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Evaluation of the LynxRail Machine Vision Wheel Measurement System

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Summary

System accuracy for a strobe-based wheel measurement system was better than 96 percent for tread-hollow and flange-height measurements, and better than 93 percent for flange-width measurements, according to test results of a production LynxRail system that was installed on the Railroad Test Track at the Transportation Technology Center, Pueblo, Colo. Moreover, data repeatability was better than 98 percent for all three of these parameters. Rim thickness measurements were initially considerably less accurate due a difference in the reference point used by the system. LynxRail reconfigured the system to reference the inside face of the rim as prescribed by Association of American Railroads (AAR) standards and system accuracy improved to 95 percent for this parameter.

The LynxRail system is similar to one that is currently in use on the BHP Iron Ore Railroad in Port Hedland, West Australia. The system at BHP was installed in 2001 and has been in continuous operation since. Testing indicated that, with some minor enhancements, the system has the potential to perform satisfactorily in North American railroad applications. Values are within desired accuracies for tread hollow, flange height, and flange thickness measurements.

Development of machine vision-based wheel measuring and monitoring systems for railroad applications continues to show promising results. Several systems are currently operating in revenue service and vendors are continuing to refine hardware and software to improve performance. Two basic types of systems are currently available. Laser-based systems project a laser line across the tread and flange of the wheel to develop an outline or profile of the wheel. This profile is then used to determine wheel parameter values. Strobe-based systems take a high-speed snap shot of the wheel and derive parameter values from the resulting picture. Both technologies have shown the ability to achieve desired accuracies. This study is part of a continuing effort by TTCI to evaluate machine vision technology based systems produced by a number of different suppliers.[1,2,3]

Besides working to change the reference point for rim thickness measurements to the AAR standard, LynxRail is also addressing further system hardening issues to deal with the temperature extremes and other weather related challenges of North American operating environment.

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INTRODUCTION

In an effort to "accelerate the rate at which beneficial technologies are safely and efficiently utilized by the railway industry," TTCI continues to monitor advances in machine vision systems.[1,2,3] Development of these systems to increase wheel inspection capabilities on North American railroads has continued to yield promising results. Thus far vendors have used two basic system configurations: laser- and strobe-based. Laser-based systems project a laser-generated line across the wheel rim and flange to produce a wheel profile. The profile is then measured to determine parameter values. Strobe-based systems use a high-intensity flash lamp to take a snapshot of the wheel flange and rim to generate a high-resolution photo that is used to determine parameter values.

LynxRail, a business division of Lynx Engineering Consultants Pty Ltd, based in Perth, Australia, manufactures and markets a strobe-based wheel measurement system as part of its Automated Train Examiner (ATEx) system. That system was tested by Transportation Technology Center, Inc. (TTCI), Pueblo, Colo., and test results showed that the system is capable of satisfactorily measuring flange height and thickness and tread hollow to the desired accuracy of ±1 millimeter. Measurement repeatability was also acceptable for these parameters.

The LynxRail system measures rim thickness at the outside face of the rim as opposed to the prescribed AAR method of measuring rim thickness at the back face. Because of this discrepancy, rim thickness measurements were well below desired accuracies. LynxRail is addressing this problem for the North American market.

The following accuracies were recorded during testing:

- 100 percent accuracy for tread hollowing
- 96.3 percent accuracy for flange height
- 93.4 percent accuracy for flange width

METHODOLOGY

A production LynxRail WPM system module was installed on the Railroad Test Track at the Federal Railroad Administration's Transportation Technology Center (Figure 1). A test consist made up of various car types with wheel diameters ranging from 28 to 36 inches and wheel profiles ranging from a new AAR 1B to nearly condemnable thin flange, high flange, thin rim, and hollow tread was used for the test. Test runs were made in both directions at speeds ranging from 10 mph to 40 mph.

For comparison purposes, static measurements were taken of each wheel of the consist using a profilometer to determine target values for flange height, flange thickness, and tread hollowing. Rim thickness measurements were taken manually with a simplified steel wheel gage. A control chart for each parameter of each wheel was used to evaluate system accuracy. To create the control charts, a target value was determined for each parameter of each wheel as described above. Repeated measurements made at various locations on wheels in previous tests indicate that there is a slight variation in parameter values around the periphery of a wheel. This variation coupled with the required ± 1/32-inch wheel gage tolerance was used to establish upper and lower control limits for each parameter. These limits were set at ± 1 millimeter for flange height and flange width, ± 1.4 millimeter for rim thickness, and ± .6 millimeters for tread hollow. Data from the Lynxrail system collected during the test runs was then compared to the target values to determine overall measurement accuracy. Data repeatability was determined by comparing system data to the system average for each measurement parameter.

Figure 1. LynxRail ATEx Wheel Profile Measurement System installed at TTC

BACKGROUND

The LynxRail wheel profile measurement system has been in continuous service on the BHP Railroad in Port Hedland, West Australia, since 2001. The module is one component of the larger LynxRail ATEx automated inspection system. The system was first evaluated by TTCI personnel at Port Hedland in December 2001.

Initial evaluation of the system showed promise in data repeatability, but lacked the desired accuracy. In an effort to correct the accuracy problem and adapt the system to the North American market, LynxRail made appropriate software changes and agreed to install a production system at TTC for additional testing and evaluation.

System installation and setup required approximately two weeks. TTCI personnel monitored the installation process. The system was originally installed in the same configuration as used in Australia. This setup consisted of a camera and strobe light mounted within the gage on each rail to capture flange images for each wheel and a camera and strobe mounted outside of each rail to capture rim images for each wheel. This resulted in rim thickness measurements based on a reference point on the outside rim face.

RESULTS

Several days of setup and calibration runs were made to allow LynxRail the opportunity to evaluate and adjust system performance. Once LynxRail was comfortable with the setup, formal evaluation test runs were conducted. Results were compiled from 10 consecutive test runs made with a consist of four cars and a locomotive. Wheel sizes ranged from 28 inch to 36 inch, and wheel conditions ranged from newly turned AAR 1B profiles to wheels nearing condemning limits for thin flange, high flange, thin rim and hollow tread. Runs were made in both directions over the system at speeds of 10, 20, 30 and 40 mph. The locomotive wheels were not processed for this test. Figure 2 shows an example of a control chart with system data plotted.

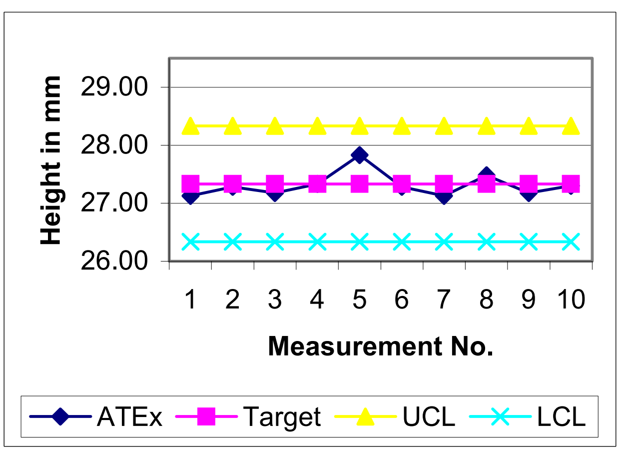

Figure 2. Control Chart for CEI 588382, Flange Height Measurements

Based on the above methodology, system accuracy (% of measurements within the upper and lower control limits) for this test was determined to be:

- 100 percent for tread hollow measurements
- 96.3 percent for flange height measurements
- 93.4 percent for flange width measurements
- 31.6 percent for rim thickness measurements for original setup (outside rim reference)
- 95.0 percent for rim thickness measurements for reconfigured setup (inside rim reference)

Data repeatability was:

- 100 percent for tread hollow measurements
- 99.1 percent for flange height measurements
- 98.7 percent for flange width measurements
- 88.1 percent for rim thickness measurements for original setup (outside rim reference)
- 82.5 percent for rim thickness measurements for reconfigured setup (inside rim reference)

Figures 3 and 4 show these results.

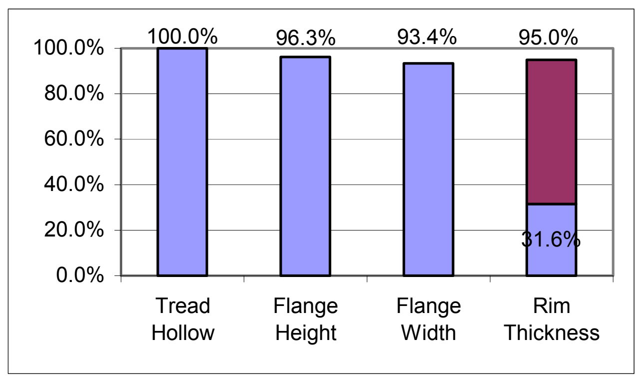

Figure 3. LynxRail System Accuracy

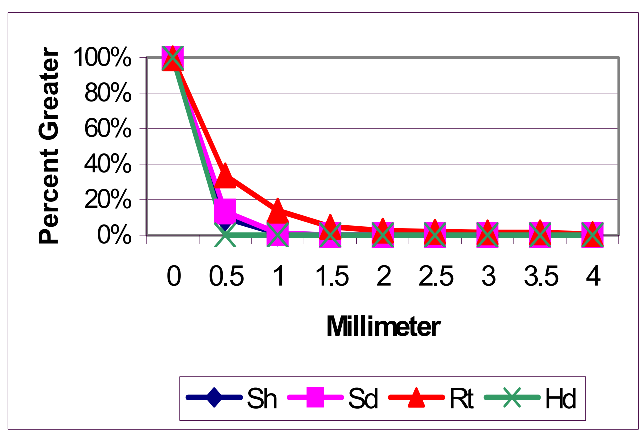

Figure 4. LynxRail System Repeatability

FUTURE WORK

The performance of the LynxRail WPM system (as well as other WPM systems) will need to be evaluated and monitored in actual revenue service applications. This is necessary to determine long-term environmental effects on system accuracy. In addition, studying the trending capabilities of the systems will require significantly longer test periods than are possible under test conditions at TTC.

CONCLUSIONS

System performances for hollowing and flange measurement parameters are well within the targeted accuracies. Speed (up to 40 mph) and direction had no effect on measurement accuracy or repeatability of these parameters.

System performance for rim thickness measurements was affected because the LynxRail system referenced the front face of the rim, whereas AAR specifications use the back face of the rim as the reference point.

The LynxRail system was moved to TTC's Facility for Accelerated Testing (FAST) and reconfigured to correct this deficiency. Rim cameras were mounted inside the gage of the rail in order to capture the inside edge of the wheel rim. New algorithms were developed to measure rim thickness using this reference. Figure 5 shows the repositioned camera configuration, and Figure 6 shows the captured image.

Additional testing was conducted during August and September of 2004. Results show that the new configuration is capable of measuring rim thickness to an accuracy of 95 percent with data repeatability of 82.5 percent.

Figure 5. Reconfigured Camera Arrangement

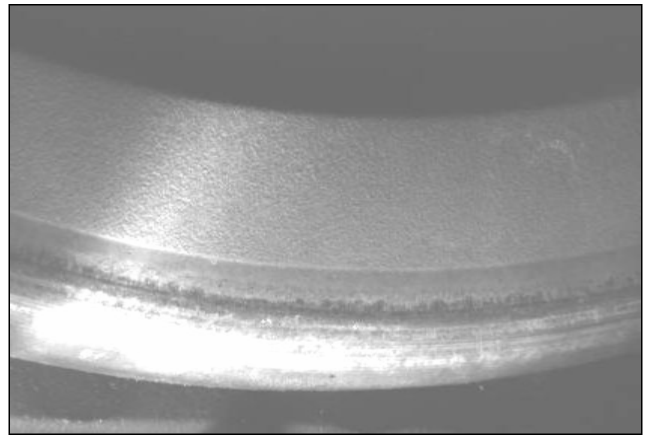

Figure 6. Inside Rim Image

Although the LynxRail system has performed well at the BHP Western Australia location, further system hardening may be required for the North American environment. Temperature extremes and snow cover will need to be addressed. LynxRail is currently developing additional covers and protection for these conditions.

References

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