and steel cleanliness testing. Multiple samples were tested for tensile properties, fracture toughness, and microcleanliness. The tensile and fracture toughness testing was conducted at room temperature and at -40°F.

**Microstructural Analysis**

Most railroad wheel steels have a pearlitic microstructure, which typically has been viewed as the optimized combination of strength and wear resistance. Seven of the eight wheel types were pearlitic, while Type 6 was bainitic. Figures 1 and 2, respectively, show examples of pearlitic and bainitic microstructures in test wheels at approximately 1000x.

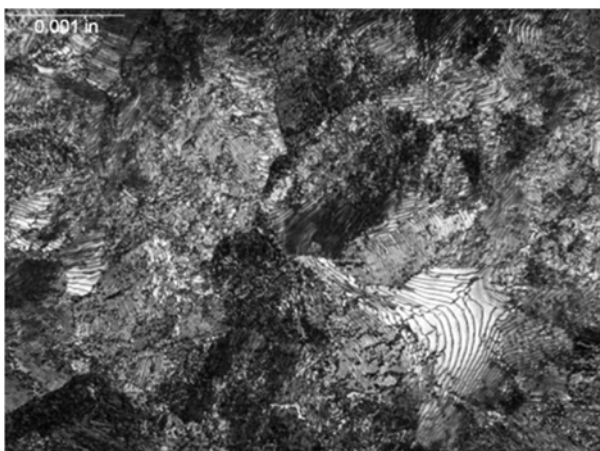


Figure 1. Pearlitic Microstructure of an AAR Class C Wheel

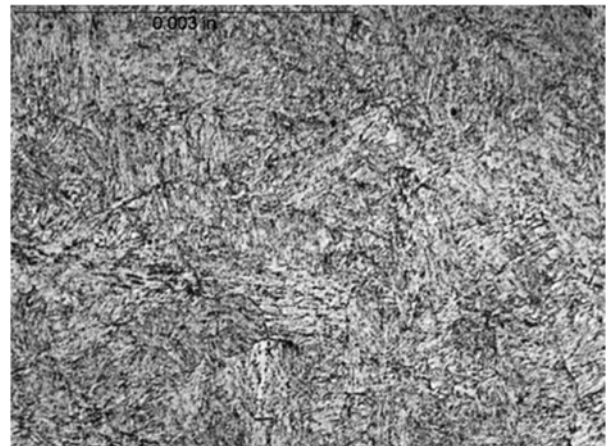


Figure 2. Bainitic Microstructure of a Type 6 HPW

**ACCELERATED TESTING AT FAST**

Durability testing of the wheels began in 2008 at FAST. The wheelsets were placed under 286,000-pound and 315,000-pound cars. Surface condition and wheel profiles were monitored two times per year. Table 1 is a summary of the wheelsets in the test at FAST. Types 3, 4, 6, and SRI experienced shattered rims or excessive wear and were subsequently removed.<sup>2</sup>

Currently, Types 2, 7, and DS-SRI are still running at FAST. None of the Type 2 wheels have been removed. Types 2 and 7 have accumulated the most distance, with an average of 140,000 miles. The DS-SRI wheels have only been in the test since early 2013, so their accumulated distance is less than other types. One has been removed for high impact. Most of the remaining wheels show surface initiated cracks, but material breakout from these is small.

Wheel wear was calculated by measuring the wheel profiles over time. Measurements included flange root radius, flange width, hollowing, and tread depth. These measurements are incorporated into the parameters  $S_d$ ,  $S_h$ , and  $qR$  and are shown in Figure 3.

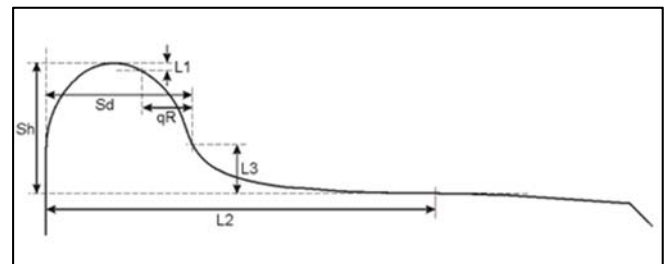


Figure 3. Parameters used in wheel wear determination

Using these parameters, wear between the different types was calculated. Types 2 and 7 had similar values and showed less wear than Types 1 and 5.

Table 1. Wheelset Information for Testing at FAST

Wheel Type	Initial Wheelsets	Current Wheelsets	Removed for Shelling or High Impact	Average Distance Travelled, miles
1	3	0	3	51,900
2	3	3	0	147,000
3	2	0	2	81,600
4	2	0	2	76,000
5	3	0	1	77,400
6	3	0	1	77,200
7	3	1	2	120,000
SRI	2	0	1	38,000
DS-SRI	16	15	0	57,900

**REVENUE SERVICE TESTING**

In 2009, the test expanded to revenue service in a unit coal train on a western United States railroad. With the exception of the DS-SRI wheels, the same HPW types were used in this portion of the test. All cars in this test were steel coal cars. AAR Class C wheels from various manufacturers were used as a control group. Some of them were used with high friction composition brake shoes and were designated CMP. The remaining AAR Class C wheels were used with two types of tread conditioning brake shoes, TC-A and TC-B. In 2011, the TC-B brake shoes were removed and replaced with TC-A shoes.

Most of the cars used the same wheel type on all axles; however, not all wheelset types were available in multiples of four, so some cars contained multiple wheel types.<sup>3</sup> Since 2010, TTCI personnel have conducted visual inspections and obtained profile measurements of the wheels. The cars are no longer in the same unit train, but have since been dispersed throughout the system. Because of this, fewer wheelsets have been inspected during more recent inspections.

Table 2 summarizes the initial and current number of the different types of wheelsets in the revenue service test.

Table 2. Wheelset Data for the Revenue Service Test

Wheel Type	Initial Wheelsets	Current Wheelsets	Removed for High Impact
1	29	26	1
2	28	27	0
3*	29	0	2
4*	30	0	3
5	23	18	2
6*	26	0	1
7	25	19	5
SRI*	13	0	1
Class C	126	104	14

\*Removed after wheels developed shattered rims at FAST

As previously mentioned, Types 3, 4, 6, and SRI HPWs experienced shattered rims or excessive wear at FAST. As a result, they were also removed from the revenue service test as a safety precaution.

Eight HPWs have been removed for shelling or high impact, and 14 AAR Class C wheels have been removed for the same reasons to date. The three best performing HPWs have only three of these removals among them.

Table 3 shows the average mileage accumulated to date in the test. The HPW numbers reflect only Types 1, 2, 5, and 7.

Table 3. Average Accumulated Distances for Wheels in the Revenue Service Test

Wheel Type	Average Mileage Active Wheels
Class C	274,700
HPW	288,700

Further analysis of the wheel life and removal data using Weibull and survival plots yields more information about the removals of the AAR Class C and HPWs. Figure 3 shows a Weibull probability plot, and Figure 4 shows a survival plot. Each point on the probability plot represents a wheel removed for high impact or shelling; approximately 11 percent of the AAR Class C and 8 percent of the HPWs have been removed for these causes. The average mileage of 282,000 is given by the vertical blue line in both graphs.

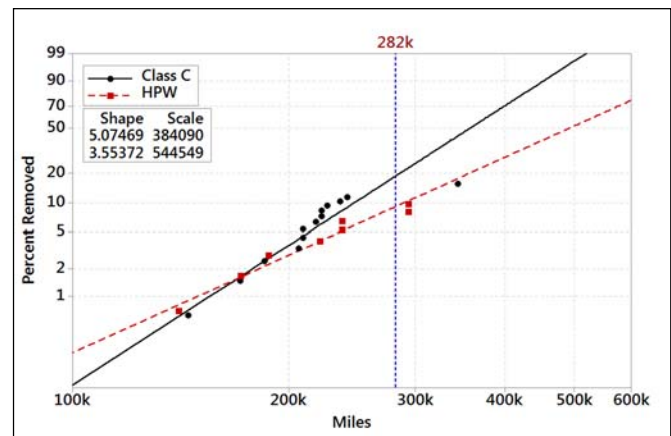


Figure 3. Weibull Probability Plot for AAR Class C and HPWs

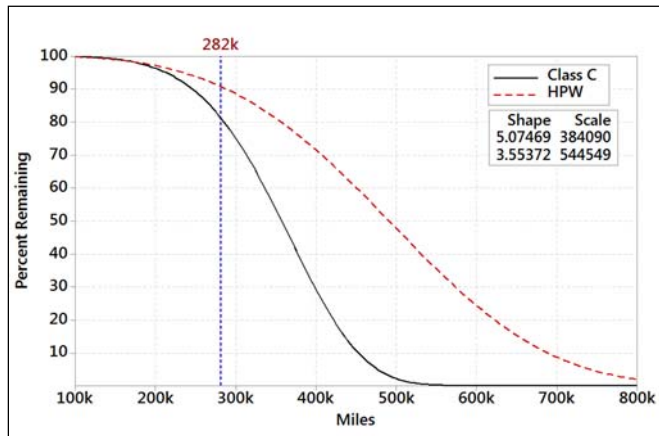


Figure 4. Survival Plot for AAR Class C and HPWs

Wheel wear in the revenue service test was calculated using the same parameters used in the accelerated testing at FAST. Due to the cars not being together in the same train and the same wheels not being measured each time, fewer profiles were collected. There was not enough data in the revenue service profiles to provide sound statistical analysis for wheel wear. Only one HPW has been removed for excessive wear. Wheel profile data from wayside detectors will be analyzed for these wheels, as almost all of them have passed through these detectors multiple times. This analysis will be available in the final report after the test concludes at the end of 2015.

## SUMMARY AND CONCLUSIONS

The HPWs were designed to improve performance to increase the service life of wheels as compared to the AAR Class C wheels.

TTCI proposed mechanical and metallurgical properties that were improvements over AAR Class C properties. Eight high performance wheel types, plus some AAR Class C wheel types, were examined. All of the wheel types met most of the desired properties.

Two to three sets of HPWs were placed under cars on the High Tonnage Loop at FAST. Types 3, 4, 6, and SRI experienced cracking and wear, and were removed from the test. Types 2 and 7 have accumulated the most distance, an average of 140,000 miles, and also show the least wear.

The test was then expanded to revenue service, with the same wheel types placed under coal cars in a unit train. AAR Class C wheels were used as a control group. To date, the wheels have accumulated an average of 282,000 miles. Eight HPWs have been removed for high impacts, while 14 AAR Class C wheelsets have been removed for high impact. Types 1 and 2 HPWs have seen the fewest high impact or shelling removals.

Wayside detector wheel wear data is being collected and will be analyzed for the final report at the end of 2015.

Future testing will use fewer wheel types, specifically the best performers from this test, and will increase the sample size for each type.

## REFERENCES

1. Hernandez, Francisco C. Robles, Semih Kalay, and Scott Cummings. January 2009. "Properties and Microstructure of High Performance Wheels." *Technology Digest* TD-09-001. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
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3. Cummings, Scott. September 2009. "Initiation of the Revenue Service Test of High Performance Wheels." *Technology Digest* TD-09-025. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

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