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Instrumented Freight Car for Performance-based Track Inspection

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Summary

Transportation Technology Center, Inc. has developed an instrumented freight car (IFC) technology for performance-based track geometry inspections. As part of the Association of American Railroads' Strategic Research Initiatives Program, IFC inspection technology is currently being used for nightly track inspections at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, to monitor and determine track geometry degradation under heavy axle loads.

Tests showed that top chord strain gages, vertical carbody accelerometers, and suspension displacement transducers all captured the pitch and bounce track geometry perturbation. Thus, any of these transducers would be capable of determining this type of track geometry condition. However, accelerometers installed on the side frames were not as good at capturing this type of vertical track perturbation.

For the test conducted over the twist and roll perturbation, top chord strain gages and suspension displacement transducers again captured the actual track geometry variations on the track. Neither vertical nor lateral carbody accelerometers (also accelerometers on the side-frames) were as good at capturing this type of cross-level perturbation. However, from the tests conducted at FAST, where broken rails (short wavelength track geometry deviations) occurred, accelerometers on the side frames were the best to identify this type of perturbation.

The operation of IFC technology at FAST showed consistent inspection results from lap to lap and from night to night and has identified both short- and long-wavelength track geometry problems. The following are several additional findings from nightly inspections at FAST:

- Changes of vehicle responses from lap to lap, due to defect growth to a broken weld or broken rail, were shown on the data recorded and will require further software development to generate a warning of incipient rail breakage.
- The data on most of the sensors provided good correlation in terms of exception/top event locations identified (basis to reduce the number of sensors in the production use of this technology); however, some vehicle performance issues were only identified by one specific type of sensor (e.g., locations that generated highest top chord stresses), thus more than one type of sensor may be needed for this inspection technology.

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INTRODUCTION

Performance-based track geometry inspection is an emerging technology to assess track geometry condition based on vehicle performance. There are two types of this technology. One uses actual track geometry measurement from a track geometry inspection vehicle as input to a black box to determine likely vehicle performance. This black box is essentially an add-on to a track geometry inspection vehicle, without any additional instrumentation. TTCI's PBTG™ (performance-based track geometry) inspection technology works using this approach.[1]

IFC is another type of inspection technology. With the IFC technology, sensors are installed on freight cars to measure vehicle responses directly, which are then used to assess track geometry conditions and their maintenance needs. In general, such a measurement system is unattended and measurement results are transmitted to the office via wireless communication. With this technology, track geometry inspections can be conducted frequently without affecting track occupancy, which would help railroads determine track geometry conditions and degradation for their routes with heavy axle load (HAL) train operation on a more frequent basis.

BHP in Australia was the first to develop and use an instrumented freight wagon for automated track inspections to determine track maintenance needs for its heavy haul iron ore route.[2]

In late 2006, TTCI started to develop IFC inspection technology for implementation on North American railroads, under the Association of American Railroads' Strategic Research Initiatives Program. This TD describes the technology developed to date and presents the results obtained on the test tracks at TTC.

INSTRUMENTATION ON A COAL CAR

A coal car was selected for the development of IFC inspection technology. The test car, equipped with ride-control trucks, was loaded with sand and gravel to a gross weight of 285,375 pounds.

For research purposes, a large number of sensors were installed on the IFC, including:

- Tri-axial accelerometers at both ends of the carbody
- Strain gages for measuring axial and lateral bending stresses on the top chords on both sides of the carbody
- Vertical accelerometers on both sides of side frames
- Vertical and lateral suspension displacement transducers on both sides of the trucks
- Strain gages for measuring bolster loads

Figure 1 shows the placement of the various onboard sensors on the IFC. Note that for future production use of this technology, the number of sensors can be reduced, depending on the vehicle performance issues and concern about for the routes to be inspected. The system is also flexible enough to adapt to additional types of sensors not used to date.

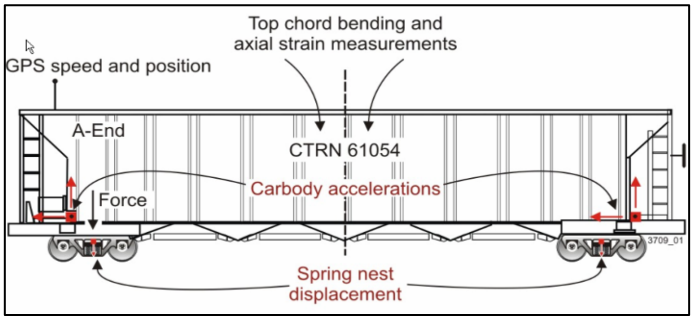

Figure 1. Instrumented Freight Car

The onboard system is powered by solar panels or an axle generator. An unattended data acquisition and analysis box collects data and interpret results real-time relating vehicle response exceptions to actual track geometry conditions. Cellular phone technology is then used to transmit reports back to the office on a regular basis.

SOFTWARE DEVELOPEMENT

A major part of the IFC research is software development. This includes the software used onboard for real-time data processing and interpretation as well as the database program used in the office for viewing exceptions and conducting trending analysis on the current and historic data.

For the real-time analysis, vehicle response exceptions, and top events (part of statistics) are generated on the basis of a pre-determined track length. Currently for the operation at FAST, this length is about 2.7 miles, which corresponds to the length of the High Tonnage Loop (HTL) at FAST. As such, exceptions and top events are reported lap by lap, as the train at FAST operates around this loop throughout the night.

Exceptions are calculated from a pre-determined threshold for each sensor. To determine those threshold values, statistical analysis is done based on the historic data collected to determine an allowable magnitude for each sensor, which is considered an indication of poor vehicle response due to poor track geometry.

When an exception is generated, the software determines if it is a short or long wavelength exception. For a long wavelength exception (exceeds a duration of 50 milliseconds), the software also calculates the actual length of the exception on the track.

In an exception report generated and transmitted to the office, top events (over the pre-determined track segment length) are also included, whether they are exceptions or not. These top events can be used to characterize the variations of actual track geometry conditions from segment to segment.

Table 1 shows a simplified example of an actual exception/top event report generated onboard and transmitted to the office from the operation of this test IFC at FAST. Table 1 lists the names of sensors, magnitudes of exception or top events, allowable threshold values, durations of exceptions on track, GPS coordinates and actual train operation speed when an exception or top event occurs.

Table 1. Example Exception/Top Event Report (Simplified)

Channel	Value	Criteria	Unit	Duration (feet)	Longitude	Latitude	Speed
Suspension Displacement (L)	0.63	0.5	Inch	6.9	104.353027	38.4468918	38.7
Suspension Displacement (R)	-0.52	-0.5	Inch	4.1	104.351135	38.4458389	40.0
Lateral Carbody Acceleration (A)	0.14	0.5	g		104.334396	38.4501801	41.8
Lateral Carbody Acceleration (B)	-0.14	-0.5	g		104.351151	38.4458427	40.0
Vertical Carbody Acceleration (A)	0.19	0.5	g		104.353058	38.4469185	38.7
Vertical Carbody Acceleration (B)	-0.15	-0.5	g		104.345146	38.4544678	36.2
Top chord bending strain (L)	1,189	1,200	psi		104.338776	38.4538116	41.2
Top chord bending strain (R)	576	1,200	psi		104.335327	38.4490204	42.0
Top chord axial strain (L)	3,028	5,500	psi		104.335121	38.4491844	42.0
Top chord axial strain (R)	4,719	5,500	psi		104.335121	38.4491844	42.0

A second piece of software was developed for use in the office. This software allows a user to view and analyze exceptions and top events from different sensors, recorded on different dates, whether they are vertical or lateral and whether they have a short or long wavelength.

RESPONSES OF SENSORS ON PERTURBATION TRACKS

One of the earlier tasks of the IFC research was to examine how different onboard sensors installed at different locations of the vehicle would respond to various track perturbations built on the test tracks at TTC.

Tests were conducted on the perturbation test tracks with the pitch and bounce perturbation (39-foot repeated in-phase vertical excitations), twist and roll perturbation (39-foot repeated out-of-phase cross-level excitations), and yaw and sway perturbation (39-foot repeated lateral excitations with wide gage). In addition, test results were examined to short wavelength excitations such as broken rails, rail joints, and discontinuities associated with special trackwork.

Figure 2 shows responses of several sensors to the pitch and bounce excitations when the IFC was running at 50 mph. As Figure 2 illustrates, top chord strain gages, vertical carbody accelerometers, and suspension displacement transducers all captured the actual track geometry perturbation. Thus, any of these transducers would be capable of determining this type of track geometry condition. Accelerometers installed on the side frames were not as good at capturing this type of vertical track perturbation.

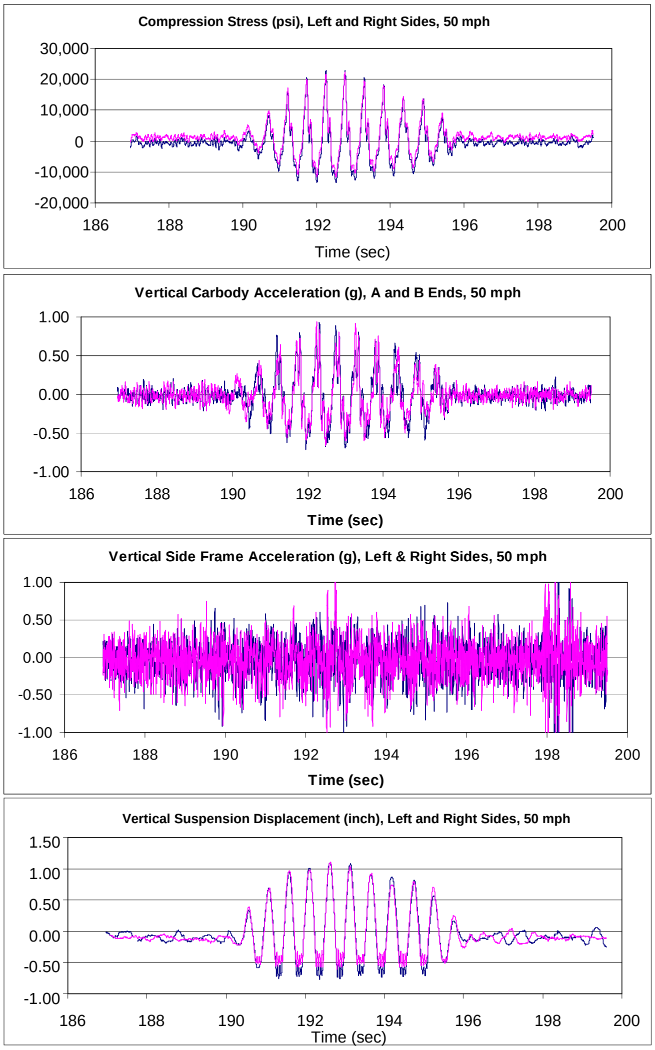

Figure 2. Responses to Pitch and Bounce Perturbation

For the test conducted over the twist and roll perturbation, top chord strain gages and suspension displacement transducers again captured the actual track geometry variations on the track. Neither vertical nor lateral carbody accelerometers (also accelerometers on the side-frames) were as good at capturing this type of cross-level perturbation. However, from the tests conducted on the HTL, where broken rails (short wavelength track geometry deviations) occurred, accelerometers on the side frames were the best to identify this type of perturbation.

TRACK INSPECTION AT FAST

In the second half of 2007, the IFC was included as part of the HAL train at FAST for nightly track inspections on the HTL. Every morning around 9:00 a. m., following the operations from the previous night, a report is sent automatically from the IFC to several engineers responsible for the program at FAST as well as this research project. This report includes vehicle response exception and top events, as Table 1 shows. By using the database program developed under this research, it can be determined where poor vehicle responses have occurred and what kind of track geometry conditions might have caused and contributed to vehicle response exceptions.

Figure 3 shows where several short wavelength vertical exceptions were identified at FAST on the night of November 27, 2007. Three identified areas corresponded to the turnout locations and the test zone for rail joints, where rail discontinuities or gaps are present. The other three spots identified corresponded to two broken rails and a broken weld that occurred that night. Figure 4 shows a broken rail that occurred on the HTL at FAST.

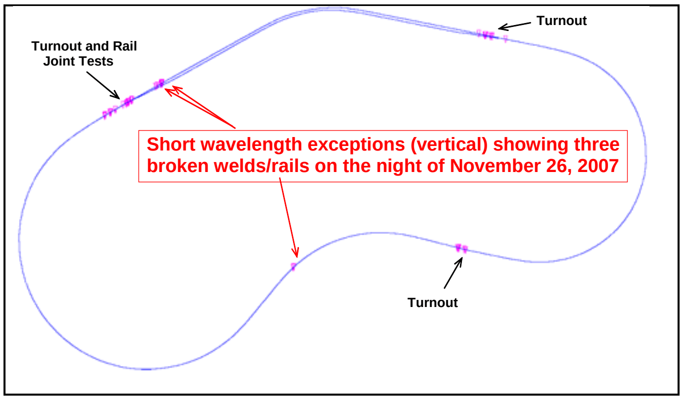

Figure 3. Track Inspection Results at FAST Showing Short Wavelength Vehicle Response Exceptions

Figure 4. Broken Rail at FAST

Figure 5 is another example of inspection results at FAST. This map shows where long wavelength vehicle response exceptions were identified in a segment of track on the night of December 17, 2007. These exceptions corresponded to a cross-level issue at this location and were verified in the following morning. This location required tamping and surfacing maintenance operation in that morning.

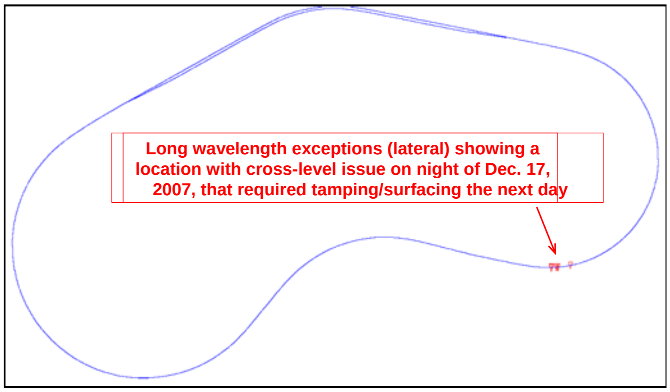

Figure 5. Track Inspection Results at FAST Showing Long Wavelength Vehicle Response Exceptions

In general, the operation of this IFC as a part of the train at FAST showed consistent inspection results from lap to lap and from night to night. The following are several additional findings from nightly inspections at FAST: (1) changes of vehicle responses from lap to lap, due to defect growth to a broken weld or broken rail, were shown on the data recorded and will require further software development to generate a warning of incipient rail breakage, and (2) data on most of the sensors provided good correlation in terms of exception/top event locations identified (basis to reduce the number of sensors in the production use of this technology); however, some vehicle performance issues were only identified by one specific type of sensor (e.g., locations that generated highest top chord stresses), thus more than one type of sensor may be needed for this inspection technology.

FUTURE WORK

Work will continue to further develop IFC inspection technology. This technology will be applied to other freight car types such as covered hoppers and intermodal cars. The next phase of this project, however, is to take an IFC for a demonstration and inspection of track in revenue service.

ACKOWLEDGEMENTS

Sirius Roybal and Steve Luna, Instrumentation Group of TTCI, have made significant contributions to the progress presented in this TD.

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