TECHOLOGY DIGEST

Timely Technology Transfer — 00-002

Field Performance of Two Alternative Broken Rail Detection Systems

by Richard P. Reiff

Summary

Data collected over a nine-month period from two prototype, non-track circuit-based broken-rail detection systems installed at the Facility for Accelerated Service Testing (FAST) indicates these systems are capable of detecting broken rails. However, system reliability and sensitivity resulted in occasional occurrence of rail breaks which were not detected with sufficient reliability for revenue-service applications. The fiber optic system exhibited the potential for early warning of rail breaks caused by cracks in welds; however, fiber repair techniques need to be improved. Additional development in software interpretation, hardening of equipment, and fiber optic detection material application techniques is suggested before implementation of either system into a train control system.

Two technologies were evaluated. One utilized sensors that measure longitudinal rail strain/stress, spaced at about 150-foot intervals. At a periodic time interval, each sensor broadcasts the state of rail stress and temperature to a master control station that utilizes proprietary methods to interpret changes in these parameters to determine if a rail break has occurred. The second technology utilizes a fiber-optic strand bonded along the rail web. A light source is introduced at one end of the fiber and received at the other end. A crack or rail separation will break the fiber, thus blocking the light source which the receiver indicates as a broken rail.

Experience at FAST has shown that sensors of both technologies could be damaged by track repair activities associated with heating rail during de-stressing operations and being struck by work equipment. Additional efforts to improve sensor ruggedness and facilitate repair after a rail break occurrence should be investigated.

The primary purpose of track circuits is to detect the presence of a train in order to operate train control devices. A broken rail will normally block the electrical path of a track circuit, thus providing broken-rail detection as a side benefit to train detection capabilities. Under certain conditions, such as a break occurring over a tie plate, the track circuit may not be reliably interrupted and the system will not always detect a break. The emphasis of this initiative was to determine if alterative, non-track circuit-based detection systems would detect broken rails with reliability equal to or greater than conventional circuits.

Suggested Distribution:
- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by TTCI Transportation Technology Center, Inc.
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INTRODUCTION

The AAR has identified a need for alternatives to conventional in-track circuit-based broken-rail detection systems for potential application in dark territories, and to replace conventional signal control circuits in areas where Positive Train Control (PTC) may be implemented. A technology search conducted in 1997 identified concepts that had been demonstrated in the laboratory and appeared to be feasible for limited field demonstrations. Two were included in this evaluation:

- **Strain gage detection system**. This system monitors the state of rail longitudinal stress at discreet locations spaced at intervals of 100 to 200 feet along the rail. By monitoring rail temperature and stress, changes in the relationships of these two factors can be interpreted as a rail break, or in some cases, as a buckled track.
- **Fiber optic based system**. This system utilizes light transmitted through a single fiber optic carrier bonded to the web of the rail: A break in the fiber will disrupt the signal, which is interpreted as a broken rail. Additional features, which require more sophisticated analysis of the transmitted light signal, have been shown to interpret buckled track conditions.

This study was limited to evaluating capabilities of both technologies to detect broken rails.

TEST LAYOUT

Prototypes of both systems were installed during 1998 over a 605 foot length of the outside rail of a 5-degree curve. This was located on the FAST test zones 1 to 3, overlapping a location where rail containing internal defects was being closely monitored. This location not only had the highest potential of a broken rail occurrence at FAST, but the need to periodically remove and replace defects created a number of known rail break occurrences in support of rail replacement activities. Exhibit 1 shows a schematic of the two detection systems installed in this area.

DETECTION SYSTEM OVERVIEW

Strain gage system

The 605-foot test zone included seven strain gage sensors installed on the gage side of the high rail. After installation of the gages, rail was cut in several locations and allowed to relax, thus creating a zero stress state for calibration purposes. Under revenue service applications, sensors could be installed at the welding plant or in track just prior to de-stressing activities to calibrate for a zero stress state. Each sensor location consists of a strain gage microwelded to the web of the rail. A protective cover, which contains the battery, signal conditioning, and transmission equipment, is bolted to the rail web. Under production conditions,two trained technicians would require a minimum of 30 minutes to install the strain gage and cover.

Not shown on the schematic is the base master station, which receives the signals, transmitted

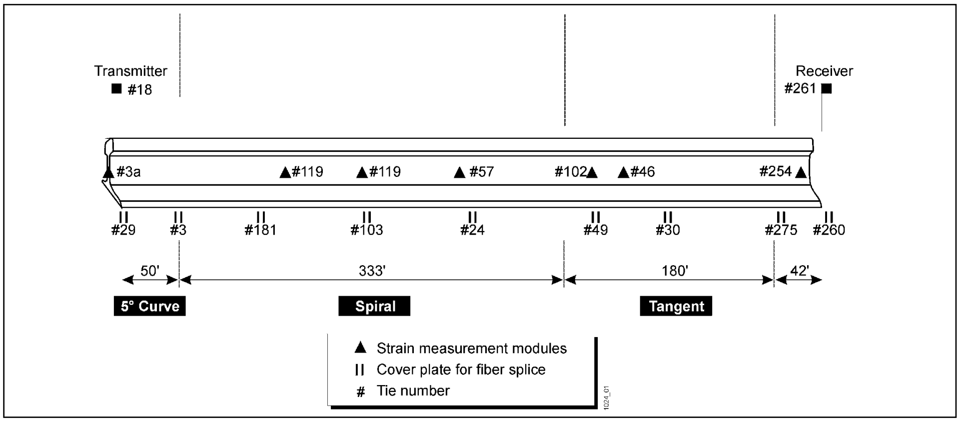

Exhibit 1. Test Layout Schematic

TTCI = Transportation Technology Center, Inc.; AAR = Association of American Railroads from each of the sensors. For this test the master station and antenna were located in a nearby signal bungalow. On a periodic basis the master station polls stress/temperature readings are sent from each sensor. For this test, the frequency of transmission was once every 10 minutes. The polling rate selected is based on obtaining a battery life of about 10 years. A more frequent transmission rate would result in reduced battery life.

Fiber Optic System

The fiber optic system consisted of a light transmission source adjusted to a wavelength of 1550 nanometers. The 62.5-micron-diameter fiber is bonded to the rail using epoxy. The initial installation utilized a hand application process requiring several days to complete the entire segment. A prototype production applicator fixture has been designed and built under contract by the University of Illinois/Urbana, as shown in Exhibit 2. This cart facilitates the application of fiber along the rail by metering out fiber and a bonding tape as the unit is pushed along the rail. Regardless if epoxy or tape is utilized, the rail surface over which the fiber is attached must be cleaned of loose rust, dirt, grease and other surface material to ensure a firm bond.

Due to the bond between the rail and epoxy, it was not possible to repair or splice the fiber. Thus after a rail break the entire section of fiber would need to be replaced. To avoid this need while an improved attachment and splicing technique is developed, an extra 3 feet of fiber and a splice was placed along the fiber approximately every 100 feet. These locations are indicated as splice covers on the layout in Exhibit 1. Thus a rail break repair requires only the 100 feet of fiber between splices to be replaced.

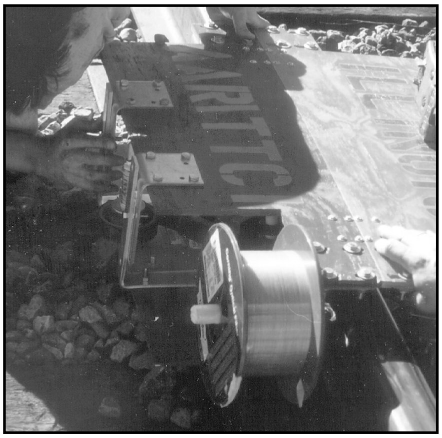

Exhibit 2. Prototype Fiber Strand Applicator Cart

Under normal conditions, the light transmitted through the fiber is received at the end of the monitored section and converted to approximately a 5 volt signal. Small variations in light will produce small variations in voltage, thus the go/no go threshold voltage for a broken rail was set at less than 0.5 volts.

PERFORMANCE

Exhibit 3 summarizes results of evaluating this section over a nine-month period during which six broken rail occurrences were observed in this 605- foot section. Some of these were "forced" breaks associated with cutting the rail in support of rail defect change out activities, while others were natural occurrences. Although the strain gage system did not interpret the broken-rail occurrence on Dec. 8. 1998, subsequent evaluation of the strain history recorded by each sensor indicated that the break was measured at several sites. The interpretation software was upgraded, improving subsequent performance. Due to rail replacement needed from the buckling test, the fiber optic system was purposely disabled and shut off until improved fiber application techniques can be implemented. Of special note is the broken weld event occurring on March 29, 1999. Detailed evaluation of the time history is shown in Exhibit 4. Note that the weld cracked in the evening of March 26, which cut the fiber optic strand. The weld actually broke at 1:04 a.m. on March 29, which set the signal system to a stop indication. However, due to the polling interval,

Date	Event	Fiber	Strain
12/8/98	Rail cut	yes	no
3/26/99	Weld crack	yes (p.m.)	no
3/29/99	Weld break	already	yes
9/8/99	Forced buckle	yes	no
9/14/99	Rail cut/destress	yes	no
10/3/99	Weld break	system off	yes
11/19/99	Weld break	system off	yes
12/15/99	Rail break	system off	yes

Exhibit 3. Summary of Broken Rails Detected/Missed

Broken Rail events log		
3/25		Last train operations
3/26	21:28:30	Fiber signal drops
3/28	21:00	Green signal/track circuit
3/39	01:04	Red signal/track circuit; train stopped, broken weld in test zone
3/29	01:08:48	Strain gage indicator

Exhibit 4. Summary of Events Surrounding Detection of a Cracked Weld

the strain gage system did not interpret the rail as broken until 4 minutes 48 seconds later.

SUMMARY OF FEATURES

Both technologies evaluated exhibited features not found in track circuits, but they also need additional development in order to be considered reliable for revenue service application.

Strain Gage System

Unless a sensor is damaged by the broken rail event, the strain gage system is available for detection immediately after the rail is repaired. Should the repair utilize a bolted plug, however, any free play in the joints may reduce sensitivity. Strain gage modules are susceptible to damage from work equipment, including rail heating operations. Exhibit 5 shows a sensor module damaged from a rail heater that was inadvertently operated too slowly past the site. The polling cycle selected is needed to obtain an extended battery life; however, the time between polling is dead time, and, depending on how much before the next poll, a delay between the broken rail event and notification of a broken rail will occur.

Exhibit 5. Heat Damaged Strain Gage Sensor Cover

Fiber Optic System

Detection of a rail break with the fiber optic system is immediate and continuous along the rail. Attachment of the fiber around thermite welds is difficult; however, this technology also has the potential of detecting a partial break before it becomes a service failure. Repair of the fiber is difficult and usually requires removal and reinstallation for the entire length of rail between two existing splices. The rail must be clean of oil and loose material prior to installing the fiber.

FUTURE WORK

One major railroad is currently evaluating the strain gage system. This year, a prototype fiber optic detection system will be installed over a 2 mile length of track in revenue service. For this installation the production applicator and improved installation materials will be utilized.

ACKNOWLEDGMENTS

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.