TECHNOLOGY DIGEST

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Evaluation Results for WheelSpec ä Wheel Profile Measurement System

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Summary

A machine vision, laser-based, wheel profile measuring system, developed by E.H. Reeves & Associates, Inc., has demonstrated the capability of accurately measuring railcar wheel parameters at speeds up to 35 mph. These parameters include flange thickness, flange height, rim thickness, and tread hollowing. Transportation Technology Center, Inc. (TTCI) personnel conducted tests of the system in conjunction with Norfolk Southern (NS) in September 2001 at NS's Loudon, Tennessee, installation site.

WheelSpec™ data taken during test runs was compared to reference values obtained from Miniprof™ profile measurements of specific test wheels. Measurement accuracies required for "good" data points were based on gage specifications required by Association of American Railroads (AAR) interchange rules. Results show system accuracy to ±1/32 inch (1 mm) to be greater than 90 percent for flange height, 60 percent for flange thickness, 45 percent for rim thickness, and 99 percent for tread hollow.

In addition to accuracy, system reliability was also considered, comparing the number of expected wheel measurements to the actual number of reported data points. The system exhibited better than 92 percent reliability for all measured parameters.

Data repeatability (consistency), within ±1 millimeter of the average parameter value, was 96.0 percent for flange thickness, 99.2 percent for flange height, 83.1 percent for rim thickness, and 100 percent for tread hollow.

This test was performed as part of the AAR's Strategic Research Initiatives (SRI) Program.

Suggested Distribution:

- ☐ Mechanical
- ☐ Planning & Analysis
- ☐ Signals & Communications
- ☐ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

SYSTEM DESCRIPTION

E.H. Reeves & Associates, Inc.'s WheelSpec™ system is a fully environmentally hardened assembly. Norfolk Southern's (NS) Loudon, Tennessee, (Exhibit 1) installation is mounted completely below grade using a short "bridge" arrangement to accommodate system components. The system uses triggered laser illumination in conjunction with multiple high-speed cameras to produce a profile image of the wheel flange and tread. Data is sent to a wayside bungalow computer that processes the images and records the relevant parameter information. The system is designed for operation under all light and weather conditions. The trackside hardware is completely enclosed. Sensors allow protective shutters to be opened as a train approaches to provide an unobstructed view of each passing wheel for each laser and camera. The test system measures wheels on both rails in either direction of travel at speeds up to 35 mph.

Exhibit 1. WheelSpec™ Installation on NS, Loudon, TN

SYSTEM REQUIREMENTS

AAR interchange rules require wheels to be measured within specific tolerances. If a railroad that interchanges cars were to use a wheel profile measurement system to enhance its methods of manual inspection, then that system must be able to measure wheels to the same degree of accuracy as would be expected through conventional manual inspection. Thus, the AAR-sponsored SRI evaluations determined whether wheel profile measurement systems could measure wheels to the accuracies specified in Table 1.

Table 1. Dynamic Profile Accuracy Requirements

Parameter	Accuracy (in.)	Accuracy (mm)
Flange Height	±1/32	±0.80
Flange Thickness	±1/32	±0.80
Rim Thickness	±1/32	±0.80
Tread Hollow	±1/50	±0.50

Flange height was measured from the tapeline of the tread to the top of the flange. Flange thickness was measured at a point 3/8 inch above the tapeline of the tread. Rim thickness was measured from the tapeline of the wheel to the corner at the inside diameter of the back face of the rim. Tread hollow was measured from the lowest point of the tread near the tapeline to the highest point near the outer edge of the tread.

FIELD TEST EVALUATIONS

A special test consist was used for field test evaluations to ensure system compatibility with various car types, wheel diameters, and wheel parameter conditions. The consist included a six-axle (SD-70) locomotive with 42-inch wheels, two loaded coal hoppers with 36-inch wheels, an empty auto rack with 28-inch wheels, and the NS research and test caboose with 33-inch wheels. A total of six wheels were designated (two on the NS caboose, two on the empty auto rack and two on one of the loaded coal hoppers) as test candidates. The test wheel parameters ranged from new condition to near condemning limits. Although all wheels in the consist were measured and recorded by the WheelSpec™ system (including the locomotive wheels), only data from the six designated test wheels was considered for this evaluation. Test runs were conducted and data was collected at speeds of 15 and 35 mph in both directions. A total of 24 test runs (12 in each direction) conducted on the morning of September 6, 2001, were used for this evaluation.

DATA ANALYSIS

Previous investigations under this program have shown there can be slight variations in parameters around the circumference of a wheel. Since the exact location of every measurement taken by the test system was not known, baseline measurements were taken at six locations, approximately every 60 degrees around the

circumference of each test wheel, using the Miniprof™ wheel-profile gage for flange thickness and height and tread hollow measurements, and the steel wheel gage for rim thickness measurements. The six measurements were averaged and used as a target or baseline value for comparison. The variation, if any, was added to the target value along with the accuracy tolerances in Table 1 to give a tolerance band, within which each measurement from the test system was required to fall in order to be considered an accurate measurement. The limits of this range are termed upper and lower bounds.

Exhibit 2 shows an example of the performance for the WheelSpec™ system for wheel flange height for the R2 wheel on the loaded coal hopper**.** The horizontal axis shows the measurement number while the vertical axis displays the measured flange height in inches.

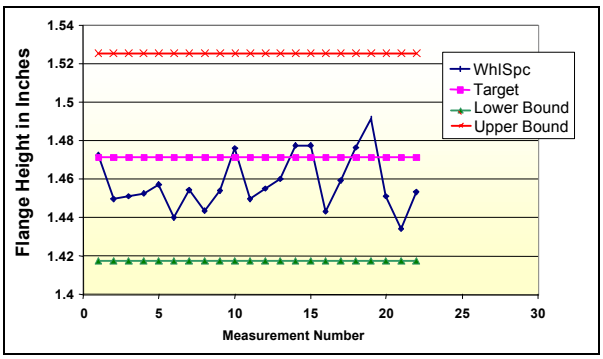

Exhibit 2. Wheel Flange Height for HYWX 2108 R2

Exhibit 2 demonstrates two analysis results. First, the total range for an acceptable measurement for this particular test wheel is ±0.054 inch, which is larger than the ±1/32-inch accuracy specified. For this example, this indicates that the measured flange-height variation was 0.023 inch. This value was added to the 1/32-inch tolerance to obtain ± .054 inch as the acceptable measurement range for this particular wheel. Second, out of 24 test runs, 22 measurements (insufficient data on the remaining test runs) were recorded and all were within the accuracy band giving a 91.7 percent reliability rate and a 100 percent accuracy rate for HYWX 2108 R2 wheel-flange height measurements.

RESULTS

Table 2 summarizes the accuracy of the WheelSpec™ system for this evaluation. The values indicate the percent of system measurements that were within ±1/32 inch and ±1/16 inch of the baseline measurement.

Exhibit 3 represents system accuracy within ±1/32 inch and system reliability for each parameter, as well as combined system results.

Table 2. WheelSpec™ System Accuracy

Parameter	Accuracy 1/32 inch*	Accuracy 1/16 inch*
Flange Height (Fh)	91.8%	98.0%
Flange Thickness (Ft)	62.5%	84.6%
Rim Thickness (Rt)	46.8%	77.4%
Tread Hollow (Th)	99.2%	99.6%

* Plus or minus half the range of the variation around the circumference of the wheel.

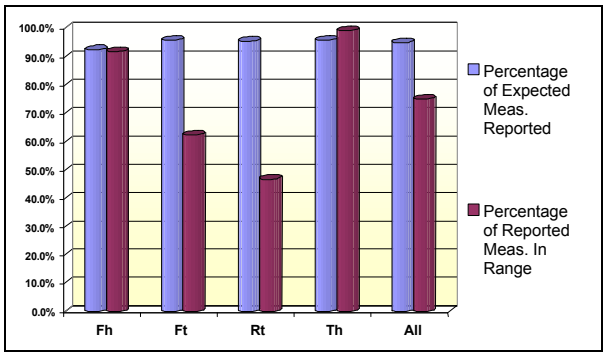

Exhibit 3. WheelSpec™ System Accuracy and Reliability

Exhibit 4 shows the accuracy data curve for all parameters. The curve was calculated by plotting the absolute values of the target value deltas. The horizontal axis represents the delta of the baseline target value and the measured value. The vertical axis represents the percentage of delta values that were greater than the associated horizontal axis values. The vertical grid lines at 0.8 millimeter and 1.6 millimeters are 1/32 inch and 1/16 inch, respectively. The curve of the graph does not match exactly to the numbers in Exhibit 3 because of the wheel variations described above. The standard deviations for the target values compared to the measured values (accuracy) were 0.50 millimeter for flange height, 1.00 millimeters for flange thickness, 1.71 millimeters for rim thickness, and 0.32 millimeter for tread hollow.

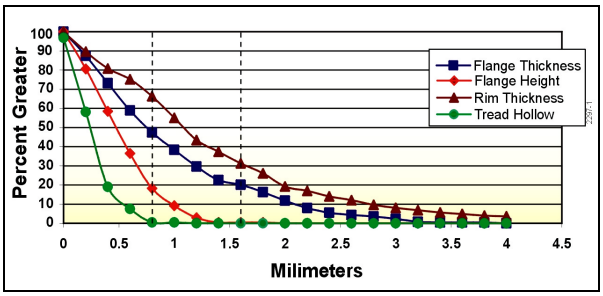

Exhibit 4. WheelSpec™ System Accuracy Graph

A concern with dynamic wheel profile systems is their ability to measure each parameter of the same wheel consistently over several train passes. Data from this evaluation was analyzed to determine the repeatability of the system independent of accuracy. All measurements of a particular wheel were averaged, and the deltas from the individual measurements from that particular wheel were calculated. The standard deviations were then calculated to determine the consistency and repeatability of the system.

Repeatability (or consistency) analysis of the system indicates that better than 96 percent of flange height and flange thickness measurements are consistent to within ±1 millimeter of the average of all measurements. Exhibit 5 shows the consistency of the WheelSpec™ system for each parameter.

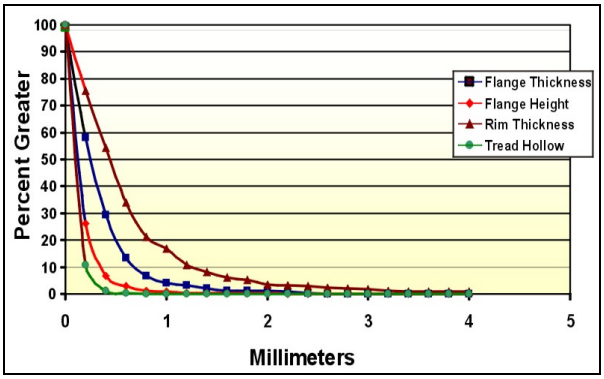

Exhibit 5. WheelSpec™ System Repeatability (Consistency)

The curve was calculated by plotting the absolute values of the target value deltas. The horizontal axis represents the delta of the average system measurement values and the actual measured values. The vertical axis represents the percentage of delta values that were greater than the associated horizontal axis values. The standard deviation for flange thickness measurements is 0.49 millimeter, 0.26 millimeter for flange height, 0.92 millimeter for rim thickness, and 0.13 millimeter for tread hollow.

DISCUSSION

E.H. Reeves & Associates, Inc.'s WheelSpec™ system is a fully functional system that has been in track at the NS Loudon, Tennessee, location for more than a year. It is a completely automated system designed to work under all weather and lighting conditions. The TTCI evaluation was conducted during daylight hours under good weather conditions and the study did not address any environmental issues that may affect system performance.

The system demonstrated the capability to measure flange height and tread hollow near or above the required degree of accuracy. Flange thickness and rim thickness measurements showed the need for further refinement. It should be noted that although tread hollow measurements showed the highest accuracy, the majority of the test wheels did not have a hollow condition.

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