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Durability Test of High Performance Wheels: 20,000-Mile Interim Results

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Summary

Eight types of high performance wheels are currently undergoing a durability test in the controlled track environment at Transportation Technology Center, Pueblo, Colorado, as part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) Program to prevent wheel failures. The goal of this SRI is to develop and test high performance wheels to improve the wear and fatigue performance in revenue service. The operating conditions of the durability test are intended to accelerate rolling contact fatigue (RCF) damage on the wheels.

After approximately 20,000 miles of service, all of the wheels in the durability test were free of safety concerns and AAR condemnable defects. The inspection showed small RCF cracks on the tread surface of 21 of the 40 high performance wheels; however, most of the cracks were too shallow to produce visible indications using dye penetrant inspection methods. Additionally, five of the high performance wheels had developed very small shells. At least one wheel from each type of high performance wheel had RCF cracks or shelling. Estimates of the initial wear rates of the high performance wheels showed the wheel steel with the bainitic microstructure had a higher wear rate than any of the wheels with pearlitic microstructures. The durability test is ongoing, and wheel tread surface conditions and wheel wear rates continue to be assessed periodically.

Three cars in the durability test were loaded to 315,000 pounds to produce large contact stresses at the wheel/rail interface. The other three cars were loaded to 286,000 pounds and had been subjected to high wheel temperatures in a drag brake test prior to the start of the durability test.

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



INTRODUCTION

As part of the AAR's SRI program to prevent wheel failures, eight types of high performance 36-inch diameter wheels are currently undergoing a durability test. The goal of this project is to develop and demonstrate the benefits of high performance wheel steels. The operating conditions of the durability test are intended to accelerate fatigue damage on the wheels.

Griffin, Luchini, OneSteel, Standard Steel, Sumitomo, and Valdunes donated high performance wheels for this project. OneSteel is participating with two steel formulations. TTCI's high performance wheel steel, known as the SRI wheel, is also being tested. With the exception of the SRI wheel, a generic naming convention was used to identify each manufacturer's wheels.

Seven of the eight high performance wheels have a pearlitic microstructure, similar to AAR Class C wheels currently used in North American freight service. One wheel, identified as wheel 6, had a bainitic microstructure.

DURABILITY TEST

A durability test of the high performance wheels began in mid-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.

In addition, three cars loaded to 315,000-pounds gross rail load (GRL) were equipped with 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. Cars at this heavy axle load are intended to be used with 38-inch diameter wheels to provide a larger wheel/rail contact patch and to reduce the contact stress. Thus, placing the 36-inch diameter high performance wheels under cars loaded to 315,000 pounds provides a higher stress environment for the wheels compared to normal service conditions. Special wheel mounting procedures were used for the wheelsets in the 315,000-pound cars to fit the high performance wheels on the wheel seat of the AAR Class G (7x12) or AAR Class M (7x9) axles necessary to carry these heavy loads.

These six cars were placed in the test train at the Facility for Accelerated Service Testing (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 RESULTS

A visual inspection of the wheels involved in the durability test was conducted after the wheels had reached approximately 10,000 miles of service¹ and again at 20,000 miles of service. Cars are occasionally cut out of the test train for servicing, and so the mileage of the wheels in the durability test is not identical. Delays in the manufacturing of the SRI wheels necessitated a later start date for these wheels, and therefore they have accumulated fewer miles than the other wheels. Wheel profiles were recorded on all wheels to allow wear rates to be calculated. The AAR Class C wheels were not new at the start of these tests, so the total mileage is unknown. No conditions were observed on any of the wheels in the durability test that would qualify as condemnable under the AAR Interchange rules.

RCF cracks are a *potential* precursor to wheel shelling. RCF cracks are commonly referred to as "heat checks" and are not a condemnable condition according to AAR interchange rules.² Twenty-one out of 40 high performance wheels had RCF cracks, and five high performance wheels had very small shells. Two out of eight AAR Class C wheels in the test also had RCF cracks, and three AAR Class C wheels had small shells. Each of the six cars involved in the durability test had at least two wheels with RCF cracks or shelling. At least one wheel from each type of high performance wheel had RCF cracks or shelling. Although RCF cracks were observed on more wheels at the 20,000-mile inspection than at the 10,000-mile inspection, the cracks do not appear to be increasing in severity, possibly indicating that the rate of crack growth and wear are nearly equal. Dye penetrant was applied to the wheels that had RCF cracks visible on the tread surface. On the majority of wheels, the cracks were too shallow to hold a sufficient quantity of dye to produce a visible result upon application of the developer. Figure 1 shows an example of a wheel with RCF cracks that were visible upon inspection, but too shallow to show any result when dye penetrant was applied. Figure 2 shows an example of some of the deeper RCF cracks where the dye penetrant inspection method produced visible results.

Figure 3 is a photo of small wheel shells. These shells are the most severe shelling present on the test wheels. Small shells were observed on more wheels at the 20,000-mile inspection than at the 10,000-mile inspection, but the shells that were observed during the 10,000-mile inspection do not appear to be growing.

Because the HTL is largely comprised of curves, wheels in the train at FAST tend to concentrate wear near the flange root and between the tapeline and the rim, leaving a small ridge of material near the tapeline.



Figure 1. Example of RCF Cracks that were Too Shallow to Produce a Visible Result with Dye Penetrant Applied



Figure 2. Example of RCF Cracks that Produced a Visible Result with Dye Penetrant Applied

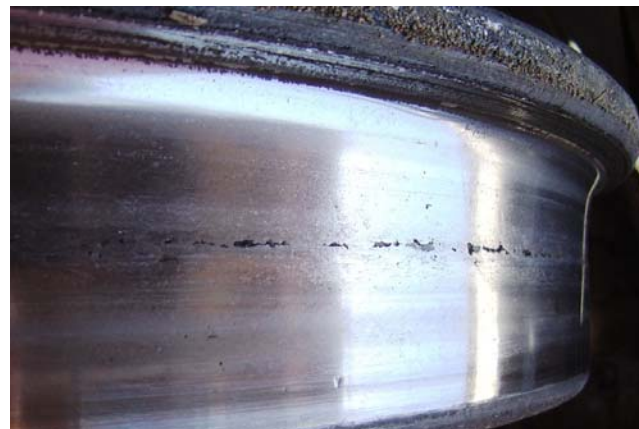


Figure 3. Small Wheel Shells Near the Tapeline Ridge

Figure 4 shows the HTL, and Figure 5 shows a typical worn wheel profile at FAST. The reverse curve of the HTL ensures that the rail contacts this ridge at least twice per lap (2.7 miles). The geometry of this ridge produces higher contact stresses compared to typical revenue service wheel/rail profiles. All of the shelling observed to date on the wheels in the durability test has occurred near the area of this ridge, implying that the durability test is accelerating fatigue damage not only with heavier axle loads or thermally abused wheels, but also through increased contact stresses due to the wheel wear profiles.

Table 4 lists the results of the inspection.

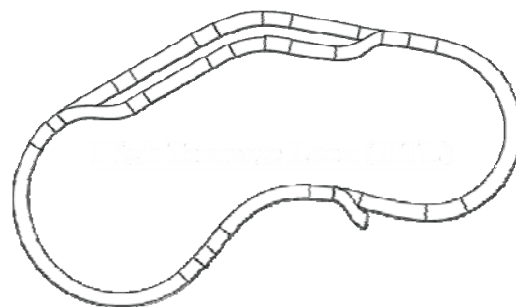


Figure 4. Outline of the HTL – Durability Test Site

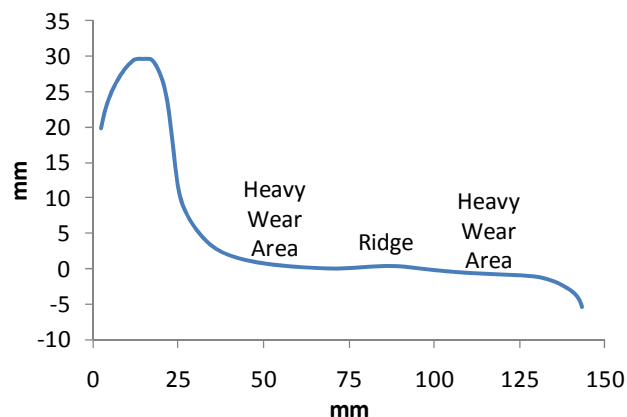


Figure 5. Typical Worn Wheel Profile at FAST Stretched along the Wheel Radial Dimension to Accentuate the Wear Ridge

Table 4. Wheel Inspection Results

Test Car No.	GRL*	Axle/Side	Wheel	Mileage	Comments
474	286	1L	7	21,664	RCF cracks
474	286	1R	7	21,664	RCF cracks, Tiny Shells
474	286	2L	AAR Class C	Unknown	Tiny Shells
474	286	2R	AAR Class C	Unknown	RCF cracks
474	286	3L	AAR Class C	Unknown	RCF cracks
474	286	3R	AAR Class C	Unknown	-
474	286	4L	1	21,664	-
474	286	4R	1	21,664	-
545	286	1L	4	21,356	-
545	286	1R	4	21,356	-
545	286	2L	3	21,356	RCF cracks
545	286	2R	3	21,356	-
545	286	3L	AAR Class C	Unknown	-
545	286	3R	AAR Class C	Unknown	Tiny Shells
545	286	4L	6	21,356	-
545	286	4R	6	21,356	-
546	286	1L	5	21,351	RCF cracks
546	286	1R	5	21,351	-
546	286	2L	SRI	15,695	-
546	286	2R	SRI	15,695	-
546	286	3L	AAR Class C	Unknown	Tiny Shells
546	286	3R	AAR Class C	Unknown	-
546	286	4L	2	21,351	RCF cracks
546	286	4R	2	21,351	-
331	315	1L	SRI	15,132	RCF cracks
331	315	1R	SRI	15,132	RCF cracks
331	315	2L	7	21,027	RCF cracks
331	315	2R	7	21,027	-
331	315	3L	1	21,027	-
331	315	3R	1	21,027	RCF cracks
331	315	4L	2	21,027	RCF cracks, Tiny Shells
331	315	4R	2	21,027	-
346	315	1L	6	21,346	Tiny Shells
346	315	1R	6	21,346	RCF cracks
346	315	2L	2	21,346	RCF cracks
346	315	2R	2	21,346	RCF cracks
346	315	3L	3	21,346	RCF cracks
346	315	3R	3	21,346	RCF cracks
346	315	4L	4	21,346	RCF cracks
346	315	4R	4	21,346	RCF cracks
514	315	1L	7	21,346	RCF cracks
514	315	1R	7	21,346	RCF cracks, Minor Shelling
514	315	2L	6	21,346	-
514	315	2R	6	21,346	-
514	315	3L	5	21,346	RCF cracks
514	315	3R	5	21,346	RCF cracks, Minor Shelling
514	315	4L	1	21,346	-
514	315	4R	1	21,346	-

*GRL units are pounds x 1,000

Figure 6 shows the average tread wear rate for each type of wheel in units of millimeters of wear per 10,000 miles of service. It should be noted that wheel wear rates tend to be highest when wheels are new, the sample sizes for the data in Figure 6 are small, the wheels are operated in an environment with an extremely high density of curved track, and wheel profile comparisons have some inherent subjectivity.

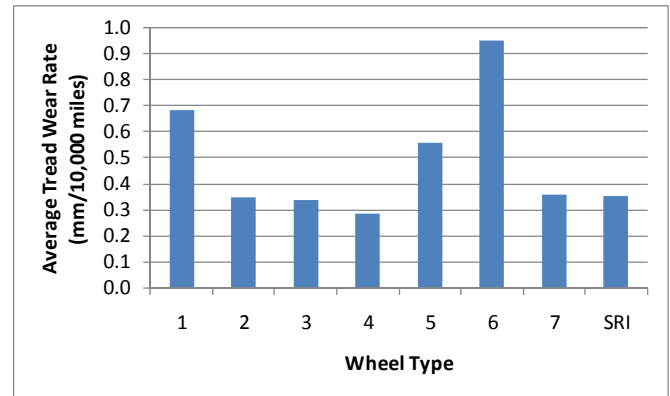


Figure 6. Tread Wear Rate

The bainitic wheel (wheel 6) shows a higher tread wear rate than the other wheels in the test, all of which have a pearlitic microstructure. This result is not surprising, because previous test results of rail wear rates have also shown that steel with a bainitic microstructure wears more quickly than steel with a pearlitic microstructure in the wheel/rail contact environment.³

CONCLUSION

All wheels have performed safely in the durability test, and none have developed condemnable defects. Shallow RCF cracks have appeared on 21 of the 40 high performance wheels, and minor shelling has developed on five high performance wheels with just over 20,000 miles of service. Estimates of the initial tread wear rates of the high performance wheels show that the bainitic wheel has a higher tread wear rate than the pearlitic wheels. Wheel tread condition and wheel wear will continue to be periodically assessed throughout the durability test.

A revenue service test of the high performance wheels will be initiated in 2009 on a Union Pacific coal train.

REFERENCES

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2. Association of American Railroads. 2009. *Field Manual of the AAR Interchange Rules*, Rule 41 - Wheels. Washington, D.C.
3. Sawley, K. and R. Jimenez. June 2001. "Track Wear Tests of Bainitic and Pearlitic Rails: Final Results." *Technology Digest* TD-01-012. AAR/TTCI, Pueblo, CO.

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