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## Drag Brake and Durability Tests of High Performance Wheels

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### Summary

Eight high performance wheel types have completed a drag brake test and 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' Strategic Research Initiatives (SRI) Program to prevent wheel failures. The goal of this SRI is to develop and test high performance wheels. The operating conditions of the drag brake test and the durability test are intended to accelerate the fatigue damage on the wheels.

All of the test wheels performed satisfactorily during the drag brake test. The durability test has revealed several issues related to wheel longevity. With less than 12,000 miles of service in the durability test, 12 of the 40 high performance wheels have developed small rolling contact fatigue (RCF) cracks and two additional high performance wheels have developed minor shelling. At least one wheel from each type of high performance wheel has RCF cracks or shelling. RCF cracks are considered a potential precursor to wheel shelling, although it is possible that the cracks could wear off prior to developing into shells. Estimates of the initial wear rates of the high performance wheels show large differences between wheel types. The durability test is ongoing and the wheel tread condition and wheel wear rates will continue to be assessed periodically.

Griffin, Lucchini, 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.



**INTRODUCTION**

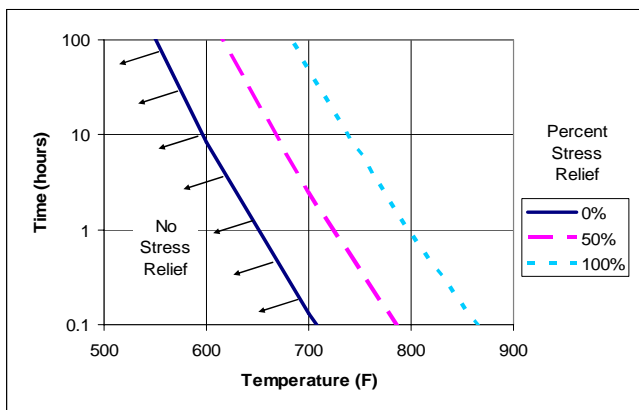
As part of the Association of American Railroads’ SRI program to prevent wheel failures, eight high performance wheel types have completed a drag brake test and are currently undergoing a durability test. The goal of this project is to develop and demonstrate the benefits of advanced or high performance wheel steels. The operating conditions of the drag brake test and the durability test are intended to accelerate the fatigue damage on the wheels.

Griffin, Lucchini, OneSteel (formerly Smorgon), Standard Steel, Sumitomo and Valdunes donated high performance wheels for this project. OneSteel is participating with two steel compositions. TTCI’s high performance wheel is also being tested.

The best test of the performance of the high performance wheels studied in this SRI will be their longevity in a revenue service train. Therefore, their performance under extreme operating conditions in a controlled environment is essential to ensure safe operation in revenue service.

**DRAG BRAKE TEST**

Elevated temperatures from tread braking affect the fatigue life of a wheel by reducing the yield strength and relieving beneficial residual stresses.<sup>1</sup> Figure 1 shows the estimated residual stress relief in an AAR Class C wheel as a function of time and tread temperature.



**Figure 1. Estimated Residual Stress Relief in AAR Class C Wheels<sup>1</sup>**

A drag brake test was conducted on one wheelset of each high performance wheel type and three control wheelsets with AAR Class C wheels. These wheelsets were installed in cars loaded to 286,000 pounds gross rail load (GRL). The cars were pulled at 25 mph around TTC’s 9.1-mile-long Transit Test Track (TTT) with the brakes applied. Each lap was completed in approximately 20 minutes. Three laps were completed in continuous succession during each test session. Table 1 shows the operating conditions of a typical test day. The drag brake test consisted of 5 test days total per wheelset and more than 250 miles traveled with the brakes applied. Figure 2 shows wheel plate bluing, which is indicative of exposure to heat from tread braking.

**Table 1. Typical Drag Brake Test Day**

Test Session	Train Speed (mph)	Brake Pipe Pressure Reduction (psi)	Number of Laps on TTT with Brakes Applied
Morning	25	12	3
<i>Stop consist, allow wheels to cool for approximately 2 hours</i>			
Afternoon	25	16	3



**Figure 2. High Temperatures have Blued this Wheel Plate during the Drag Brake Test**

During the drag brake test, wheel temperatures were measured once per lap using a wayside wheel temperature detector. Previous studies show that when wheels are heated with tread brakes, the wheel tread temperature can be estimated at 150°F hotter than the value reported by the wayside detector.<sup>2</sup> Figure 3 shows temperature statistics for each wheel in the drag brake test. The high performance wheels donated by the manufacturers are generically labeled 1 through 7. The presence of an “i” or “o” in the wheel name is used to identify wheels in the inner and outer rails of the TTT, respectively. Figure 4 shows the number of laps for each wheel at elevated temperatures. Some wheels did not reach the elevated temperature (>650°F).

Freight car brake systems do not distribute the heat load evenly to all wheels in the car. Thus, each wheel involved in the brake test was exposed to a different temperature history. While not ideal, this is an unavoidable outcome of a drag brake test. According to the curves in Figure 1, some of the wheels were heated sufficiently during the drag brake test to relieve beneficial residual stresses. Other than heat discoloration, no damage was visually observed on any of the wheelsets involved in the drag brake test. Select wheels were

inspected for thermal cracks using the magnetic particle method following the drag brake test. No cracks were found.

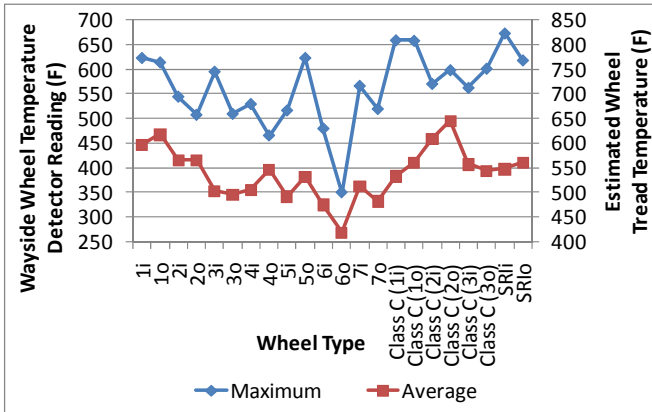


Figure 3. Wheel Temperature Statistics

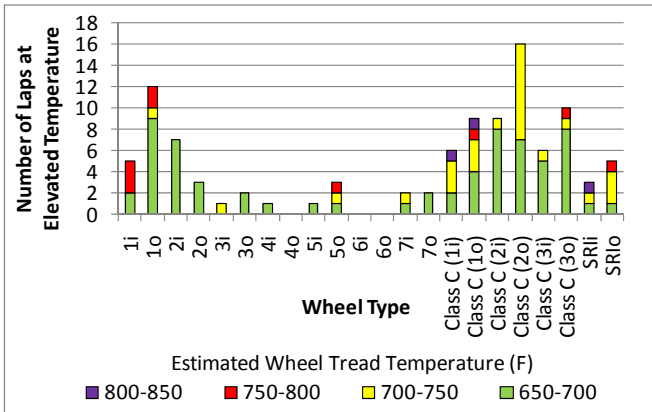


Figure 4. Number of Laps at Elevated Temperature

**DURABILITY TEST**

Following the drag brake test, the 286,000-pound cars with the high performance wheels were placed in the test train at FAST for durability testing to monitor the performance of the wheels in a quasi-normal service environment after thermal abuse.

In addition, three cars loaded to 315,000-pounds 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 load are intended to be used with 38-inch diameter wheels to provide a larger wheel/rail contact patch and 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.

Although the High Tonnage Loop where the test train operates 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.

A visual inspection of the wheels involved in the durability test was conducted after the wheels had reached approximately 10,000 miles. Wheel profiles were recorded on all wheels. This allowed the wear rates of the wheels in the 315,000-pound cars to be calculated. Initial wheel profiles were not recorded on the wheels in the 286,000-pound cars, so the wear rate was not able to be calculated. 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. The Class C wheels were not new at the start of these tests, so the mileage is unknown. Figure 5 shows an example of RCF cracks observed on many of the wheels. Figure 6 shows minor shelling present on two wheels. Table 2 lists the results of the inspection.

RCF cracks are a potential precursor to wheel shelling. These cracks may either wear off or grow, connect, and turn in to shells. Fifteen out of 48 wheels have RCF cracks and 2 more have minor shelling. Each of the six cars involved in the durability test has at least one wheel with RCF cracks. At least one wheel from each type of high performance wheel has RCF cracks or shelling. The presence or absence of RCF cracks on the wheels in the 286,000-pound cars is not well correlated with the wheel temperatures from the drag brake test.



Figure 5. RCF Cracks were observed on 15 of 48 Wheels



Figure 6. Minor Wheel Shelling was observed on Two Wheels

Table 2. Wheel Inspection Results

Test Car No.	GRL*	Axle/Side	Wheel**	Mileage	Comments
474	286	1L	7i	11,472	-
474	286	1R	7o	11,472	-
474	286	2L	Class C (2i)	Unknown	RCF cracks
474	286	2R	Class C (2o)	Unknown	RCF cracks
474	286	3L	Class C (1i)	Unknown	-
474	286	3R	Class C (1o)	Unknown	RCF cracks
474	286	4L	1i	11,472	-
474	286	4R	1o	11,472	RCF cracks
545	286	1L	4i	8,678	-
545	286	1R	4o	8,678	-
545	286	2L	3i	8,678	RCF cracks
545	286	2R	3o	8,678	-
545	286	3L	Class C (3i)	Unknown	-
545	286	3R	Class C (3o)	Unknown	-
545	286	4L	6i	8,678	-
545	286	4R	6o	8,678	RCF cracks
546	286	1L	5i	8,041	-
546	286	1R	5o	8,041	-
546	286	2L	SRli	2,385	-
546	286	2R	SRlo	2,385	-
546	286	3L	Class C	Unknown	-
546	286	3R	Class C	Unknown	-
546	286	4L	2i	8,041	RCF cracks
546	286	4R	2o	8,041	-
331	315	1L	SRI	2,385	-
331	315	1R	SRI	2,385	RCF cracks
331	315	2L	7	8,349	-
331	315	2R	7	8,349	-
331	315	3L	1	8,349	-
331	315	3R	1	8,349	RCF cracks
331	315	4L	2	8,349	-
331	315	4R	2	8,349	-
346	315	1L	6	10,475	-
346	315	1R	6	10,475	RCF cracks
346	315	2L	2	10,475	-
346	315	2R	2	10,475	RCF cracks
346	315	3L	3	10,475	-
346	315	3R	3	10,475	-
346	315	4L	4	10,475	RCF cracks
346	315	4R	4	10,475	-
514	315	1L	7	10,748	-
514	315	1R	7	10,748	Minor Shelling
514	315	2L	6	10,748	RCF cracks
514	315	2R	6	10,748	-
514	315	3L	5	10,748	-
514	315	3R	5	10,748	Minor Shelling
514	315	4L	1	10,748	RCF cracks
514	315	4R	1	10,748	RCF cracks

\*GRL units are pounds x 1,000, \*\*The wheel label convention was the same from the drag braking test

Figure 7 shows the average tread wear rate for each type of wheel in units of millimeters of wear per 10,000 miles of service. While this is the best assessment of wear rate with the currently available data, several sources of error should be considered. Wheel wear rates tend to be highest when wheels are new and slow down as the wheel profiles wear to a more conformal fit with the rail profile. The average wear rates are calculated from small sample sizes (either 2 or 4 wheels of each type) using wheels that are loaded in excess of their expected service loads and operated in an environment with an extremely high density of curved track. Wheel profile comparisons have some inherent subjectivity and are more prone to error when small amounts of wear are involved, as is the current case.

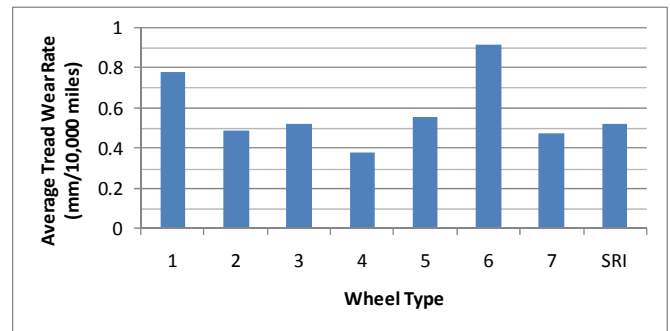


Figure 7. Tread Wear Rate

**CONCLUSION**

During the drag brake test, all of the high performance wheels performed satisfactorily with respect to any safety related issues, which would affect their placement into a revenue service train. To date, all wheels have performed safely in the durability test as well. RCF cracks have appeared on 12 of the 40 high performance wheels and minor shelling has developed on two additional high performance wheels with less than 12,000 miles of service. Estimates of the initial wear rates of the high performance wheels show large differences between wheel types. Wheel tread condition and wheel wear will continue to be periodically assessed throughout the durability test.

**REFERENCES**

1. Stone, D. and S. Cummings. 2008. "Effect of Residual Stress, Temperature and Adhesion on Wheel Surface Fatigue Cracking." RTDF2008-74029, *Proceedings of 2008 Fall Conference of the ASME Rail Transportation Division*, Chicago.
2. Cummings, S., H. Tournay, K. Gonzales. March 2008 "Wayside Wheel Temperature Detector Test," *Technology Digest* TD08-013. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

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