TECHNOLOGY DIGEST

Timely Technology Transfer — 98-003

North American Wheel-Profile Survey

by Kevin Sawley and Ned Parker*

Summary

A survey of North American wheel profiles has provided the railroad industry with numbers and distribution specifics for hollow-worn wheels in revenue service. Principle achievements of the survey are listed as follows in two areas.

Distribution of hollow wheels:

- Forty-five percent of wheels have no appreciable hollow wear.
- Fifteen percent of wheels are worn more than 2mm (0.08 inch) hollow, while 6 percent are more than 3mm (0.12 inch) hollow.
- The depth of hollow wear increases linearly with the depth of tread wear.

Pattern of hollow wheels within trucks:

- For trucks with hollow wheels, the most common pattern is for only one axle to have both wheels hollow.
- The next most common patterns are for a truck to have all wheels hollow, followed by only one wheel hollow.
- Trucks with only two diagonally opposed hollow wheels are rare.

Associated studies show that hollow wheels can increase rolling resistance, rail wear and gage-spreading forces. These parameters are also likely to be affected by the pattern of hollow wheels within trucks. Computer predictions backed by tests show that trucks with wheels worn 3mm (0.12 inch) hollow have significantly higher rolling resistance and rates of rail wear, and impose higher lateral forces upon the rail. These predictions and the results of this survey have contributed to an economic analysis examining the costs and benefits of revised wheel-profile maintenance standards. The analysis (described in TD 97-048) concludes that railroad costs may be reduced by removing wheels with 3mm (0.12 inch) or more of hollow wear.

The wheel survey was in two parts. Part 1 was a random survey of revenue-service cars in which more than 6,000 wheel profiles were measured. In part 2, repeat wheel measurements were made to establish rates of tread wear and hollow wear. More than 12,000 profiles were taken in total.

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Suggested Distribution:

- o Equipment/Rolling Stock
- o Equipment Maintenance
- o Planning and Analysis
- o Track Maintenance

Work performed by TTCI Transportation Technology Center, Inc.

a subsidiary of the Association of American Railroads

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INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) has conducted a wheel-profile survey as part of the Wheel/Rail Profile Optimization Project. The objectives of the survey were to determine the numbers and distribution of hollow-worn wheels in revenue service, and to find the rate at which new wheels wear.

The wheel-profile survey had two parts. Part 1 consisted of a random survey of revenue-service cars, in which 6,628 wheel profiles were measured. In part 2, repeated measurements of wheel profiles were made on selected cars to determine the rates of tread wear and hollow wear on new wheels.

Conclusions are:

- Forty-five percent of wheels have hollow wear less than 0.25mm (0.01 inch).
- Fifteen percent of wheels have more than 2mm (0.08 inch) hollow wear, and 6 percent more than 3mm (0.12).
- The depth of hollow wear increases linearly with the depth of tread wear.
- If a hollow wheel is defined as one with more than 1mm (0.04 inch) hollow wear, 46 percent of trucks have no hollow wheels. Nineteen percent have two hollow wheels on only one axle, 15 percent have all wheels hollow, and 12 percent have only one wheel hollow. The incidence of diagonally opposed worn wheels in a truck is small (about 1 percent).
- Tread wear increases linearly with mileage. Norfolk Southern (NS) coal hoppers had a tread-wear rate of about 2mm (0.08 inch) in 100,000 miles.

Tests and computer predictions show that trucks with wheels worn 3mm (0.12 inch) hollow give significantly higher rolling resistance, rail wear, and lateral forces. Using these predictions, and results from this survey, the economic model described in TD 97-048 concludes that cost savings are achievable by removing wheels worn 3mm (0.12 inch) or more.

WHEEL-PROFILE MEASUREMENT

All wheel profiles were measured using the Miniprof™ wheel-measuring machine. This clamps to the back of the wheel flange and has a measuring arm which is moved manually around the wheel from back of flange to the end of the tread. Software supplied with the machine regenerates the wheel profile in an x-y coordinate system, with an accuracy of better than 0.05mm (0.002 inch). A typical measured wheel profile is shown in Exhibit 1, which also illustrates the tread-wear and hollow-wear measurements made in the survey. Hollow-wear measurements require a horizontal line to be constructed with reference to the outer edge of the wheel. Early work indicated that small misalignments in the seating of the Miniprof™ on the wheel could rotate measured profiles, producing significant errors in hollow-wear measurement. These errors were reduced by using software developed by The Arc Group Incorporated to rotate the measured wheel profiles to fit AAR 1-B design standards. Rotation corrections made were generally less than 2 degrees.

SCOPE OF SURVEY

The wheel survey was divided into two parts. In the first, wheel profiles were taken from revenue-service cars chosen at random. The range of cars examined, and the number of wheel profiles taken, is shown in Exhibit 2.

In the second part of the survey, an attempt was made to follow the progression of wheel wear on a number of different revenue-service fleets by making repeat profile measurements at regular

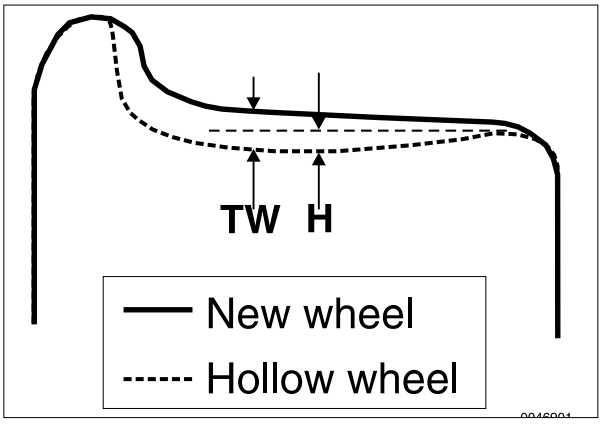

Exhibit 1. Hollow Wheel Illustrating Tread Wear and Hollow Wear

Random wheel-wear survey	
Type of car	**Wheels measured**
Autorack	1976
Box car	836
Gondola	704
Hopper	940
Intermodal	1012
Tank car	1000
Others	160
Total	6628
Follow-up wheel-wear survey	
Type of car	**Initial cars measured**
NS* coal hopper	30
PSCO** coal gondola	40
BN*** intermodal	28
Coors Box Cars	51
Coors Tank Cars	32
DuPont Tank Cars	68
Autoracks	175

*Norfolk Southern, **Public Service of Colorado, ***Burlington Northern

Exhibit 2. Car Types in the Random Wheel Survey and Follow-up Wheel Survey

intervals. The main fleets chosen, and the number of cars initially examined, are shown in Exhibit 2. Tracking these cars proved difficult, and fewer and fewer follow-up measurements could be made. Most repeat measurements were made on the NS coal hoppers, and only these results from the follow-up survey will be described.

RANDOM WHEEL SURVEY

The random survey was designed to measure wheel profiles from the major car types in proportion to their percentage in the total car fleet. Railroad yards were targeted based on their relative volume of specific cars, and a total of 6,628 wheels had profiles measured. Values of tread wear and hollow wear were calculated from these profiles.

Exhibit 3 shows the distribution of hollow-wheel tread wear for the random wheel survey population. Approximately 45 percent of wheels measured had less than 0.25mm (0.01 inch) hollow wear. Fifteen percent of wheels had hollow wear more than 2mm (0.08 inch) deep; 6 percent had more than 3mm (0.12 inch) hollow wear, while 2 percent of wheels had more than 4mm (0.16 inch) hollow wear. Exhibit 4 shows that hollow wear increases almost linearly with tread-wear depth. Very similar behavior was also seen with the data collected from the NS, Public Service of Colorado, and Burlington Northern Santa Fe cars in the follow-up wheel-wear survey. As expected, a similar linear relationship was also found between flange height and hollow wear, although scatter was greater.

Data from the random survey were also analyzed to find the most common patterns of wheel hollowing within trucks. This was done to set priorities for calculating the effect of hollow-worn wheels — and their distribution within a truck — on rolling resistance. The hollow-wheel criterion was set at 1mm (0.04 inch). That is, wheels with less than 1mm (0.04 inch) hollow wear were said to be "tapered." Those with more than 1mm (0.04 inch) hollow wear were said to be "hollow."

Seven categories of truck hollowing were examined:

- None — no wheels hollow
- One — one wheel hollow, three tapered
- Ld/tr — two wheels hollow (both wheels on lead axle or trail axle), two tapered
- L/r — two wheels hollow (both wheels on left side or right side of truck, two tapered

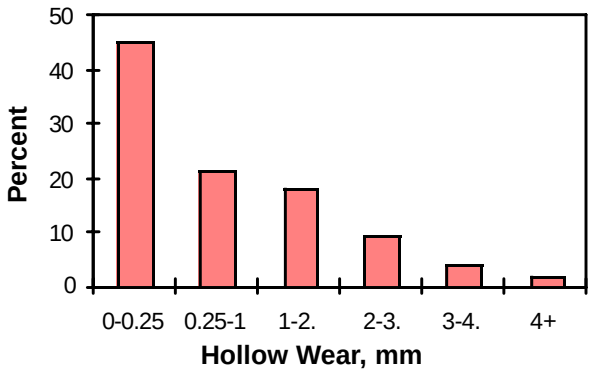

Exhibit 3. Percentage of Hollow Wheels Found in the Random Survey

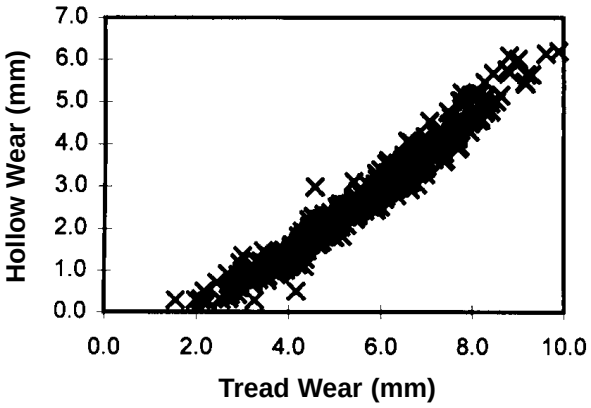

Exhibit 4. Relationship between Tread Wear and Hollow Wear

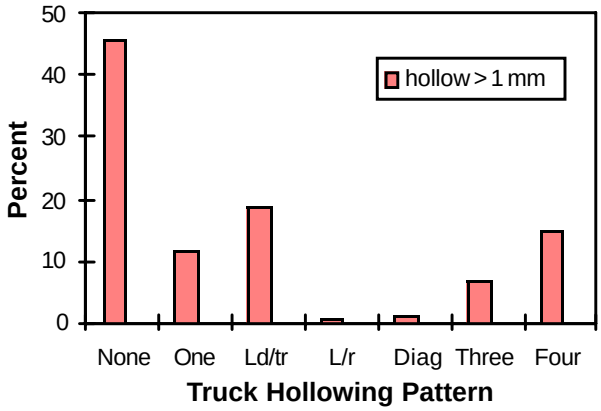

Exhibit 5. Patterns of Hollow Wheels in Trucks

- Diag — two wheels hollow (diagonal in truck), two tapered
- Three wheels hollow, one tapered
- Four wheels hollow

Results are shown in Exhibit 5. With the 1 mm hollow-wheel criterion, 46 percent of trucks have no hollow wheels, 19 percent have the wheels on one axle hollow, and 15 percent have all four wheels hollow. The incidence of diagonally worn wheels in a truck is very small (1.3 percent), as is the incidence of wheels worn only on one side of the truck (0.7 percent).

The same general pattern of hollowing was observed when the hollow-wheel criterion was set at 2mm (0.08 inch). At this level, however, 67 percent of trucks had no hollow wheels.

NORFOLK SOUTHERN COAL HOPPER SURVEY

Wheel profiles from cars in NS unit coal trains were measured periodically to determine the rate at which new wheels wear in this service. Wheel tread wear was calculated as the largest gap between new and worn profiles (see Exhibit 1). Exhibit 6 gives the resulting relationship between depth of tread wear and wheel mileage.

The relationship is reasonably linear, giving a wear rate of about 2mm (0.08 inch) per 100,000 miles. This compares with a typical assumed industry value of 3mm (0.12 inch) per 100,000 miles. As well as apparently wearing below the nominal industry rate, the NS wheels are not developing severe hollow wear. Measurements show a maximum hollow wear of only 1.5 mm (0.06 inch) at the 200,000 mile mark. The reasons for these low wear and hollowing rates are not yet known.

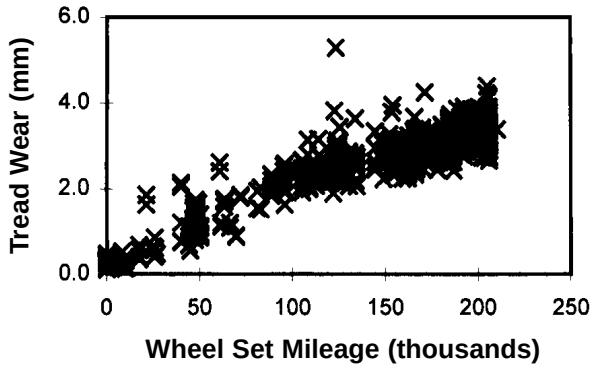

Exhibit 6: Relationship between Tread Wear and Wheel Mileage for NS Coal Hoppers

Note: Contact Kevin Sawley at (719) 584-0636, with questions or comments about this document.
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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON D.C., 20001