TECHNOLOGY DIGEST

Timely Technology Transfer

"HOLLOW TREAD WHEELS INCREASE RAILCAR ROLLING RESISTANCE IN CURVES,"

by Stephen E. Mace and
Jon S. Hannafious

TD 95-021

Summary

A recent study at the Association of American Railroads' (AAR) Transportation Technology Center (TTC), Pueblo, Colorado, has determined that the poor steering characteristics of hollow tread wheel sets can double railcar rolling resistance in curves compared to tapered wheel sets.

The study was conducted in support of the AAR's Wheel/Rail Profile Optimization Project. The primary objective of this project was to optimize the North American railroad industry wheel/rail profile system. Operating costs are one of the major economic areas considered in the optimization process. Train resistance (fuel consumption) is a major component of the operating costs affected by the wheel/rail profile system.

The study used a combination of track tests and AAR's railcar dynamics computer model NUCARS to evaluate the rolling resistance of a loaded 100-ton hopper car with the following wheel profiles: (1) hollow tread wheel profiles based on worn revenue service wheels, (2) tapered tread wheel profiles representing new wheels, and (3) differentially worn treads representing revenue service wheel sets with a worn hollow tread wheel on one side and an un-worn tapered wheel on the other side.

Tests were conducted in a 6-degree curve of TTC's High Tonnage Loop at 5, 10, 15, and 20 mph. NUCARS was also used to investigate the effect of wheel profiles and track lubrication on rolling resistance.

Suggested Distribution:

- ❑ R&D/Test Dept.
- ❑ Car Dept.
- ❑ Equip./Rolling Stock
- ❑ Track Maintenance

Association of American Railroads
Research and Test Department
September 1995

INTRODUCTION AND CONCLUSIONS

The Association of American Railroads' (AAR) Transportation Technology Center (TTC), Pueblo, Colorado, is working to optimize the North American freight railroad wheel/rail profile system. The AAR's Wheel/Rail Profile Optimization Project will use a cost/benefit analysis in the optimization process to evaluate the performance of the wheel/rail profile system in the following areas:

- Rail Spalling and Wear
- Wheel Shelling and Wear
- Damage to Special Trackwork
- Track Maintenance
- Rail Rollover/Flange Climb Derailments
- Train Rolling Resistance

The key to performing a high quality cost/benefit analysis is to accurately evaluate the performance of the wheel/rail profile system in the critical areas. Toward this end, the Wheel/Rail Profile Optimization Project recently studied the effects of wheel/rail profiles and track lubrication on train rolling resistance.

Recent AAR research (*Technical Digest* 95-006) has demonstrated that railcar trucks with hollow worn wheels do not steer properly in curves where the rails have excessive gage corner relief from grinding. Instead, the trucks often warp; a situation in which the truck bolster rotates horizontally relative to the side frames such that both wheel sets develop large angles of attack and move laterally into flange contact with the outer rail. Because both wheel sets run in hard flange contact with the rail, the rolling resistance of a warped truck is much larger than that of a properly steered truck.

The effect of wheel/rail profiles on train resistance was evaluated in a series of track tests and computer simulations using AAR's NUCARS railcar dynamics model. The results of the study are summarized below:

1. Changing the wheel profiles from tapered to hollow tread nearly doubled the test car's rolling resistance in a 6-degree curve.
2. Changing the wheel profiles from tapered to differentially worn increased the test car's rolling resistance by approximately 50 percent.
3. The test car's rolling resistance increased because the leading truck was warped by the poor steering characteristics of the hollow tread wheel sets.
4. NUCARS indicated that warped trucks generate large lateral forces that push both wheel sets into flange contact with the outer rail, thereby increasing a railcar's rolling resistance.
5. NUCARS indicated that lubricating the gage face of the outer rail does not significantly reduce the rolling resistance of a warped truck.
6. NUCARS indicated that lubricating the gage face of the outer rail does reduce the rolling resistance of a properly steering truck.

TRACK TESTS

Track tests were conducted to compare the rolling resistance of a 100-ton hopper car alternately equipped with wheels having the following profiles: (1) hollow tread wheel profiles based on worn revenue service wheels,

(2) tapered tread wheel profiles (originally modified Heumann profiles), and (3) differentially worn wheel profiles representing revenue service wheel sets with a hollow tread wheel on one side and a tapered tread wheel on the other side. These profiles are shown in Exhibit 1 along with the rail profiles in the test curve.

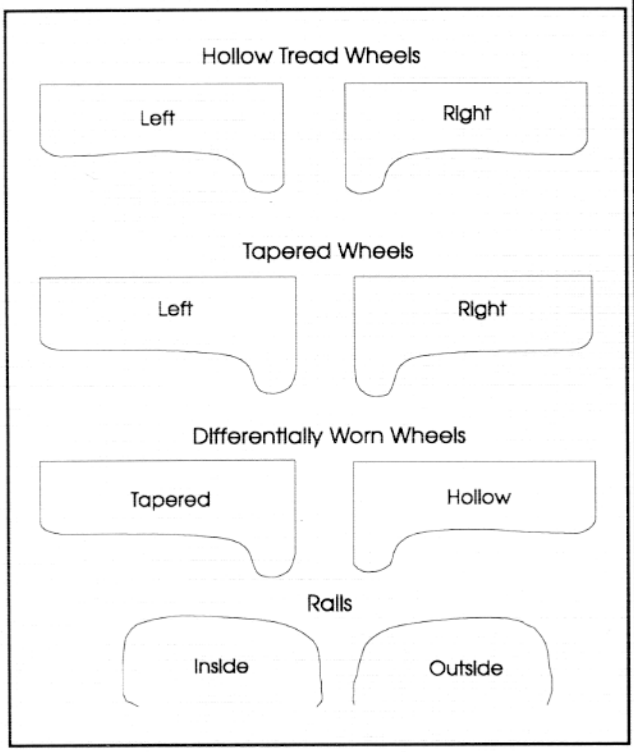

Exhibit 1. Wheel and Rail Profiles used in Test

The first two tests with hollow tread and tapered tread wheel profiles used instrumented wheel sets in the leading truck of the test car and matching non-instrumented wheel sets in the trailing truck. Non-instrumented differentially-worn wheel sets were used in both trucks for the third test because differentially-worn instrumented wheel sets were not available. The wheel sets were installed with the worn wheels diagonally opposite to one another in each truck.

Truck-mounted "stick" type flange lubricators were used on the outer wheels of the test car to provide flange lubrication. The running surfaces of the rails were left dry. Tests were conducted in a 6-degree curve at TTC's High Tonnage Loop at 5, 10, 15, and 20 mph for each wheel profile type.

The test car's rolling resistance was measured with a special high-sensitivity load cell coupler. The average rolling resistance measured by the load cell coupler was calculated and the effect of grade resistance removed. Exhibit 2 shows the rolling resistance of the test car equipped with hollow tread wheel sets, differentially worn wheel sets, and tapered wheel sets. The average rolling resistance of the test car equipped with hollow tread wheel sets was nearly double that of the test car with tapered wheel sets. The results for the differentially worn wheel sets fell in between.

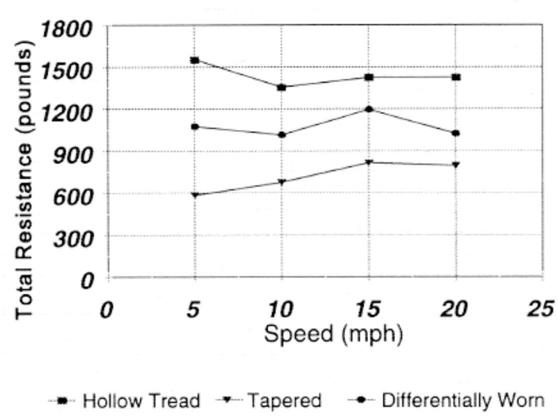

Exhibit 2. Total Rolling Resistance of Test Car with Different Wheel Profiles

Exhibit 3 shows the truck warp angles measured for the 5 mph test runs. The largest truck warp angles, approximately 17 mradians (1 degree), were measured for the hollow tread wheel sets. In general, the relative magnitudes of the truck warp angles corresponded to those of the average rolling resistances; i.e., the average rolling resistance of the test car increased with the truck warp angle. This confirmed the idea that truck warp increases rolling resistance.

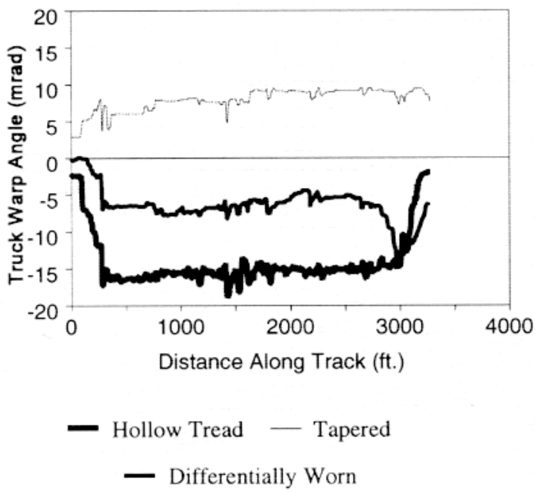

Exhibit 3. Leading Truck Warp Angle of Test Car with Different Wheel Profiles

NUCARS ANALYSIS

Computer simulations of the track tests were used to provide additional insight into the effects of wheel/rail profiles and track lubrication on rolling resistance. The simulations were run with a model of the test car in a 6-degree curve. The simulations used running surface friction coefficients of 0.45 and an outer rail gage face friction coefficient ranging from well lubricated (0.1) to dry (0.4).

Exhibit 4 lists the total rolling resistance for the NUCARS simulation of the test car with hollow tread and tapered wheel profiles at 15 mph. In general, the rolling resistance of the model car, in the well-lubricated case (0.1), compared reasonably well to the track test results of approximately 14,000 pounds (hollow tread) and 800 pounds (tapered) at 15 mph. As expected, the tapered wheel set model rolling resistance increased with increasing friction. However, the rolling resistance and truck warp angle of the hollow tread wheel set model actually decreased as the friction coefficient was increased from 0.1 to 0.4. This surprising result was due to the fact that the wheel set develops some steering from the longitudinal creep force at the flange. In the case of the hollow tread wheel set model, the flange provided all of the positive steering for the wheel set because the worn tread rolling radius was insufficient to produce positive steering moments for this degree of curvature. Therefore, the increased coefficient of friction at the flange resulted in larger steering forces that resisted truck warp. This demonstrates that lubrication can actually reduce the steering of hollow worn wheel sets and contribute to truck warp.

Note: Contact Stephen Mace at (719) 584-0563 with questions or comments about this document.

Exhibit 4. NUCARS Simulation Values

Gage Face Friction	Tapered Wheel Set Model		Hollow Tread Wheel Set Model	
	Truck Warp Angle (mrad.)	Rolling Resistance (pounds)	Truck Warp Angle (mrad.)	Rolling Resistance (pounds)
0.1	-4	566	-15	1480
0.2	-4	660	-14	1495
0.3	-3	795	-12	1441
0.4	-2	940	-10	1275

Disclaimer: Preliminary results in this document are disseminated by the AAR for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR makes no representations or warranties, either express or implied, with respect to this document or its contents. The AAR assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk.

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, WILL BE AVAILABLE AT A LATER DATE THROUGH THE DOCUMENTATION DISTRIBUTION CENTER, CHICAGO TECHNICAL CENTER, 3140 SO. FEDERAL STREET, CHICAGO, ILLINOIS 60616. PHONE: BETTY J. VAUGHAN (312) 808-5421. A REPORT LIST IS AVAILABLE UPON REQUEST.