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Braking Test of a Thirty-Six Inch Wheel for 315,000-Pound Cars

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Summary

Equipping 315,000-pound cars with 36-inch wheels exceeds current AAR Load limits, but results in a better net-to-tare ratio than currently used car/truck configurations for 263,000- or 286,000-pound cars. The improved net-to-tare ratio can help offset the increased track maintenance cost associated with the operation of heavier cars, thus making freight operation more productive and more profitable. While early studies indicate that the higher wheel loads provide acceptable performance for 315,000-pound cars, there are some concerns about the braking performance of the 36-inch wheels, which weigh about 200 pounds less than the 38-inch wheels typically used for 39-kip wheel loads.

To test the thermal capacity of 36-inch wheels for 315,000-pound cars, a dynamometer drag brake test was done on a 36-inch wheel following 82,000 miles of service on the Facility for Accelerated Service Testing (FAST) located at the Transportation Technology Center (TTC). The test was set up to simulate extreme braking on a steep grade for 60 minutes followed by a full service brake set. This was done for three runs. A rail wheel was used in connection with the dynamometer to better simulate actual operating conditions.

The following table summarizes test conditions for the three runs:

Run	Brake Horsepower	Speed (MPH)	Test Duration (Minutes)	Wheel Tread Maximum Temperature (°F)	Time to Max Temp (Minutes)
1	45	20	60	1013	60
2	45	20	60	915	50
3	45	20	60	901	45

After the dynamometer test, the test wheel was cut and analyzed. The wheel remained in compression after the drag brake test was performed on the dynamometer. Initial studies point to 36-inch wheels performing similarly to 38-inch wheels. While these studies do show promise, additional tests are needed before firm conclusions can be drawn on the effects that 315,000-pound cars have on 36-inch wheels. Comprehensive testing would be required before revenue-service acceptance.



INTRODUCTION

Around the world, the tendency over the past few decades in rail freight operations is to increase gross weight and capacity of freight cars. Increasing the gross weight and capacity is one way to improve productivity. If the ratio of net-to-gross tons can be increased, additional savings can be achieved in fuel and equipment costs. An increase in capacity and a reduction in meet-pass delays should also result due to fewer trains being needed to move a given tonnage.

During the past 15 years, the Transportation Technology Center, Inc. (TTCI) has completed research in safety, technical, and economic issues related to increasing axle loads. TTCI's Heavy Axle Load (HAL) program operates on the Facility for Accelerated Service Testing (FAST) track located at TTC in Pueblo, Colorado.

Economic analysis has shown that 315,000-pound cars equipped with 36-inch wheels can be more economical than 263,000- and 286,000-pound cars equipped with 36-inch wheels, or 315,000-pound cars equipped with 38-inch wheels and larger, heavier trucks. The improved net-to-tare ratio offered by the 36-inch wheel car/truck configuration can help offset the increased track maintenance cost associated with the operation of heavier cars.

The 38-inch wheels under 315,000-pound cars at FAST have performed well. It is believed that similar results can be achieved with 36-inch wheels under 315,000-pound loads. There are however, some wheel performance concerns about 36-inch wheels under 315,000-pound cars. The areas of concern are:

- Wheel wear and wheel surface conditions
- Thermal failure and braking
- Contact stresses/shattered rims and shells

In 2002, three cars at FAST were equipped with 36-inch wheels and trucks designed for 315,000-pound cars to further investigate these and other performance issues. The cars, always loaded and with infrequent use of brakes, operate on the High Tonnage Loop, which is a 2.7 mile track that is about 75 percent curves (5 and 6 degree) and spirals. The performance of the test components has been similar to the wheels and trucks in the rest of the train.¹

WHEEL PROFILES

Profiles of the tested 36-inch wheels are regularly measured with a MiniProf™ profilometer. Figure 1 shows a new 36-inch wheel compared with the same wheel with 82,000 miles of service wear at FAST.

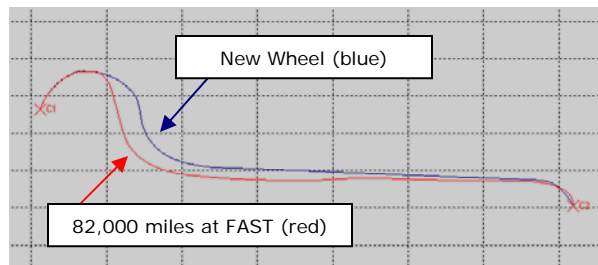


Figure 1. Wheel Profiles of a 36-inch Wheel under 315,000-Pound Car

Compared to when the tested 36-inch wheel was new, there is about 3 mm of wear at the wheel tread and close to 6 mm of wear at the wheel flange. This wheel was dynamometer brake tested.

THERMAL FAILURE AND BRAKING

Thermal failure occurrences are due to the formation of thermal cracks. Thermal cracks form due to tensile residual stresses from repeated cycles of heating and cooling that occur during drag braking. Thermal cracks are distinguished in appearance from rolling contact fatigue by their length and orientation. These cracks extend vertically into the surface material. Impact may cause accelerated crack growth and may cause the wheel to fracture.²

Residual compressive stresses are the controlling factor in wheel thermal failure. Residual compressive stresses are formed when wheel rims are heat treated by quenching during the manufacturing process. However, overheating of the wheels due to severe drag braking may reverse this beneficial compressive residual stress.

DYNAMOMETER TEST

TTCI's dynamometer, shown in Figure 2, is a single-ended inertia dynamometer used to conduct research and tests on railroad wheels, axles, and brake shoes.

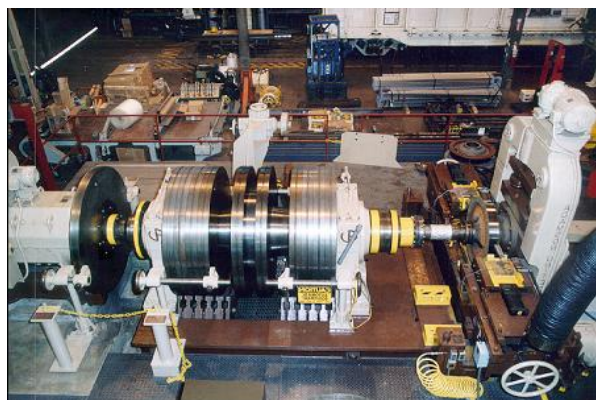


Figure 2. Dynamometer Located at TTC

A dynamometer drag-brake test was conducted on a 36-inch wheel with 82,000 miles of service to evaluate the thermal capacity of the wheel design for 315,000-pound car service. Figure 3 shows the braking test. The drag-brake test was setup to simulate the following braking conditions:

- Four, 210-ton locomotives
- 100 cars: Total train weight 16,590 tons
- Constant 20 mph
- 15 psi brake application
- Braking HP of 45
 - Simulating braking on a steep grade for 60 minutes followed by a full service stop
- Rail contact



Figure 3. Braking Test on Dynamometer

Rail contact was simulated by raising a steel circular wheel below the dynamometer up to the test wheel. The contact size and location between the wheels match the size and location as if the test wheel were moving down a railroad track. By doing this, the dynamometer is able to better simulate the temperature range that would occur in a wheel on track. Figure 4 shows the wheel used to simulate rail contact in the dynamometer pit before it was raised into contact with the test wheel.



Figure 4. Wheel Used to Simulate Rail Contact

The test wheel was subjected to three, 60 minute tests. Each test consisted of the application of constant brake horsepower of approximately 45 hp at a constant speed of 20 mph. At the end of each run the wheel was stopped with a simulated full service application. Table 1 shows conditions measured during the first test run.

Table 1. Test One Results

Braking Time (minutes)	Speed (MPH)	Brake Shoe Force (lb)	Brake Torque (lb-ft)	Brake Force (lb)	Brake HP	Tread Temp (°F)
5	19.9	3243.5	1999.7	867.9	46.1	543.8
10	20	3517.0	1328.8	887.3	47.3	650.5
15	20	3786.7	1328.6	887.2	47.3	751.6
20	20	3647.6	1328.8	887.3	47.3	796.4
25	20	3846.6	1328.8	887.3	47.3	836.8
30	20	4422.7	1328.6	887.2	47.3	862.7
35	20	5089.9	1328.6	887.2	47.3	877.5
40	20	5667.3	1328.8	887.3	47.3	934.8
45	20	4633.3	1328.8	887.3	47.3	977.6
50	20	5071.6	1328.0	886.8	47.3	990.9
55	20	5373.1	1328.6	887.2	47.3	1003.1
60	20	5295.0	1328.3	887.0	47.3	1013.4
Average values		4466.2	1326.2	885.5	47.2	853.3

Table 2 shows a summary of the all of the dynamometer tests.

Table 2. Drag-Brake Test on the Dynamometer

Run	Brake Horse Power	Speed (MPH)	Test Duration (Minutes)	Max. Tread Temp (°F)	Time to Max Temp (Minutes)
1	45	20	60	1013	60
2	45	20	60	915	50
3	45	20	60	901	45

The drag-brake test used fade resistant brake shoes to ensure a test duration of 60 minutes. The fade resistant brake shoes were replaced after each 60 minute test. Figure 5 shows a fade resistant brake shoe after a 60 minute dynamometer drag brake test.

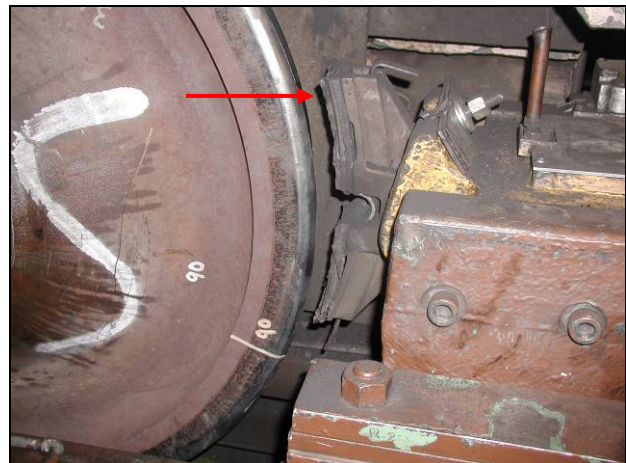


Figure 5. The Brake Shoe after 60 Minutes of Testing

After the three 60 minute tests, the 36-inch wheel was saw cut in the radial direction from the flange into the plate to determine if circumferential residual compressive stresses added to the rim during the manufacturing process were reversed.

Two angles were mounted on the rim of the test wheel before it was saw cut. A clip gage was placed between the two angles to measure the change in distance between the angles versus the saw cut depth. Figure 6 shows the change in the clip gage distance versus saw cut depth.

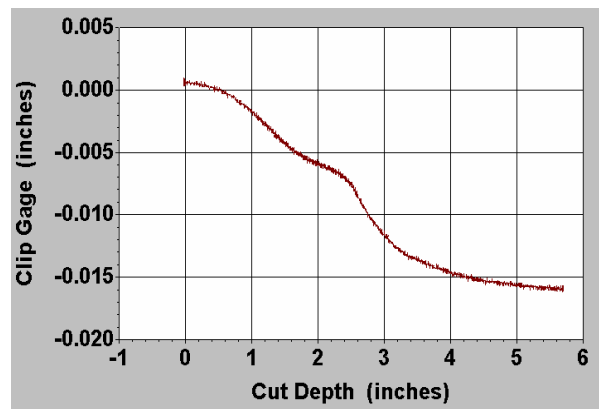


Figure 6. Graph of Deflection Saw Cut

From the graph, it can be seen that the wheel is in a state of compression and that the residual compressive stresses are still present in the rim and were not reversed during dynamometer testing. If the residual stresses had been reversed the clip gage would have shown the cut opening, widening rather than narrowing. The saw cut can be related to a crack in the wheel. If there are compressive residual stresses in the rim then the crack is less likely to grow. Conversely, a reversal of the residual stresses in wheel rim could accelerate crack growth.

CONCLUSIONS

- There was no reversal of the residual compressive stresses imparted to the rim during manufacturing after three 60 minute, 45 hp constant braking tests at 20 mph.

FUTURE WORK

Initial studies point to 36-inch wheels performing similarly to 38-inch wheels. While these studies do show promise, additional tests are needed before firm conclusions can be drawn on the effects that 315,000-pound cars have on 36-inch wheels. The test cars will remain in service at FAST to accumulate more mileage. At the end of its service life, another wheel will be subjected to drag braking test. The same parameters will be used when testing this wheel. More comprehensive testing would be required before the wheels could be accepted for revenue service.

ACKNOWLEDGMENTS

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REFERENCES

1. LoPresti, J., J. Robeda, and T. Guins, "Initial Performance Evaluation of Lightweight Trucks Under Heavy Axle Loads at FAST," *Technology Digest* TD-05-008, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO, March 2005.
2. International Heavy Haul Association, "Guidelines to Best Practices for Heavy Haul Railway Operations: Wheel and Rail Interface Issues," Virginia Beach, VA, May 2001.

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