TECHNOLOGY DIGEST

Timely Technology Transfer

THE ECONOMICS OF REMOVING HOLLOW-WORN WHEELS

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Summary

An economic analysis weighing the predicted decreases in fuel and rail-wear costs realized by removing hollow-worn wheels against the increased wheel-maintenance costs incurred has yielded the following conclusions:

- Hollow-worn wheels lead to significant increases in fuel and rail-wear costs.
- For the ideal case where all wheels in a truck have the same wear, removing 3 millimeter (mm) hollow-worn wheels from service gives a net decrease in operating costs for 1-wear and 2-wear wheels.
- The study is performed comparing the costs of operating and maintaining wheels from a newly contoured tapered condition to a 3mm hollow tread condition versus a 4mm hollow tread condition. Of approximately 7,000 random profile samples, only 1.9 percent of the wheels had hollow tread profiles greater than 4mm.
- It is assumed that wheels are removed due to wear only, and when recontoured, have 5mm (approximately 3/16 inch) of tread metal removed (at the tapeline).
- Multi-wear wheels comprise only 0.01 percent of wheel replacements, as identified in the AAR Car Repair Billing Data Base, and are not considered in this analysis.

The economic model considers 100-ton coal cars with standard three-piece trucks operating over typical Eastern and Western coal-hauling routes. It is assumed that within each truck all wheels have the same profile, either all tapered or all hollow-worn (1mm, 2mm, or 3mm). With the model established, it is intended to extend the analysis to cover more probable distributions of hollow-worn wheels within trucks, possibly including 4mm hollow-worn wheels.

The study forms part of the Association of American Railroads' Wheel/Rail Profile Optimization Project. Future Technology Digests will report the distribution of hollow-worn wheels in revenue-service cars, and the effect of hollow wheels on rolling resistance.

Suggested Distribution:

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

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INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) is studying the effect of hollow-worn wheels on rolling resistance, a factor which translates directly to fuel and rail-wear costs. An economic analysis weighing the increased wheel-maintenance costs (caused by removing hollow-worn wheels) against predicted decreases in fuel and rail-wear costs has led to these conclusions:

- Hollow-worn wheels lead to significant increases in fuel and rail-wear costs.
- For cases in which all wheels in a truck have the same wear, removing 3mm hollow-worn wheels gives a net decrease in operating costs for 1-wear and 2-wear wheels.

The economic model considers 100-ton coal cars with standard three-piece trucks operating over typical Eastern and Western routes. With the model established, it is intended to extend the analysis to cover more probable distributions of hollow-worn wheels within trucks. The study forms part of the AAR's Wheel/Rail Profile Optimization Project. Future Technology Digests will report the distribution of hollow-worn wheels in revenue-service cars, and the effect of hollow-worn wheels on rolling resistance.

BACKGROUND

Hollow-worn wheels adversely affect truck steering, causing increased wheel/rail rolling resistance (and thus increased fuel consumption), gage-spreading forces, and rail wear. All these factors increase railroads' operating costs.

An analysis based on a random survey of several thousand wheel profiles in North American service indicates that 15 percent of wheels have more than 2mm hollow wear, while 6 percent have more than 3mm hollow wear. The survey also indicates how hollow-worn wheels are distributed within trucks. A hollow wheel is illustrated in Exhibit 1, and the distribution of hollow wheels is itemized in Exhibit 2.

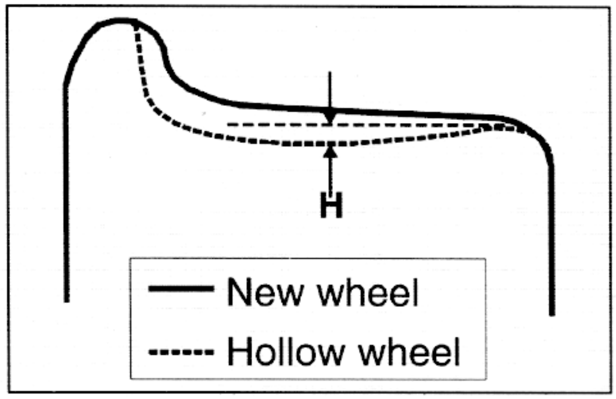

Exhibit 1. Illustration of Worn Wheel Showing Hollow Wear

An accompanying study on the effect of hollow-worn wheels on rolling resistance and gage-spreading forces will be reported in a future Technology Digest. The study included track tests and computer modeling for the cases where all wheels in a truck had the same degree of hollowing. For these cases, there was little effect on rolling resistance and gage-spreading force if hollow wear was equal to or less than 2mm. In contrast, 3mm hollow-worn wheels raised resistance and force significantly.

By removing wheels with excessive hollow wear, and so reducing wheel/rail resistance and gage-spreading forces, it is expected that the operating cost of revenue-service cars can be lowered. Using results from the wheel survey and rolling resistance study, the economic model described here is being developed to define a wear criterion for removing hollow-worn wheels.

Hollow Wear (mm)	Current Distribution of Hollow Wheels (%)
0	66.67
1	18.29
2	9.22
3+	5.82

Exhibit 2. Assumed Initial Distribution of Hollow Wheels

OVERVIEW OF ECONOMIC MODEL

The model is based on estimating the increased incremental costs of adopting a change-out policy for hollow-worn wheels, and the decreased incremental fuel and rail-wear costs. That is, wheel, fuel, and rail-wear costs are calculated for trucks with and without hollow-worn wheels.

This first application of the model assumes the current distribution of hollow wheels given in Exhibit 2. It also assumes that all wheels in a given truck have the same degree of hollow wear (either 0, 1mm, 2mm, or 3mm). This second assumption is simplistic, but is used to gage the scale of costs associated with a policy to remove hollow-worn wheels from service. Further applications of the model will study measured distributions of hollow wheels within trucks. The assumptions used are given in Exhibit 3.

SAMPLE RESULTS

A summary of the incremental costs calculated for typical Eastern and Western routes is given in Exhibit 4. This gives the estimated savings in fuel and rail wear from removing 3mm hollow-worn wheels, the associated increased wheel-maintenance costs, and the net change in operating costs (expressed in dollars per 1,000 truck-miles).

For the hollow-wheel removal policy considered, the figures show a net decrease in the operating cost for 1-wear (1W) and 2-wear (2W) wheels.

The major cost of operating wheels with 3mm hollow wear is fuel, due to increased rolling resistance. This is especially the case in curvy routes (see Eastern Route). The reduction in fuel consumed due to rolling resistance is estimated at 10.2 percent and 8.0 percent for the Eastern and Western routes respectively. This equates to an approximate reduction in overall fuel costs of 2 percent for both routes, when compared to data generated by the AAR's Train Energy Model during the Heavy Axle Load Phase I through III program.

1	Rolling-resistance values have been established for trucks with tapered and hollow (1mm, 2mm, 3mm) wheels.
2	Fuel and rail-wear costs are based on removal of wheels at a 3mm hollow profile. Wheel costs are based on the incremental cost between performing maintenance at 3mm hollow or leaving the wheels in service until they achieve a 4mm hollow profile.
3	It is assumed wheel-tread wear progresses at the rate of $\frac{1}{16}$ inch per 50,000 miles.
4	Linear relationship between hollow wear and tread wear established by wheel survey is used.
5	Wheel costs are based on an annual car mileage of 80,000 miles.
6	Wheel-maintenance costs are estimated using data from Rule 41 of the AAR Field and Office Manuals of Interchange Rules, and include 48 hours of vehicle out-of-service costs at $0.53 per hour per wheel change-out.
7	Rail wear is based on a route tonnage of 60 million gross tons.
8	Rail-replacement costs are $234k per track mile for tangent track, and $258k per track mile for curved track.
9	Fuel is found by calculating the work energy requirements for each hollow-wheel profile and a diesel-electric efficiency of 0.286.
10	Fuel costs for #2 diesel are $0.60 per gallon.
11	Fuel and wheel costs are expensed.
12	An after-tax discount rate of 11.0% and an average annual inflation rate of 2.59% are used.
13	All costs are reduced to steady-state present value $ per 1000 truck-miles.
14	Rail is capitalized with 20-year tax life for tangent rail and 7-year tax life for curved rail using the Modified Accelerated Cost Recovery System (MACRES) depreciation schedule.
15	Costs are estimated for typical Eastern and Western coal-haul routes for standard 100-ton coal cars with standard three-piece trucks, 36-inch curved-plate heat-treated 1-wear and 2-wear wheels.

Exhibit 3. Assumptions Used in Economic Model

Eastern coal route: Incremental costs, $/1,000 truck miles		
	Wheel Wear Types	
	1W	2W
	0.211	0.349
Fuel	-0.68	-0.68
Rail	-0.07	-0.07
Net cost	-0.54	-0.4

Western coal route: Incremental costs, $/1,000 truck miles		
	Wheel Wear Types	
	1W	2W
	0.211	0.349
Fuel	-0.57	-0.57
Rail	-0.11	-0.11
Net cost	-0.47	-0.34

Exhibit 4. Results from Economic Analysis of Trucks with All Wheels 3mm Hollow

The incremental benefit of improved rail life is about 10 percent of the fuel benefit on the Eastern route and 20 percent of the fuel benefit for the Western route. Neglecting rail benefits, the analysis indicates that it is still economical to remove 1W and 2W wheels at 3mm hollow wear.

Changes in annual tonnage and car mileage change the timing of cash flows. Increased annual car mileage (more than 80,000 miles per year) will lower the incremental wheel costs and increase the net savings, and increased annual tonnage will decrease the incremental benefits of rail-wear reductions.

This limited case (that all wheels in a truck have the same degree of hollow wear) has led to three conclusions. First, hollow-worn wheels cause significant extra fuel and rail-wear costs. Second, these extra costs can make it more economical to remove hollow-worn wheels than to leave them in service. Third, that based on the overriding impact of fuel savings, it may be safe, and is certainly conservative, to ignore all but fuel costs.

FURTHER MODELING EFFORT

The case analyzed above is limited in scope, but has proved valuable. Work in 1998 will focus on analyzing additional cases in which wheels within a truck have differing degrees of hollow wear. For example, a case which may need analysis is that in which two wheels have 3mm hollow wear and two have 2mm wear. Distributions of hollow wheels within trucks, and the probability of occurrence, are available from the previously mentioned random wheel survey. It is also intended that the study examine whether increased hollowing (4mm) leads to even larger increases in rolling resistance, and hence fuel costs and rail wear.

The methodology is now established to assess any particular hollow-worn wheel case. First, the NUCARS computer modeling package predicts the effect of the hollow-wheel distribution on rolling resistance. Second, the NUCARS results are applied to the economic model to evaluate the effect of a particular wheel-removal criterion (based on hollow wear) on the balance between increased wheel-maintenance costs and decreased fuel (and possibly rail-wear) costs.

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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