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**Federal Railroad  
Administration**

# Research Results

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## Video System for Joint Bar Inspection

### SUMMARY

An automated video inspection system of joint bars has been developed and successfully field evaluated to detect cracked joint bars. The Federal Railroad Administration (FRA), Office of Research and Development, and ENSCO, INC jointly funded this research effort. The system utilizes high-resolution scan line cameras and two joint bar detection laser sensors mounted on a hi-railer (Figure 1). In two field demonstrations, the system detected cracks in joint bars with acceptably low false alarm rates (40 percent of detected cracks were confirmed and 60 percent were rejected by the system operators). Though the system missed 15 percent of the cracks, none of the missed cracks were center cracks. The crack detection algorithm is being refined and tested to reduce the number of missed cracks and false detections caused by high ballasts and vegetation, grease, mud, or other conditions on or near joint bars.



*Figure 1. Joint Bar Inspection System is fully deployed and ready for testing.*



## BACKGROUND

Broken joint bars have been identified as one of the significant causes of main line derailments in the United States. Currently, railroad maintenance personnel visually inspect joint bars during regular track inspection. The quality of this inspection, which is usually performed from a hi-railer, is questionable. Visual inspection of joint bars on foot provides good results; however, inspection on foot is a very slow and labor-intensive process. FRA, supported by ENSCO, Inc., developed and tested an automated video inspection system of joint bars, which operates from a moving vehicle (Figure 2).



**Figure 2.** Side sections of instrumentation beam are folded for traveling on highway.

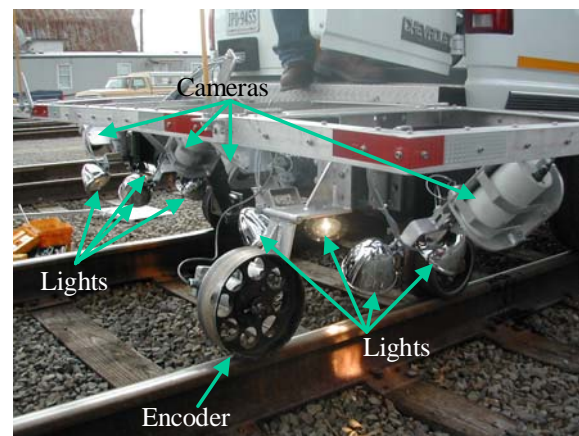
Development of the system was accomplished in several stages. The initial stage consisted of designing and testing a single camera system with a laser-based joint bar detection sensor. Subsequent stages included integrating a complete functioning system with four cameras and two joint bar detection sensors, installing the system on a hi-railer, testing the system over several railroads, collecting data, and analyzing the images to find cracked joint bars.

## DESCRIPTION OF THE SYSTEM

The system utilizes high-resolution line scan cameras inspecting joint bars on both sides of the left and right rails. The cameras are triggered at a fixed distance rate of 0.5 mm by a signal from an optical encoder (tachometer) mechanically connected to a measuring wheel. A lighting subsystem provides consistent uniform illumination of the cameras. Two laser distance sensors provide joint bar detection. All these components are mounted outside the hi-

railer, either on an instrumentation beam suspended from the hi-railer body (cameras, lights) or on hi-railer gear (laser sensors, encoder). Figure 3 shows the mounted cameras, lights, and encoder.

In addition to the imaging components under the vehicle, the system includes a signal conditioning unit, a power distribution unit, a Global Positioning System (GPS) receiver, and a hand-held Termiflex unit for manually marking mileposts and other ground features. The system uses two computers: an Image Acquisition and Analysis Computer with specialized image acquisition and counter timer boards and a laptop computer that provides image storage and an operator interface.



**Figure 3.** Joint bar inspection system mounted to the rear of the Hi-Railer.

## RESULTS OF DEMONSTRATIONS

ENSCO conducted two field tests at a small railway yard for verification of system functionality. Two railroads with Class 1 track supported ENSCO during the two field demonstrations. The following summarizes the conditions and results of these demonstrations.

The first field demonstration was performed on April 7-8, 2005. The goal of this test was to verify the system operation in real survey condition and to collect images for developing crack detection algorithm. On the first one, 15 miles of track was tested and on the second 50 miles of class 2 track was tested at 25 mph. No real-time crack detection software was running. The images collected from this test series were then used to aid in developing the crack detect algorithm. Once the first version of the algorithm was developed and implemented, it was used to post-process collected images. Out of 35,000



inspected joint bars, the software detected 60 joint bars (or 0.2 percent) as potential cracks. Based on visual analysis of the images, three cracked joint bars were confirmed and reported to the railroad (Figure 4).



**Figure 4. Small center crack detected by joint bar inspection system.**

Since the false detection rate was considered too high (only 1 out of 20 detected cracks was confirmed), further improvements were made to the algorithm to decrease the false detection rate. Analysis of the images demonstrated that the main causes of false detections were scratches, grease, and mud on joint bars. The algorithm was modified to better filter out these triggers, and the number of false detection significantly decreased.

The second demonstration was performed from September 19 to September 22, 2005. The first 2 days were spent calibrating and verifying that the system was operating correctly after transporting the hi-railer from Springfield, VA. Over the next 2 days, an 18-mile long subdivision was tested. This was the first extended testing with the automatic crack detection enabled. Some of the detected cracks were verified by looking at the image of the joint bars, and some were verified on the ground. A hand-held GPS receiver was used to find joint bars during on the ground verification. The GPS system provided accurate location information for the cracked joints.

The following statistics summarizes the results of this test:

- 18 mile test on Class 1 (10 mph) track
- 9,750 joint bars inspected
- 251 suspected cracks detected (2.5 percent of inspected joint bars)
- 98 cracks confirmed (1 percent of all joint bars and 40 percent of suspected cracks)
- 6 of the confirmed 98 cracks were center cracks

To determine the percentage of missed cracks, 1,700 random joint bar images were analyzed. Out of these joint bars, the system correctly detected 17 cracks and missed 3 quarter cracks (no missed center cracks). This means that 15 percent of the valid cracks were not detected.

The test revealed that the laser sensors used for joint bar detection provide a relatively high rate of false triggers from vegetation, high ballasts, debris on the track, and other conditions. Although these images are rejected during subsequent analysis, the processing of these false images places an unnecessary load on the computer system, and in some cases, it delays or slows down the system or prevents the system from correctly capturing joint bar images.

## CONCLUSION

The developed system is fully functional and provides inspection of joint bars on field and gage sides of both rails at hi-railer speed. The system detects and reports cracked joint bars and their location in near real-time during a survey. Field demonstration of the system has proven that the cracks are detected with acceptably low false alarm rates (40 percent of detected cracks were confirmed, and 60 percent were rejected by the system operators). Though the system missed 15 percent of the cracks, none of the missed cracks were in the center of a joint bar. The crack detection algorithm is being refined and tested to reduce the number of missed cracks and false detections.



## FOR FURTHER RESEARCH

Proposed future steps include:

- Testing of the developed system under different conditions, including continuously welded rail (CWR).
- Further tuning of the crack detection algorithm to decrease the probability of missing cracks.
- Development of an algorithm for automated detection of missing bolts and nuts.
- Continuous image acquisition and processing with the goal of replacing laser based triggering with image based triggering.
- Continuous automated inspection of rails and fasteners for visible cracks, missing clips, and other visible defects, including rail surface defects.

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## KEYWORDS

Joint bar, joint bar inspection system, automated video system, crack detection

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