TECHNOLOGY DIGEST
TD-15-047
©DECEMBER 2015
TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Undercarriage and Structural Component Monitoring in Revenue Service

Matthew Witte (TTCI) and Hark Braren (BNSF)

Summary

As part of the Association of American Railroads' Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI) has placed a structural undercarriage component inspection system in revenue service on the BNSF Railway at Gallup, New Mexico. The automated inspection of structural components (AISC) system is from Beena Vision Systems Inc. of Norcross, Georgia. It is the same technology as the system developed on the High Tonnage Loop (HTL) at Transportation Technology Center (TTC). The AISC system installed at the Gallup site has been under operation by the hosting railroad since 2012. This digest provides a summary of the performance of the system and lessons learned.

Several automated inspection algorithms were deployed and tested at the Gallup site. These were coupler carrier plate, brake beam, and center sill. Overall, the system demonstrated capability to inspect and diagnose the coupler carrier plate bolts and joint integrity, and it detected on average two carrier plate fastener defects per month. Algorithms for inspecting the brake rigging, the center sill, and the side sills were developed and deployed; however, no actionable alerts were generated during the test period. The sill algorithms are designed to inspect the center and side sills for continuity. The brake beam diagnostic checks the geometry of the brake beam and looks for missing fasteners. In general, the brake rigging diagnostic is not practical with the 2-D imaging system as designed. Beena Vision is working on the next generation of this AISC system to include 3-D imaging, which should improve the performance of all diagnostics on future inspection systems.

TTCI is continuing research toward 3-D imaging for undercarriage inspection. A system from China that images both undercarriage and truck components with 3-D technology is being installed on the HTL at TTC. This system has been used in China for several years. TTCI will test and evaluate this inspection system for potential application to the North American railroads.

Please contact **Matt Witte (719) 250-9261** with questions or concerns regarding this *Technology Digest.* E-mail: Matt_Witte@ttci.aar.com.
©2015 Transportation Technology Center, Inc. Unauthorized duplication or distribution prohibited.

BACKGROUND

In 2012, TTCI reported on the testing and development of an AISC system from Beena Vision.[1] Early development occurred at TTC with the initial prototype system placed on the HTL at the Facility for Accelerated Service Testing (FAST) at TTC. Algorithms were developed using a hospital train with known defects. These algorithms were then exercised on the FAST train, which could be monitored during its nightly operations on the HTL. Success of this system led to the deployment of a similar system for testing in revenue service. This revenue service experiment has been in place in Gallup, New Mexico, since 2012. This TD reports on the finding of the experiment and the lessons learned from the system deployed at Gallup.

INTRODUCTION

As part of the Association of American Railroads' (AAR) Strategic Research Initiatives Program, TTCI is currently involved in the research and development of machine vision based AISC systems. The purpose of these systems is to provide repeatable, consistent, objective inspections to enhance or replace the current manual inspection process. In addition, automated systems provide recordable data that can be stored and used to trend wear and predict maintenance requirements.

The AISC system uses an array of nine line scan cameras in conjunction with six banks of LED flood lights mounted in three hollow metal ties. The components are protected by automatic shutters that open when train presence is detected by wheel sensors. Each camera gives a slightly different view of the undercarriage and provides a continuous image of the entire train. Figure 1 shows a photograph of the AISC system installed at Gallup. Figure 2 shows a schematic of the camera views from the system.

Figure 1. Beena Vision AISC System installed at Gallup

OBJECTIVE

The AISC system is being tested at the Gallup site to validate performance of the machine vision equipment and to monitor the condition of the trains that pass the site. System validation entails assuring image quality, monitoring algorithm performance, and observing reliability of the hardware.

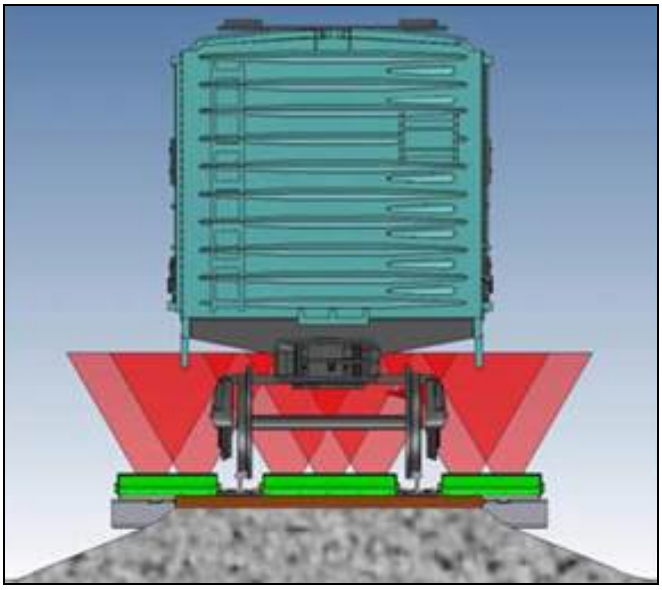

Figure 2. Camera Views from the Beena Vision AISC System

DEPLOYMENT

Several issues hindered the experiment in the first year. The AISC system installed at the Gallup site originally had very limited capacity to store images. Data was being overwritten daily and querying of historical data was not possible. Also, image quality was inferior to the test AISC system installed at TTCI. This limited the utility of the system in early testing. To improve the system, Beena Vision entered a service level agreement with TTCI and BNSF. Under this agreement, Beena Vision updated the AISC system lighting and increased storage capacity. Image storage capacity now exceeds one year.

METHODOLOGY

TTCI approached the AISC system development in a methodical manner. Early work had focused on critiquing the hardware setup and testing the durability. With reliable hardware in place, development priorities were shifted to developing automated detection algorithms. The priorities were based on risk analysis and feedback from the member railroads. From these priorities, algorithms were created to perform specific inspections on the components visible to the cameras.

Training of the algorithms requires manual review of the data. Since the AISC system has entered revenue service, Beena Vision has viewed many more types and styles of cars than was possible on the HTL at TTC. This manual review of data has facilitated the development of algorithms and also exposed some limitations of the system.

STATUS

The Beena Vision AISC system uses line scan camera technology. As such, it produces a very high resolution image of the entire train that is parsed at the car level. These images are storage intensive. Recent additions to the data storage capacity now allow for storing inspection data for up to one year before it is overwritten. The two most recent images of any car are stored and can be accessed until overwritten. This feature alone adds utility for manual review of particular cars.

Algorithms have been developed for coupler carrier plate, brake beam, and center sill. The coupler carrier plate inspects for missing fasteners and structural integrity. Brake beam inspects four structural members for continuity and geometry. The Center Sill algorithm inspects for broken center sills with separation of 2 inches or more.

RESULTS

Per agreement, BNSF railroad has been maintaining the system and monitoring the inspection results. Inspections were ongoing for 20 months. Rail traffic is steady at the Gallup location. The majority of traffic is trailer-on-flat cars, although a variety of mixed freight and passenger trains do pass the system. A typical month will see 2,300 trains and total tonnage of ~16 MGT. During the course of the testing, the coupler carrier plate fastener algorithm has been active most of the time. The center sill and side sill algorithms have been active for 10 months. The brake rigging algorithm was activated during the final months of testing.

Evaluations of the following algorithms were performed in revenue service: coupler carrier plate bolts, brake beam, center sill, and side sill. The inspection of coupler carrier retainer plate fasteners was the most reliable. Figure 3 shows an example of a missing fastener defect identified by the AISC system at the Gallup site.

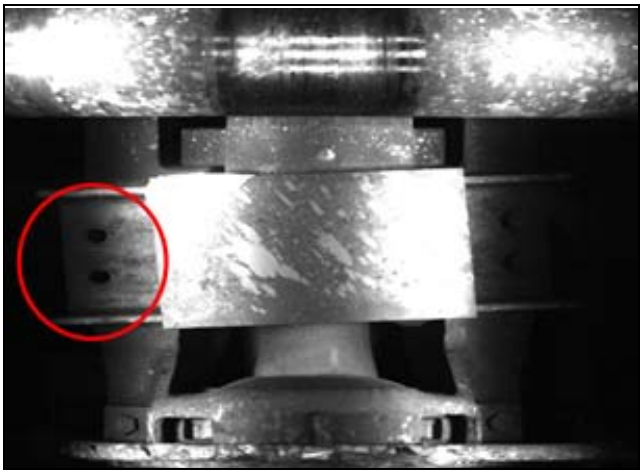

Figure 3. Missing Fastener Detected

During a 9-month test period in 2014, 15 such defects were identified by the Beena Vision AISC system. Only one false detection was logged during the entire test time and the example is shown in Figure 4.

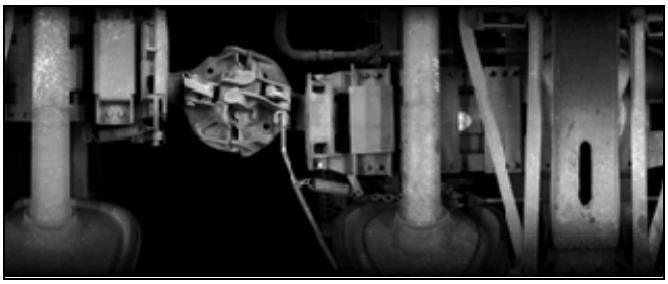

Figure 4. Car Off Center Detected by Carrier Plate Algorithm

In this case, the carbody was off of the center bowl. This serious condition triggered an alarm when the algorithm failed to complete. The carrier plate was not within the image where it was expected to be found, and the algorithm identified it as missing. It is an example of the rare occurrence that violates the assumptions implicit to the algorithm. Continuing service and vigilance in monitoring results is the method for identifying these unexpected failure modes. Four other nonactionable alerts were generated. These were all for four bolts installed in a six bolt plate, which meets AAR criteria. Again, the algorithm was fooled because it looked for, and found, empty bolt holes.

In late 2014, the center sill and side sill algorithms were deployed to check the continuity of the sill structures. Figure 5 shows the areas that are checked for continuity.

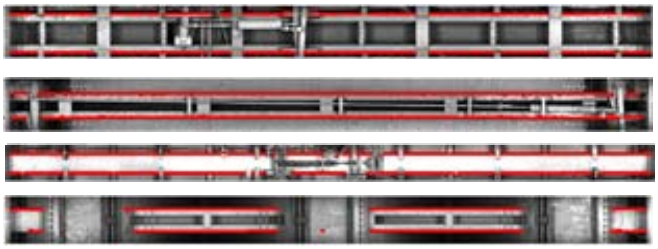

Figure 5. Red Highlights Indicate Sill Structure Areas for Continuity Check on Structural Members

During the test period, the algorithms did not identify any bent or broken structures.

Brake component inspection algorithms were also deployed at the Gallup site. This algorithm analyzes geometry of the brake rigging components. The left and right halves of the brake rigging structure are identified and inspected to assure they are not broken or bent. Figure 6 shows identification of a brake beam.

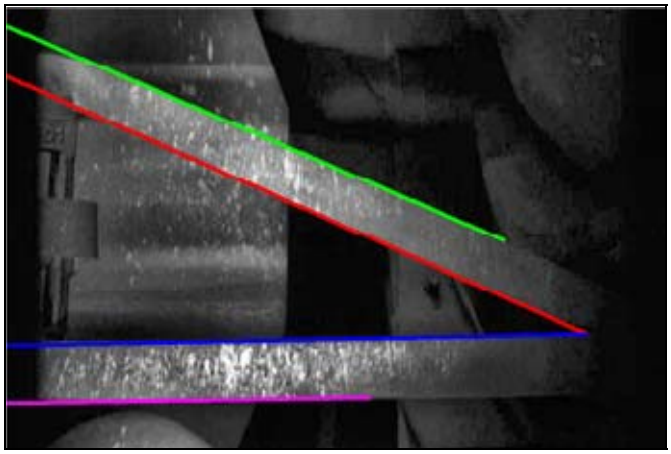

Figure 6. Brake Beam Identification and Angle Measurement

The algorithm looks for the intersection at the corners of the brake beam and measures the angle. If the beam is broken or bent, the intersection will be missing or out of position and/or the angle will be out of range. During the testing at the Gallup site, the algorithm was overwhelmed by the many different types of brake systems encountered on a variety of car types. The approach was not general enough to work reliably. The 2-D images did not provide enough information to identify low hanging brake components.

CONCLUSION

During revenue service AISC system testing, coupler carrier plate fasteners were reliably inspected. Center and side sills were inspected, but no defects were detected during the test period. Finally, Beena Vision determined that the general approach, vision inspection with 2-D planar analysis of images, was not sufficient to determine the state of brake linkage and components on all car types. A 3-D reconstruction is suggested for diagnosing brake components.

FUTURE DEVELOPMENT

The 2-D AISC system images all train car types. Certain car types have distinct components that can be addressed with the 2-D approach. Tank cars and bottom unload cars have equipment and hatches that are plainly visible. Algorithms can be developed to inspect hopper doors and latches as well as tank car drains. Figure 7 shows an image taken at the Gallup site of a tank car drain with missing cap. The system can also inspect slack adjusters and piston travel on tank cars. Figure 8 shows these components on a tank car.

Figure 7. Tank Car Drain Cap Not Installed

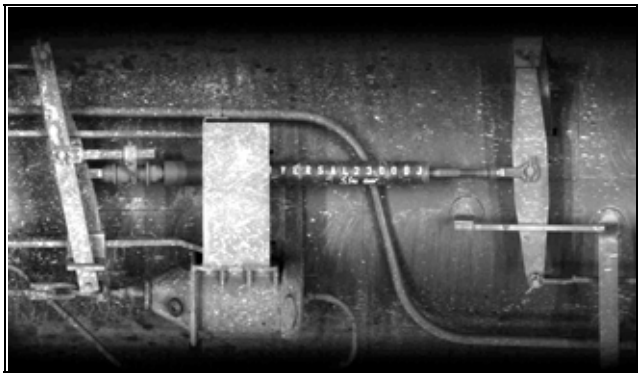

Figure 8. Images of the Brake Rigging on a Tank Car

TTCI is continuing research toward 3-D imaging for undercarriage inspection. A system from China that images both undercarriage and truck components with 3-D technology is being installed on the HTL at TTC. This system has been used in China for several years. TTCI will test and evaluate this inspection system for potential application to the North American railroads.

ACKNOWLEDGEMENTS

Kambiz Nayebi from Beena Vision provided data and analysis throughout this project.

REFERENCES

1. Robeda, J., K. Gonzales, and M.C. Jones. January 2012. “Development of Automated Inspection of Structural Components Algorithm.” *Technology Digest* TD-12-001. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Code of Federal Regulations. Title 49 Transportation. Subtitle B. Ch. II. Part 215. Railroad Freight Car Safety Standards. §215.121 “Defective car body.” [44 FR 77340, Dec. 31, 1979, as amended at 47 FR 53737, Dec. 29, 1982] Federal Railroad Administration, Department of Transportation.

Disclaimer: Preliminary results in this document are disseminated by the AAR/TTCI for information purposes only and are given to, and are accepted by, the recipient at the recipient’s sole risk. The AAR/TTCI makes no representations or warranties, either expressed or implied, with respect to this document or its contents. The AAR/TTCI assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient’s own risk.