TECHNOLOGY DIGEST

Timely Technology Transfer — 01-026

Evaluation of AEAT Wheel Profile Measurement System

by Scott Gage, Jim Robeda and Richard Morgan

Summary

A railcar wheel profile measurement system has the potential to accurately measure flange thickness, flange height, and rim thickness. The measurement system, developed by AEA Technology (AEAT), was demonstrated in tests performed by Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado. The AEAT TreadVIEW™ system uses machine vision technology, including multi-camera multi-laser imaging. Data from the test runs was compared to reference values obtained from Miniprof™ profile measurements of the test wheels. Measurement accuracies required for "good" data points were based on specifications (see Exhibit 1) in the *Office Manual of the AAR Interchange Rules*. Results from the evaluation show system accuracy to +/- 1/32 inch (1 mm) to be greater than 88 percent for flange thickness, 96 percent for flange height, and 20 percent for rim thickness measurements. System accuracy within 1/16 inch (2 mm) of baseline values is over 98 percent for flange thickness and flange height, and over 38 percent for rim thickness. Data consistency was high, with over 90 percent of flange height and flange thickness measurements within plus or minus 1 millimeter of the average parameter value.

Although the TreadVIEW™ system produced wheel parameter data immediately following each test run, initial data did not meet the accuracy criteria recommended by TTCI (Exhibit 1). After two series of manual post processing, the accuracy of the data improved significantly. AEAT discovered biases caused by a laser skew and calibration and software errors in aligning profiles. These errors were addressed by AEAT in their system.

The system was tested at the West Coast Traincare View installation at the Longsight Traincare Depot in Manchester, U.K.

This test was performed as part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) Program for Wayside Detection Systems. The program develops and evaluates new technologies designed to improve safety, network efficiency, customer satisfaction, and productivity for the railroad industry.

Suggested Distribution:

- ❑ Chief Mech. Officer
- ❑ Maintenance of Way
- ❑ Planning & Analysis
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Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

INTRODUCTION AND CONCLUSIONS

A close examination of the 2000 AAR car repair database, by components, shows that railroads spent about 37 percent on wheel-related expenses. (Running repairs for U.S. operated Class I railroads, billed through the AAR Car report billing system, were about $1.35 billion in 2000.) Inspecting and identifying wheels in need of maintenance is an important and time consuming responsibility of the North American railroads. Wheel parameters of interest to the railroads include flange thickness, flange height, vertical flange, rim thickness, and hollow-worn wheels. An accurate and repeatable dynamic wheel profile measuring system could greatly improve the efficiency of identifying worn wheels and the scheduling of wheel maintenance. These systems could also significantly increase the number of wheels annually inspected.

In August, TTCI personnel traveled to the United Kingdom to the West Coast Traincare View installation at the Longsight Traincare Depot in Manchester to test the performance of a wheel profile measuring system. This test was conducted as part of a strategic research initiative to determine the accuracy and repeatability of several different wayside detection systems. Results from the evaluation showed the AEAT TreadVIEW™ system accuracy to +/- 1/32 inch (1 mm) to be greater than 88 percent for flange thickness, 96 percent for flange height, and 21 percent for rim thickness measurements. System accuracy within 1/16 inch (2 mm) of baseline values is over 98 percent for flange thickness, 99 percent for flange height, and 38 percent for rim thickness.

Repeatability (or consistency) analysis of the system indicated that over 96 percent of flange thickness, 99 percent of flange height, and 48 percent of rim thickness measurements were consistent to within plus or minus 1 millimeter of the average of all measurements. The standard deviation for flange thickness measurements was 0.56 millimeter: 0.35 millimeter for flange height and 12.5 millimeter for rim thickness.

Although the TreadVIEW™ system was able to supply wheel parameter measurements shortly after testing was completed, the accuracy of the initial data was not within the accuracies recommended by TTCI (Exhibit 1). Data required two iterations of manual processing to achieve the accuracies mentioned above. AEAT suspects the initial accuracy errors may have been due to errors in calibration. The data in this report reflects the correction for the calibration.

Exhibit 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

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SYSTEM REQUIREMENTS

Specifications set forth in the AAR Interchange Rules require wheels to be measured within specific tolerances. If a railroad that interchanges cars with other railroads is to use a wheel profile measurement system to enhance its conventional, manual inspection methods, then that system must be able to measure wheels to the same degree of accuracy as would be expected through manual inspection methods. Thus, the AAR sponsored evaluations through its Strategic Research Initiatives (SRI) to determine whether wheel profile measurement systems are able to measure wheels to the accuracies recommended in Exhibit 1. Flange height was measured from the tapeline of the tread to the top of the flange. Flange thickness was measured at a point 10 mm 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.

SYSTEM DESCRIPTION

The AEAT TreadVIEW™ trackside system (Exhibit 2) consists of a series of cameras and lasers mounted below rail level on each side of the track and wheel sensors clamped directly onto the rail. This hardware is connected via an interface box to a trackside computer containing a frame grabber and running image analysis software. The system is entirely solid state with the exception of washers and wipers fitted to the camera enclosures, which keep the top glass clean. The system collects images of individual wheel profiles as trains pass. Image capture is controlled by the computer and wheel sensors that trigger the image capture when the wheel is optimally illuminated by a laser line. The images are analyzed automatically to extract wheel profile parameter measurements.

Exhibit 2. TreadVIEW™ System

FIELD TEST EVALUATIONS

No freight cars were available at the time of the test; therefore, four 4-axle passenger coaches were selected for testing. Two of the cars were Virgin MKII passenger cars (Nos. 9527 and 6120) and the other two were Porterbrook MKI barrier cars (Nos. 6399 and 6398). Eight wheels, four on each side, showing moderate variations in wheel parameters were selected as test wheels. The wheels on the right-hand side of each car were noted as A1 through D1; the wheels on the left hand side of each car were noted as A2 through D2.

The system for the Longsight Traincar Depot was installed on a yard track immediately adjacent to a train wash. It was set up to profile wheels entering the trainwash, and therefore measured in one direction only at speeds under 5 MPH. There were 14 train passes and 14 sets of images collected by the system.

DATA ANALYSIS

Previous investigations under this program have shown there can be slight variations in parameters around the circumference of a wheel. Because the exact location of every measurement taken by the test system was not known, baseline measurements were taken at four locations, every 90-degrees around the circumference of the wheel, using the MiniProf™ wheel profile gage. The four measurements were averaged and used as a target value for comparison. The variation, if any, was added to the target value along with the accuracy tolerances in Exhibit 1 to give a tolerance band within the range 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 3 shows an example of the performance for the TreadVIEW™ system for Wheel 9527 C1 flange thickness. The horizontal axis shows the test run number, and the vertical axis displays the measured flange thickness in millimeters.

Exhibit 3 demonstrates two analysis results. One is the total range for an acceptable measurement for Wheel A1 is +/- 0.84 millimeter, which is larger than the +/- 0.8 millimeter accuracy specified. This indicates that the variation in flange thickness, around the circumference of the wheel, was 0.08 millimeter. Half the variation was added to the accuracy requirements to define the acceptable measurement range for this particular wheel. Second, out of 14 test runs 13 of the measurements were within the accuracy band giving a 93 percent accuracy rate for Wheel 9527 C1 flange thickness measurements.

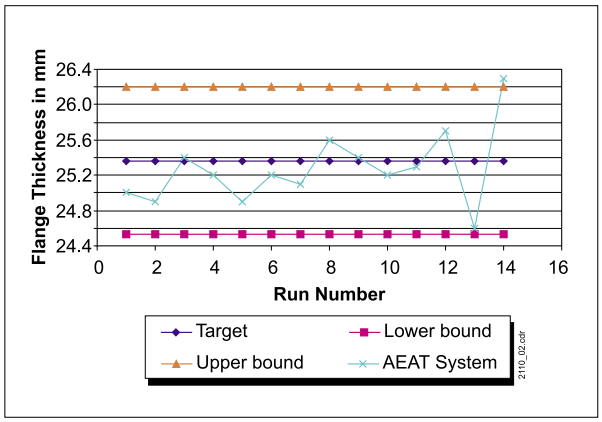

Exhibit 3. Wheel 9527 CI Flange Thickness

RESULTS

Exhibit 4 summarizes the accuracy of the AEAT system for this evaluation. The values after recalibration indicate the percent of system measurements that were within +/-1/32 inch (0.8 mm) and +/- 1/16 inch (1.6 mm) of the baseline measurement.

Exhibit 4. AEAT System Accuracy

Parameter	Accuracy +/- 1/32"*	Accuracy +/- 1/16"*
Flange Height–(Sh)	96%	100%
Flange Thickness – (Sd)	88%	98%
Tread Thickness – (Rt)	20%	38%

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* +/- half the range of the variation around the circumference of the wheel

Exhibit 5 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 was greater than the associated horizontal axis values. The vertical grid lines at 0.8 and 1.6 millimeters are 1/32 and 1/16 inch respectively. The curve of the graph does not match exactly to the numbers in Exhibit 4 due to the wheel variations described above. The standard deviations for the target values compared to the measured values (accuracy) were 0.56 millimeter for flange height, 0.35 millimeter for flange thickness, and 12.5 millimeters for rim thickness.

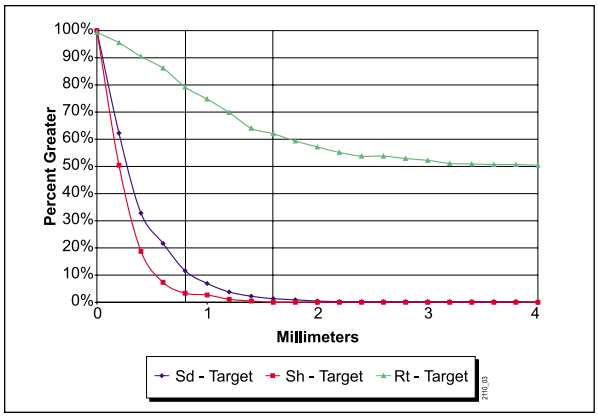

Exhibit 5. AEAT System Accuracy

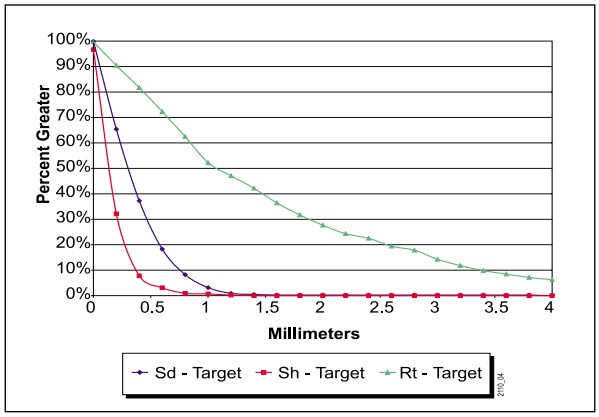

Exhibit 6. AEAT System Repeatability

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 over 96 percent of flange height and flange thickness measurements are consistent to within plus or minus 1 millimeter of the average of all measurements. Exhibit 6 shows the consistency of the system for each parameter. 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 deviations for average system measurements and actual system measurements are 0.51 millimeter for flange thickness, 0.24 millimeter for flange height and 2.9 millimeter for rim thickness.

DISCUSSION

The AEAT TreadVIEW™ system is a fully integrated and hardened system. The system has demonstrated high accuracy and repeatability when measuring flange height and thickness, although it appears more development is required to improve rim thickness measuring capabilities. Although information on wheel hollow was not provided by AEAT for this evaluation, the raw profile the system produces should give the ability to measure wheel hollow with no additional hardware.

AEAT was able to meet TTCI criteria for flange height and flange thickness, but only after two iterations of manual processing. Initial measurements for flange thickness showed a bias offset measuring high on one rail and low on the other. AEAT analysis indicated the bias was caused by calibration errors (laser skew error and calibration piece rotation error) and wheel profile combination methods in software. Through manual processing, AEAT adjusted some initial assumption and improved the flange tip definition. These adjustments significantly improved flange thickness and flange height measurement accuracy.

The system demonstrated a high degree of accuracy for flange parameters. Problems with rim thickness measurements should be easily overcome with further software development. AEAT reports that this has already been addressed.

Note: Please contact Scott Gage at (719) 584-0585 with questions or comments about this document.
E-mail: scott_gage@ttci.aar.com
Web site: www.ttci.aar.com

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