TECHNOLOGY DIGEST
TD-16-049
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TIMELY TECHNOLOGY TRANSFER

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Facilitating Machine Vision of Draft Gears

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Summary
As part of Transportation Technology Center, Inc.'s (TTCI) research into the use of machine vision for train car inspection, the application of indicators to the draft system has been evaluated as a means of monitoring and diagnosing the health of the draft components. In test, an indicator (a rare earth magnet) was added to the follower block. This indicator was visible to the undercarriage inspection cameras and demonstrated detection of the follower block position on a moving train. Ultimately, however, the indicator magnets were not durable and the test was concluded when the magnets failed structurally. While the indicator selected for this limited testing would not be adequate for revenue service, the lessons learned show that draft gear indication is feasible. A thoughtful redesign of draft gear components may be possible that would allow the diagnosis of draft gears on a moving train. This work represents an initial look at the feasibility but much work remains.

Under the Association of American Railroads' Strategic Research Initiative program, TTCI is evaluating several inspection systems for inspecting moving trains. Each system is designed to inspect specific components, including undercarriages, truck components, safety appliances, and train car body scanning. All of these systems share common challenges. The first is capturing clear images. Cameras and lighting are placed to produce images of the components to be inspected — field of view, depth of field, and component geometry are all important factors. The second challenge is analytics. Proprietary algorithms are developed by each vendor to automate the inspection process. The analytics must consider multiple failure modes — some related to dimensional wear, others related to component failure. Additional algorithms count parts and assure the detection of every component that is supposed to be in place. A whole series of diagnostics is required to assure both presence of and health of all necessary components. In any case, the parts to be inspected must be visible or leave indications of their function in an image before they can be diagnosed. Indicators can help make part function more visible. Some components, such as friction wedges or brake shoes have wear indicators to help inspectors quickly determine their wear state. The indicators that currently exist on freight cars are not optimized for machine vision; instead, they are placed to assist human inspectors.

Thoughtful application of indicators to optimize machine vision inspection may help diagnose components that are not directly visible. For instance, the draft gear is not directly visible, but its function may be indicated by features that are visible. Abnormal position of the follower block during buff or draft could indicate a problem with the draft gear. TTCI studied the application of indicators to the follower block in an attempt to measure draft gear condition.

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INTRODUCTION

Manual inspection of draft gear components is a visual process that occurs when equipment is stationary. Acceptance is based on wear limits defined by standards and regulations. Monitoring of draft gear components on a moving train would allow a more thorough diagnosis of the draft system health than is possible with static inspection. With in-motion diagnosis, more cars could be inspected more often, and performance of the hardware could be monitored for trends. A challenge of inspection is that draft gear components are not generally visible to undercarriage inspection systems. Variations in car type and draft system hardware virtually assure that no one undercarriage inspection system will be able to diagnose all draft components. Although with thoughtful design, it may be possible to add indicators to certain draft system components that will allow measurement of the relative positions. Such measurements, when considered in conjunction with the state of buff/draft, would provide a way to measure the health of the draft components. The work reported here reviews results of a first attempt to add such an indicator. TTCI created and tested a simple indicator for the draft system on a coal hopper at the Facility for Accelerated Service Testing (FAST) in Pueblo, Colorado.

BACKGROUND

Accurate machine vision diagnostics requires consistent image quality. Images must have clear, precise information for identifying components and contrast between components within the images is essential. Contrast can be created by color variations, lighting, and shadowing. In revenue service, dust buildup eventually turns components a uniform color and eliminates color contrast. This is one of the challenges that makes machine vision of railroad components difficult. Simply adding contrast paint or reflective surfaces is generally not a viable long-term solution to component indication. Typically, geometric features such as wear notches or locating tabs offer better long-term performance. They provide a positive feature that is readily identified and easily measured. Also, geometric features can be positioned to take advantage of shadows created by the illumination system. For the case of imaging draft gear components, indicators are essential because many of the parts are not directly viewable.

APPROACH

When adding indicators to the draft system, it is important not to compromise component integrity. Draft components are part of the primary load carrying structure of the train. Tabs and notches must be very carefully placed to prevent compromising structural integrity. For this reason, TTCI limited indicator test options to those that did not require drilling or welding of any draft components. For purposes of testing, modifications must model changes that avoid structural modification so that they may eventually be incorporated into the design. Such features could be index notches that act as a measuring stick between components, or wear indicators that provide status of individual parts. For this test, an indicator that improved part visibility was chosen. While the actual application is not viable, the concept tested could be expanded with redesign.

SYSTEM DESCRIPTION

The function of the draft gear is to provide compliance to the center sill structure of train cars. The impact loads generated during coupling and the dynamic effects of buff and draft forces during train action are mitigated by the draft gear. Cushioning requirements vary by car and commodity type; thus there are many styles of draft gear in service. The basic system (Figure 1) consists of a compliant block for cushioning. The compliant draft gear is captured by a yoke that is, in turn, pinned to the coupler. The draft forces are transferred to the sill structure of the car through the draft lugs. The result is a structurally strong joint with compliance in both buff and draft.

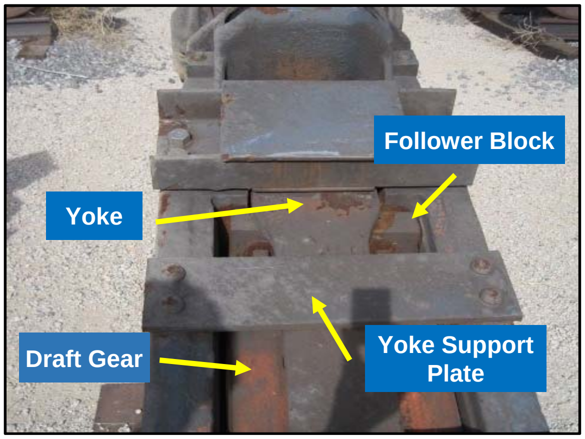

Figure 1. Typical Draft Gear Components

The follower block transmits the buff forces directly from the coupler into the draft gear and through the yoke into the sill structure; thus assuring compliance in both buff and draft. Of course, the component integrity is of the utmost importance. The draft gear and couplers are the primary load path for all of the in-train forces.

The draft gear provides the compliance and also limits the relative motion of components in the draft systems. For components in good health, there will be an expected range of motion. As the draft gear wears, motions of the yoke and follower block will begin to increase. Monitoring the relative positions of the components over time is akin to monitoring the wear of the system. Doing so should lead to the ability to predict maintenance requirements on a per car basis

Some components develop witness marks over time. For instance, the yoke will rub on the follower block, which moves with the coupler during curving. This creates a shiny area on the block. This shiny area is essentially a fingerprint. Its size, orientation, and location can partially reveal the condition of these components. This witness mark may not always be visible, depending on the position of the components. An indicator showing the position of the edge of the block would provide a positive reference.

DESIGN OF THE TEST INDICATORS

The follower block floats freely within the draft system. It is not rigidly fixed to any other component. Its position is determined by the components around it. It transmits loads between the coupler and draft gear during buff, and transmits loads from the yoke to the sill during draft. It also moves laterally during curving. Thus, position of the follower block is a tell-tale indicator of the draft system health. If it wears thin, it will be too far forward relative to the pulling lugs in draft. If the draft gear itself is worn, the yoke will be too far forward relative to the follower block during draft and too far back relative to the sill during buff. These can all be monitored visually by detecting follower block position.

On the FAST coal hopper cars, the follower block is visible on a line of site to the camera lenses. But it is not generally illuminated well enough to be visible in the images. Adding contrast and an index feature will make monitoring part location possible. The thin edge of a shiny magnet provides this means. Further, magnets model a part geometry without structurally modifying the part. TTCI selected earth magnets with 120-pound pull force. These magnets adhere strongly and, once placed, will not move. Figure 2 shows the earth magnets selected.

Figure 3 shows the magnets positioned for testing. They are located on the end of the follower block, between the block and the sill/draft lug. Magnets were positioned on both sides of the follower block on the A-end of one car. These magnets will remain unloaded during normal operation. Only during curving would the magnets in this position be stressed, experiencing a compressive loading during curving events that are tight enough to force the follower block against the sill. This might be typical of the coupler displacements encountered when negotiating a turnout or tight loop. It should be noted that the 2.7-mile loop at FAST where testing occurred is 55 percent body of curve, 17 percent spiral, and 28 percent tangent.

Figure 2. Earth Magnets to be used as Indicators

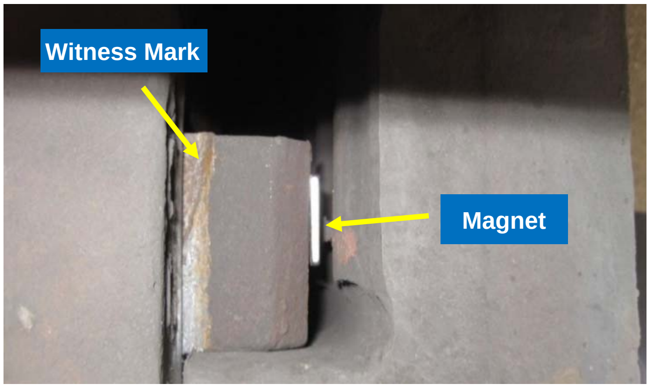

Figure 3. Magnets Placed on the Side of the Follower Block

IMAGING OF THE INDICATOR

On coal gondola cars of the FAST train, there is a space between the rear of the coupler carrier retainer plate and the leading axle. This window is imaged by the upward facing center cameras of the vehicle undercarriage examining systems. When the shiny magnet is added, there is sufficient reflection to clearly determine the position of the follower block. The window of opportunity for viewing the indicators is small but sufficient.

TEST RESULTS

The magnets initially performed well and were clearly visible to undercarriage inspection system cameras from Duos Technologies, Inc. Figure 4 shows an image of the indicator from this system.

The intent of the test plan was to monitor follower block position for several weeks, which would provide sufficient data for determining the range of normal positions for the follower block. Initially, the indicator magnets held up well. Figure 5 shows the magnets after two nights and about 4 MGT of operation at 40 mph. This still photo was taken by hand and is not an image from the Duos system.

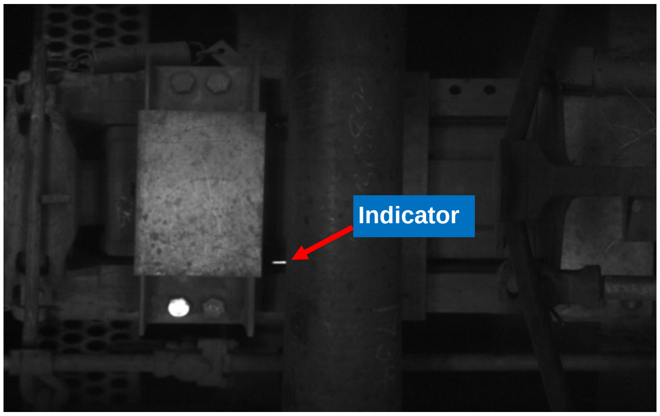

Figure 4. Indicator is Clearly Visible on an Image from the Duos Undercarriage Examiner

Figure 5. Indicator Magnets after Two Nights of Operation

During the second week of operation, the magnets failed. Although they are hard, they are also brittle and could not withstand the compressive loads encountered from repeated curving. Figures 6 and 7 chronicle the magnet failure.

Figure 6. Magnets on One Side Crushed and Ground to Dust

Figure 7. Magnets on the Other Side Fractured

CONCLUSIONS

Machine vision monitoring of draft gear components will be possible with the undercarriage inspection systems under development. But doing so will require indicators to be added to the components. TTCI applied a magnetic indicator to the follower block and demonstrated that it is visible to the Duos undercarriage inspection system on coal gondola cars. While the magnetic indicator tested is not practical for revenue service, it should be possible with thoughtful design to create an indicator within the draft components themselves that is suitable. Additionally, it is important that the vision system used has sufficient resolution so that wear limits can be recognized as they are approached. This requirement was inconclusive because of the failure of the indicator magnets.

NEXT STEPS

To continue this work, TTCI's next steps include working with component manufacturers to determine viable designs for actual indicators. High reflectivity was used for the indicator tested here, but geometry variations may be practical to make the follower block position visible.