TTCI TECHNOLOGY DIGEST

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High Performance Wheel Tests Update

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Key Findings:

- Test 1 high performance wheels (HPW1) wheels are removed at the same rate as the Class C wheels but accumulate more miles before they are removed.
- HPW2 wheels have accumulated an average of 39,000 miles at FAST since 2017. To date, the wheel wear rates correlate well with material hardness and strength.
- Five HPW2 wheelsets were removed from the test after subsurface fatigue cracks were detected. Most of the crack bands began 2.30 inches from the front rim face and were about 0.50 inch wide. Crack depths varied but most have a maximum depth of 0.30 inch.

Transportation Technology Center, Inc. (TTCI) has been conducting two long-term high performance wheel (HPW) tests. The first HPW test (HPW1) began in 2008 and compared Association of American Railroads (AAR) Class C wheels to wheels made from new steels that potentially offered improved performance before AAR Class D requirements had been defined. The steels underwent laboratory testing, as well as on-track testing at the Facility for Accelerated Service Testing (FAST) Pueblo, CO, before moving to revenue service. Seven types of HPWs were included, but only four remained after the testing was completed. More detailed information on the testing process can be found in previous issues of *Technology Digest*.[1,2]

HPW1 wheels have been installed under coal cars with 20-30 wheelsets per HPW type and 127 sets of Class C wheels. Shelling, high impact, or subsurface cracks are counted as removals for cause. About 23 percent of the Class C wheelsets have been removed for cause. Types 1, 2, and 5 are the three best performing HPWs; about 12 percent of these have been removed for cause. A survival plot predicts the rate of Class C wheel failures will increase while HPW Test 1 wheel failures will remain constant (Figure 1). Additional failures may alter the shapes of the curves.

A second HPW test (HPW2) began in 2016 to evaluate current state of the art wheel steels. More wheel manufacturers have participated in this latest evaluation. There are 14 steels from 11 different manufacturers, some of which also participated in the first test (HPW1). Like the first test, HPW2 consists of laboratory testing, on-track testing, and revenue service. Previous *Technology Digests* discussed the laboratory test results and the initiation of on-track testing.[3,4]

The HPW2 wheels have accumulated an average of 39,000 miles at FAST. Normalized values of wheel profile area loss and flange height wear showed a range of wear rates. None of the HPW2 wheels have been removed for wear, though some flange widths will soon near condemnable limits.

Five wheelsets have been removed for subsurface cracks and will be sectioned for metallurgical examination. Most of the crack bands began just to the field side of the tape line.

HIGH PERFORMANCE WHEEL TEST 1 (HPW1)

In 2008, the HPW1 test was initiated to evaluate steels that potentially offered improved performance over AAR Class C wheels, consisting of eight HPW types plus AAR Class C wheels for comparison. The wheels underwent extensive laboratory testing, then on-track testing at FAST. Four wheel types developed problems, such as shattered rims, during the on-track testing. These wheel types were removed from the test. The remaining wheel steels were placed into revenue service in 2009. The wheels were installed under hopper cars in coal service on a western U.S. railroad. Four types of HPWs plus AAR Class C wheels remain in the test.

Performance has been monitored through wheel impact load detector (WILD) data, mileage updates, and repairs, as well as visual and ultrasonic inspections. Average mileage of cars in the test is 320,000. Causes for removal include shelling, high impacts, and subsurface fatigue cracks. Table 1 provides the mileage and number of removals for each wheel type. Types 1 and 2 have had the fewest removals at 7 percent, while Type 5 have had 20 percent removals. Type 7 has had the most removals at 32 percent, which is a higher percentage removed than Class C.

Table 1. Mileage and removals for wheels in HPW1 test

Wheel Type	Average Mileage	Number of removals
1	322,000 miles	2 (7%)
2	344,000 miles	2 (7%)
5	315,000 miles	5 (20%)
7	317,000 miles	8 (32%)
AAR Class C	314,000 miles	28 (23%)

Figure 1 shows a survival plot for the Class C and HPW1 wheels. The solid blue line represents the Class C wheels, the green line represents Type 7, and the dashed red line shows HPW types 1, 2, and 5. While the data do not show a statistical difference, the percentage of wheels remaining at the average mileage is about 91 percent for HPW types 1, 2, and 5 compared to 81 percent for the Class C and 74 percent for the Type 7 wheels. The survival plot predicts this trend will continue and that the Type 7 and the Class C wheels will fail at a faster rate than the HPWs. The curve predicts that at 500,000 miles about 42 percent of the Class C wheels will remain. The HPWs are predicted to have 74 percent remaining at this mileage. TTCI will continue to monitor the test wheels, analyze data from the railroad, and publish periodic updates.

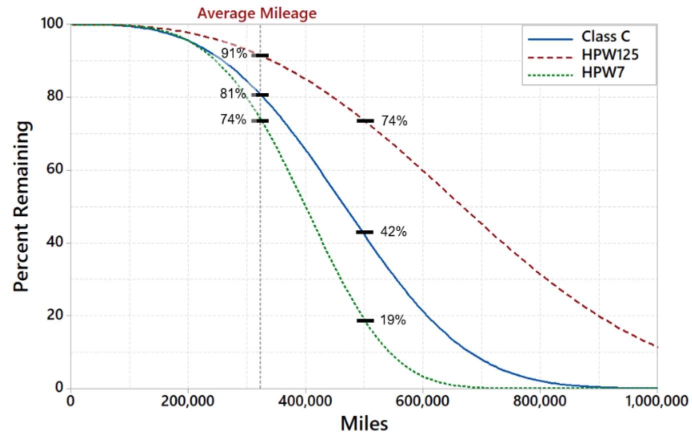

Figure 1. Survival plot of Class C and HPW Types 1, 2, and 5

HIGH PERFORMANCE WHEEL TEST 2 (HPW2)
On-Track Testing at FAST

The HPW2 test wheelsets are installed under 10 open hopper cars at FAST, each loaded to approximately 286,000 pounds. Most suppliers have three wheelsets running at FAST, while two suppliers have two wheelsets. The wheels have accumulated an average of 39,000 miles (see Figure 2).

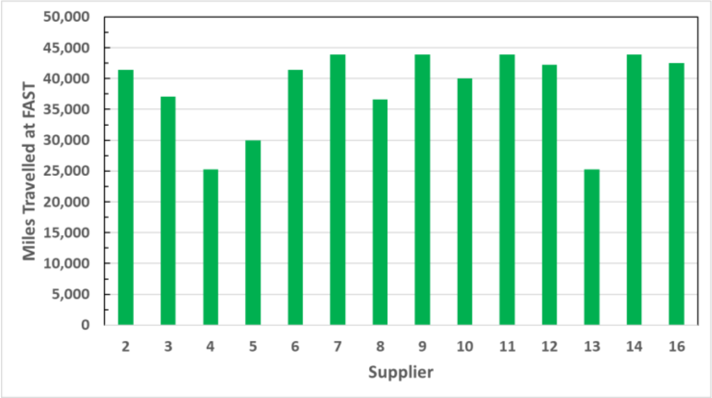

Figure 2. Average distance of travel for HPW2 wheels at FAST

The wheel profiles have been measured several times since the beginning of the test at FAST. The 2.7-mile loop contains several 5- and 6-degree curves, with very little tangent track. Figure 3 plots the normalized flange height measurements. These values correlate well with other properties such as hardness and strength. The normalized area loss was calculated and is plotted in Figure 4. The values show similar trends to the data in Figure 3.

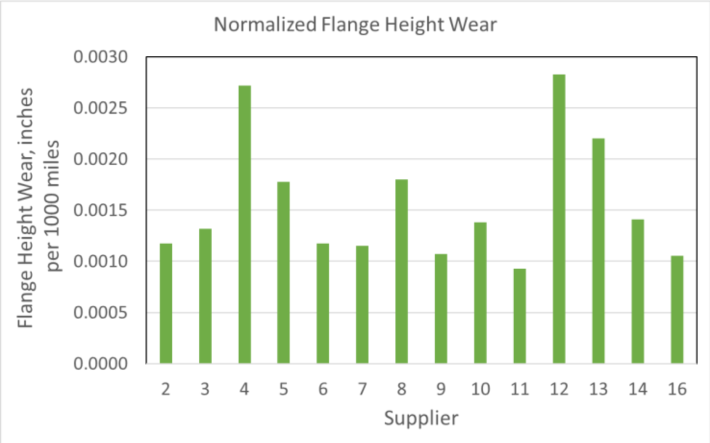

Figure 3. Normalized flange height wear for the HPW2 wheels

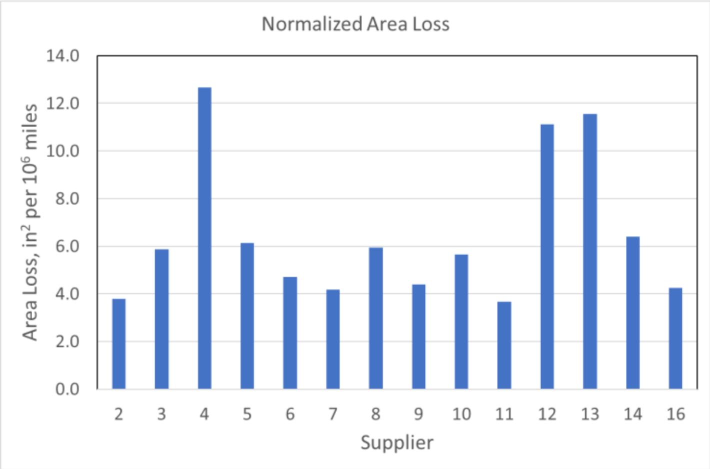

Figure 4. Normalized area loss values for the HPW2 wheels at FAST

SUBSURFACE FATIGUE CRACKS

Subsurface fatigue cracks have been detected in five HPW2 test wheels. The cracks were found by ultrasonic testing and the wheels were subsequently removed from the train. Two of the cracked wheels were from the same supplier. One wheel has been sectioned. Results of the remaining cracked wheel tests will be published in a future *Technology Digest*.

Table 2 provides information about the ultrasonic indications. Average values are given for wheels with multiple indications. In all five wheelsets, there were no indications in the mate wheels. Most of the crack band edges began 2.20 to 2.40 inches from the front rim face in narrow bands 0.16 to 0.50 inch across. The crack depth showed more variation than the other dimensions. This may have been due to the propagation pattern of the crack. When the wheels are sectioned, the crack depth can be accurately measured microscopically, as shown in Figure 5.

Table 2. Average dimensions of UT indications in cracked wheels

ID	Indications	Avg. Distance from Rim (in.)	Avg. Length, (in.)	Avg. Width, (in.)	Avg. Depth, (in.)
1	8	2.40	2.20	0.50	0.22
2	1	2.00	24.00	0.40	0.30
3	2	1.25	8.00	0.20	0.16
4	Continuous	2.20	---	0.16	0.13 – 0.34
5	15	2.30	6.02	0.50	0.27–0.30

Figure 4 shows both faces of a crack in the sectioned wheel. The texture of this crack surface is unusual in that there are multiple initiation points; typically only one is seen. Only minor surface pitting was visible on the tread above the crack. The remaining cracked wheels will also be sectioned and examined.

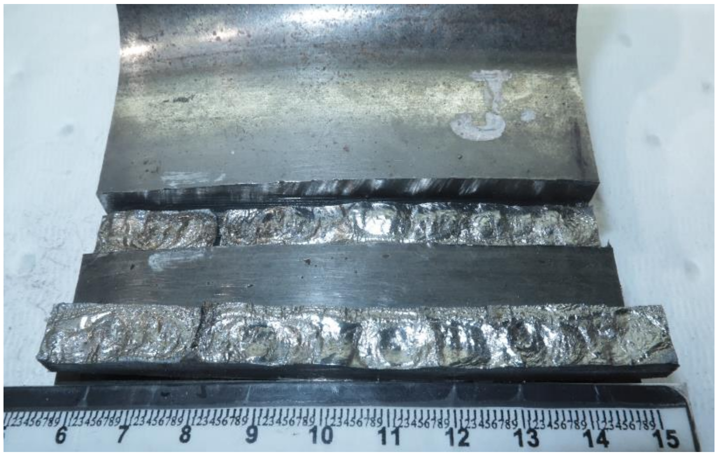

Figure 4. Subsurface fatigue crack found in test wheel

Figure 5 shows a longitudinal cross section of a crack in the same wheel from the tread surface to the lowest part of the crack. The crack depth varied from 0.162 to 0.225 inch. Near the surface, a standard two percent Nital etch reveals a very fine grain structure. Below about 0.138 inch the grain size increases. This may be due to the manufacturer's steel chemistry or thermal processing.

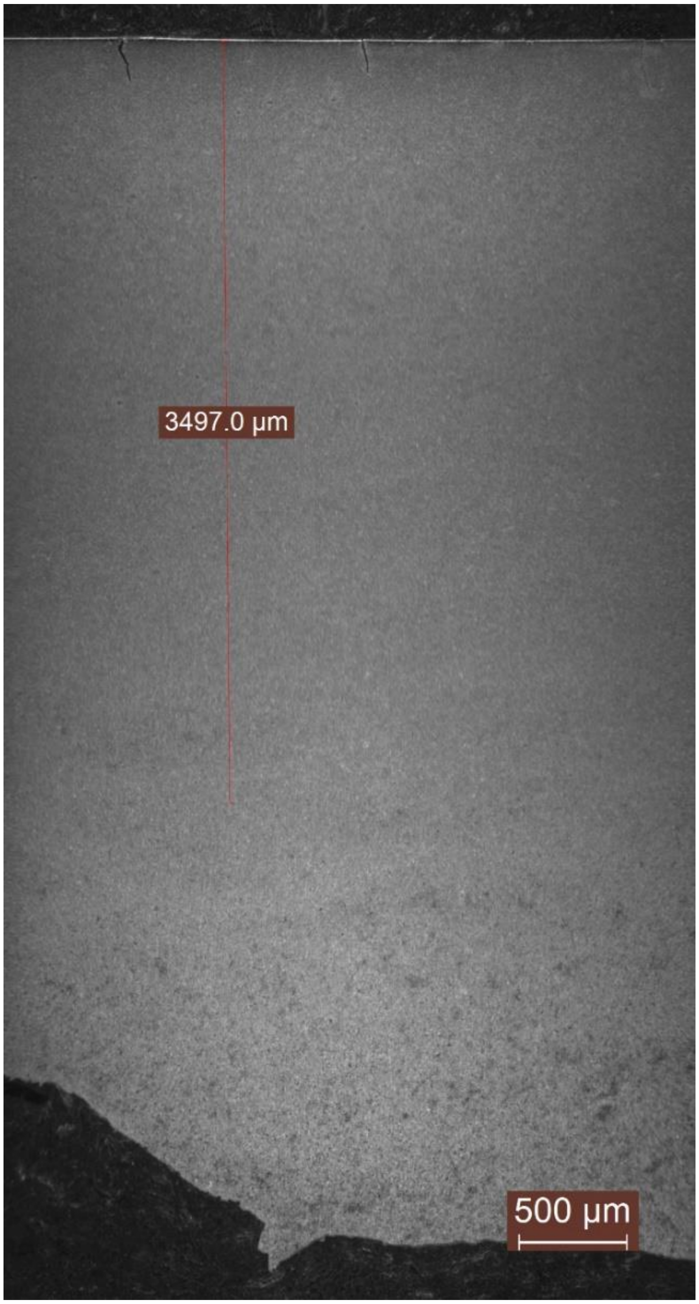

Figure 5. Photomicrograph of tread surface to crack

FATIGUE TESTS

Rotating beam fatigue tests have been completed for eight of the 14 suppliers. The remaining steels will be tested in 2020. This test provides the theoretical fatigue limit for a material, but is only comparable for the same conditions. The experimental fatigue limits will be compared to performance at FAST and during the revenue service portions of the test.

REVENUE SERVICE TEST

A Class I railroad has agreed to host the revenue service portion of the HPW2 test. The revenue service test will consist of approximately 25 wheelsets per supplier in addition to AAR Class C wheels for comparison. Test wheelsets will be installed under grain cars. If all suppliers participate, there will be approximately 350 high performance wheelsets in addition to the AAR Class C wheels. Wheel serial numbers and axle positions will be recorded, tread profiles will be captured, and visual examinations will be performed before test initiation. Subsequent periodic inspections will include profile measurement, visual examination, and ultrasonic investigation. Inspection intervals have not yet been determined.

References

1. Jones, K. I., DeGeorge, M., (June 2016) “Update: Comparison of Class C and High-Performance Wheels,” *Technology Digest* TD16-026, AAR/TTCI, Pueblo, CO.
2. Jones, K. I., “Interim Report: Comparison of AAR Class C and High-Performance Wheels,” (October 2015) *Technology Digest* TD15-032, AAR/TTCI, Pueblo, CO.
3. Jones, K. I, DeGeorge, M., (September 2018) “High-Performance Wheels: 320,000 Mile Update,” *Technology Digest* TD18-021, AAR/TTCI ,Pueblo, CO.
4. Jones, K.I., DeGeorge, M., Cong, T. ,(September 2018) “High-Performance Wheels: Laboratory Testing and Initiation of On-Track Testing,” *Technology Digest* TD18-022, AAR/TTCI, Pueblo, CO.

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