TECHNOLOGY DIGEST

Timely Technology Transfer — 01-011

Track Buckle Detection with Train Presence in Fiber Optic Circuit

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Summary

A series of tests by Transportation Technology Center, Inc. (TTCI) in 2000 determined that fiber optic technology can detect track buckling in presence of noise generated by train operation. This was achieved by installing a single optical fiber circuit covering a double track portion of the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST), and then mechanically applying a buckle on one track while the FAST train operated on the other track. The main findings of this investigation were:

- The fiber optic system can distinguish track buckles from train presence or curve breathing.
- The modified moving averages approach can successfully be used in identifying the occurrence of a track buckle in the presence of noise generated by train operation.
- Train noise, as measured through the fiber optic cable, is influenced by train speed. Its amplitude and frequency content increase with an increase in train speed.
- TTCI's fiber application system, consisting of a rail cleaner/fiber applicator cart and aluminum ramps at welds, can apply 2,000 feet of fiber cable per hour.
- A long-term revenue service test is needed to determine the durability and practicality of the system.

The fiber optic system used in previous tests was significantly enhanced for these tests in terms of the attachment of the fiber to the rail, transmission of optical signals, and the computer signal processing and analysis algorithm. However, the current likely high installation and maintenance costs may preclude use of fiber optics on a system-wide basis. This technology could be used in detection of track buckles in critical areas such as bridge approaches, special track work, and curved track with previous buckling problems. Future developments in the fiber optic technology may also lead to its application in detecting train presence or truck hunting.

Suggested Distribution:

- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by TTCI Transportation Technology Center, Inc.

a subsidiary of the Association of American Railroads

INTRODUCTION AND CONCLUSIONS

For the past three years, Transportation Technology Center, Inc. (TTCI) has been engaged in the investigation of track buckling detection using optic fiber technology. A series of tests performed at the Facility for Accelerated Service Testing (FAST) during 1999 successfully detected track buckling, which was achieved by mechanical means.[1] The signal processing used for the tests made differentiation between noise produced by train presence and the signal produced by track buckling possible. However, these track buckling and the train presence tests were conducted independently, so the separation of the fiber signals from the stochastic noise could not be studied. It was recognized that for application of the optical fiber technology in the field, further enhancements to the system were required. These included methods of fiber application to rail and particularly to rail welds, refinements to the transmitter unit and the algorithm to differentiate signals received from noise generated by train operation.

The objectives of this phase of investigation were to carry out the identified improvements to the system, conduct track buckle tests with the train present in the fiber circuit, and distinguish the track buckle signals from the noise generated from train operation and weather conditions.

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BACKGROUND

Optical fiber has a characteristic that attenuates light transmission along its length as a result of fiber curvature. This small change in light transmittance can be measured as a change in voltage using specialized photo transmitter and receiver units. The receiver unit that receives the fiber signal is connected to a data-acquisition unit. The continuous monitoring of signal strength through a fiber attached to the rail can give an indication of any change in track geometry such as a buckle. A loss of signal indicates a broken rail or fiber. Previous field evaluations have shown that a fiber optic system is capable of distinguishing a track buckle from other non-train caused rail movements, such as "curve breathing" caused by seasonal and daily temperature changes.[2] Development of the fiber optic technology for use in railroad operations has presented some problems such as achieving adequacy of attachment of fiber to the rail, a stable transmitter unit, and separation of optic signals from the stochastic noise sources. The work reported here addresses these issues.

TEST SET UP

Tests were conducted at the double track portion of the FAST loop as Exhibit 1 shows.

Multi-mode fiber optic cables were installed on the field side of the outer rail in Section 36 from tie No. 50 to tie No. 340, and on the field side of the outer rail in Section 29 from tie No. 340 and in Section 30 to tie No. 64. These two fiber optic cable segments were connected at ties No. 340 of Sections 29 and 30 by means of jumper cable in a 0.5-inch-diameter conduit. This arrangement allowed the operation of trains in Sections 29 and 30 while simulating a track buckle in Section 36 of the same fiber optic circuit. An optic transmitter unit was installed at one end of the circuit (near tie No. 64 of Section 30) and an optic receiver unit at the other end (near tie No. 50 of Section 36). Both were connected to the data-acquisition system. The transmitter sent a laser beam while the receiver received and sensed any change in the optic signals due to train noise and track buckling.

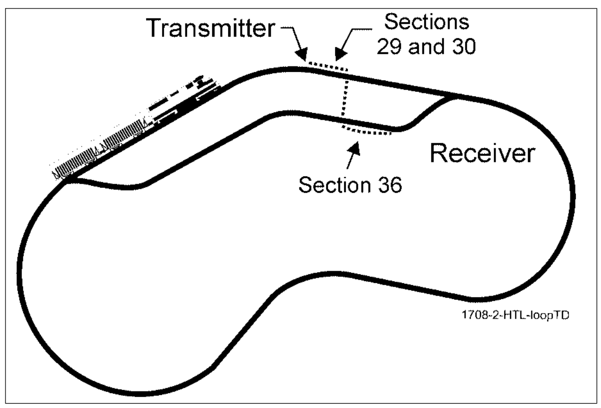

Exhibit 1. Location of Test Site

Prior to the buckle test, a couple of gage rods were installed at the point of the pull. The ballast crib was tamped and the shoulder on the side of the pull was removed to facilitate track buckling. The lateral pull was applied mechanically by means of a bulldozer. Exhibit 2 shows the track buckle test in progress in the presence of a train in the fiber circuit. Static track geometry measurements were taken before and after to determine the magnitude and shape of the buckle. Dynamic track measurements were also taken with two potentiometers attached between the ground and the point of force application of the buckle.

Exhibit 2. Track Buckle Test in Progress

FIBER APPLICATION METHOD

The fiber was applied to the cleaned rail web by a TTCI developed fiber installation cart. This cart used epoxy for attaching fiber that in turn was covered with a tape to hold it in place while the epoxy cured. At thermit weld locations, 1/16-inch-thick by 2-inch-wide by 10- to 12-inch-long aluminum strips were installed on each side of the welds to build ramps to attach the fiber. This arrangement provided a smooth and speedy transition that proved to be durable and less expensive than ramps made with epoxy fillers used in the previous tests.

FAST EXPERIMENTS

Train Noise Characteristics

A couple of days prior to the track buckle test, data was collected for several runs of the FAST train at speeds ranging from 10 to 40 miles per hour. The train consisted of four locomotives and 69 cars. The objective was to characterize train noise and to investigate the effect of train speed on fiber signals. The ambient temperature during these runs varied between 30 to 40 degrees F. Exhibit 3 shows time plots of root mean square (rms) of differentiated train noise signals at different speeds. The train noise generally possesses higher frequencies and its amplitude increases with increase in train speed.

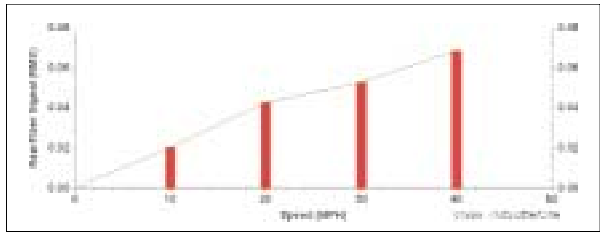

Exhibit 3. Differentiated Fiber Signal from Train Noise versus Train Speed

Track Buckle Signal Characteristic

The track buckle was applied at tie No. 180 while the FAST train was running clockwise at a speed of about 25 mph. The track was pulled laterally about 14 inches towards the center of the loop. During the pull the track slid back slightly. When the pulling force was removed, the track moved back about 4 inches and stayed in that position. Track geometry measurements were taken before it was restored back into its original position. The fiber did not sustain any damage upon restoration. Exhibit 4 is a photograph of the buckled track. Exhibit 5 shows the time plot of the raw fiber signal with the superimposed potentiometer readings. The potentiometer readings show the amount of track shift from the pull but the raw fiber data reveals nothing. The track buckle signals have low frequencies.

DATA REDUCTION

The data was collected continuously at a sample rate of 500 samples per second during the test. A signal conditioning system was used for data acquisition with software for analysis purposes. Various methods of signal accentuation such as different filter frequencies and filter types, auto-correlation, gamma function, and windows of moving averages were attempted to identify the occurrence of track buckle from the data collected. However, a "modified moving windows" approach was successful in identifying buckle signals in the presence of train noise. Exhibit 6 shows the time plot of the fiber signal as computed using the "modified moving windows" approach. The start and the end of the applied buckle forces are clearly indicated by large spikes. This approach was also applied to the 1999 test data, and it was equally successful in identifying the track buckle.

FIBER DURABILITY EVALUATIONS

The fiber optic track buckle and broken rail detection system installed in FAST was subjected to normal track maintenance over several months of testing. The fiber,

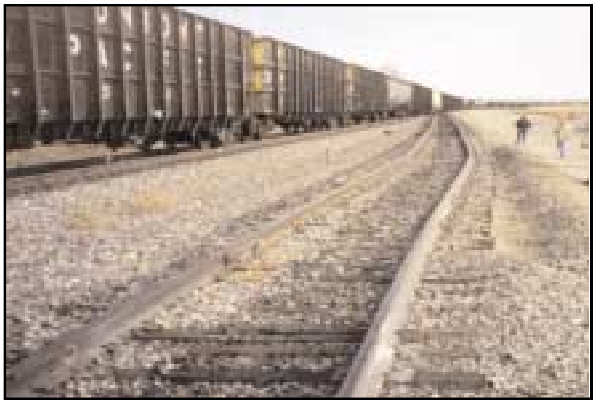

Exhibit 4. Photo of the Buckled Track

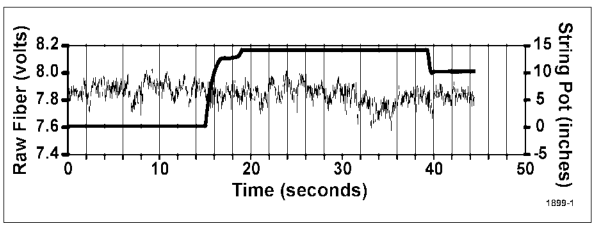

Exhibit 5. Raw Fiber Signal with Superimposed Potentiometer Readings

attached to the upper web fillet on the field side of the rail, survived track surfacing operations. Minimal ballast was added during this tamping cycle.

The effects of long-term weathering need to be evaluated. The FAST test sections were in place for several months. The fiber withstood daily and seasonal temperature cycles without any problems during this period. However, the long-term effects of temperature cycles and UV radiation exposure have not been documented.

Two methods of bridging over thermite welds C a rather sharp obstruction to the fiber on the web of the rail C were tested. One involves use of epoxy ramps built up around the weld. The second uses aluminum strips epoxied to the rail to form the ramps. Both survived the short duration test without problems.

FIELD APPLICATION ISSUES

The fiber optic system is capable of detecting track buckles in track with and without traffic present. The system is also capable of discerning buckles from long term events, such as curve "breathing." Lack of data on

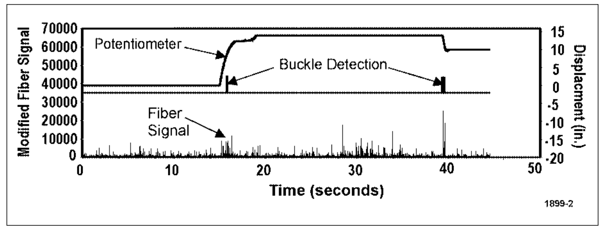

Exhibit 6. Time Plot of Fiber Signal as Computed Using the Modified Moving Windows Approach

long-term fiber durability makes assessment of system reliability and life cycle costs difficult. However, the costs of application of the system and maintenance with current technology are expected to limit the applications to higher risk areas.

The integrity of the fiber optic line and detection system is threatened by rail replacements. A rail replacement requires replacement of a much larger section of fiber since splices cannot be made to the fiber attached to the rail. It is too brittle to be removed from the rail and repaired in the unjacketed state. Thus, fiber must be installed with occasional "service loops" of fiber not attached to the rail that contain mechanical connector joints. When a rail is replaced, the fiber needs to be replaced not only on the plug rail, but also between the service loops.

If a bolted plug rail is installed that will later be welded into track, a temporary jumper cable (not attached to the rail) may be installed to keep the system functioning. The track in the plug rail section will not be protected while the jumper is in place.

REFERENCES

1. Schroeder, M.P., and Reiff, R.P., "Evaluation of Fiber Optic Method for Detecting Buckled Track or Broken Rail," Association of American Railroads, Research Summary No.RS-99-003, February 1999.
2. Uppal, A.S., Schroeder, M.P., and Davis, D.D., "Detection of Occurrence of Track Buckle Using Fiber Optic Technology," Association of American Railroads, Transportation Technology Center, Inc., *Technology Digest* No. 01-003, March 2001.

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