TECHNOLOGY DIGEST
TD-10-005
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TIMELY TECHNOLOGY TRANSFER

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Track Inspection Using an Instrumented Freight Car in Revenue Service

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Summary

From January to April 2009, the Transportation Technology Center, Inc. (TTCI) and a host railroad conducted a revenue service test of the instrumented freight car (IFC) technology. The IFC was included in trains as part of normal operations. It was configured to operate just like any other freight car in revenue service, except in the preliminary stage of testing it did not go through the loading and offloading operations.

The IFC technology is designed to help the railroads carry out frequent track inspections on a real time basis without having to reserve work windows normally required to conduct conventional track inspections. It aims to optimize track maintenance in order to help prevent derailments and reduce track and vehicle component failures. It relates poor vehicle dynamic behavior to track geometry parameters and operating speeds, produces exception reports, and relays them to the maintenance personnel via e-mail.

The IFC traveled over 8,000 miles with 20 transducers activated and set for continuous data collection. A broad range of car performance parameters were measured and assessed. IFC instrumentation and the real time analysis software offered proven performance and durability for the 3-month duration of the test. Performance reports were regularly relayed to the host railroad and TTCI engineers involved in the IFC revenue service testing.

Twenty-nine exception reports were generated. IFC identified 197 track locations that generated adverse dynamic responses. Of these locations, 13 were identified on more than one occasion under comparable operating conditions. A limited number of IFC-detected defective track locations were verified in the field by the host railroad track personnel. One particular location was identified on two different occasions (3 months apart) and the second time around caused the top chords of IFC to severely buckle after the carbody bounce mode was excited and large top chord compressive stresses were generated. The buckling event was due to vertical track geometry deviations and a 55 mph operating speed. Most of the IFC hardware remained intact and was recovered for reuse.

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INTRODUCTION

TTCI has developed an IFC technology for real time track inspection.[1] The IFC technology is a performance-based system that identifies track locations generating undesirable vehicle dynamic response. It is essentially composed of a TTCI built unattended data collection system (UDAC) with a large range of transducers installed on a 286,000-pound freight car equipped with ride control trucks.

In early 2009, after 2 years of testing the IFC technology on various test tracks at the Transportation Technology Center (TTC), Pueblo, Colorado, TTCI engineers tested the IFC technology in revenue service with a host railroad for about 3 months. The goal of testing IFC in revenue service was to examine its technology endurance in the "real world" while continuously operating on different track classes with the presence of a wide range of track conditions and features. The IFC operated just like any other freight car in revenue service conditions, except in this phase of testing the IFC did not go through loading and unloading operations. This *Technology Digest* (TD) presents the results of revenue service IFC testing.

IFC INSTRUMENTATION AND POWERING

To compare the IFC technology performance in revenue service with the testing conducted on various tracks and facilities at TTC, the instrumentation layout and configuration and the real time data logging and analysis scheme remained the same.

The IFC was equipped with the following instrumentation:

- Tri-axial carbody accelerometers on both ends of the IFC aligned along the center line of the car
- Strain gages bonded to both IFC top chords to measure the compressive axial stress and the bending stress (i.e., normal stress perpendicular to the chord length)
- Strain gages underneath the bolster to measure bolster loads
- Strain gages on the truck side bearings to measure side bearing loads
- Two vertical accelerometers mounted on the side frames on both sides of the car
- Vertical and lateral suspension displacement transducers to measure spring nest deflection and sideframe lateral displacement relative to the bolster
- GPS to determine operating speed and location

The performance of the UDAC and the activated transducers offered a good deal of robustness for over 8,000 miles of travel. Only one instance was recorded where the left spring nest vertical bend-beam displacement transducer failed and had to be replaced. These transducers were configured to relate track conditions to several car performance parameters by identifying short and long wavelength track geometry anomalies.

A self-contained power system was developed to power the IFC measurement system. Power was drawn from 12-volt DC batteries mounted on board the car. The batteries were charged by two separate power sources: a bearing generator and four solar panels mounted on top of the carbody.

The power system was optimized so that the IFC was able to remain stationary for up to 48 hours without having an adverse effect on battery power. In circumstances where batteries happened to be fully discharged, about 5 hours of operation at normal track speed was required for the bearing generator and the solar panels to charge the batteries back to the working voltage level. Recharging the batteries was also possible at a RIP track by simply plugging the IFC into a suitable power source. Figure 1 shows the IFC in revenue service testing.

Figure 1. IFC in Revenue Service

REAL TIME TRACK MONITORING

The IFC accumulated over 8,000 miles of real time track inspection in revenue service. Twenty-nine exception reports were generated and relayed to the host railroad on a regular basis. The IFC track condition assessment showed how the vehicle dynamic behavior related to track conditions and operating speed. Identifying individual geometry parameter defects as defined by current inspection standards was not emphasized, but a case in point was the long-wavelength exception detected on February 21, 2009 that did not constitute a maintenance exception. Table 1 shows the exception report for this event that was relayed to the host railroad.

Table 1. Muddy Track Location Identified by IFC

Channel Description	Value	Criteria	Units	Duration (ft)	Longitude	Latitude	Speed (mph)	Exception Type
Vertical Spring Nest Displacement A-End Right Side	1.1	1	Inch	3.4	—	—	33.3	Long Wave
Vertical Side Bearing Stress A-End Left Side	80.3	80	µE	2.7	—	—	33.9	Long Wave
Bending Top Chord Stress B-End Right Side	3558.3	2000	psi	5.8	—	—	34.0	Long Wave

At an operating speed of approximately 34 mph, three different transducers exceeded the preset allowable levels and identified the track location to be an exception. The transducers that triggered the event were the vertical spring nest displacement on the right side of the car, the side bearing on the left side of the car, and the right top chord bending strain gage.

The geometry at this track location consisted of a rough surface and contained no defect as defined by current track inspection standards. Yet, an undesirable vehicle response was generated. After field verification, the track personnel determined the location had muddy ballast and required subsequent surfacing and tamping. Figure 2 shows the geometry deviations and a visual illustration of the three transducers that identified the location.

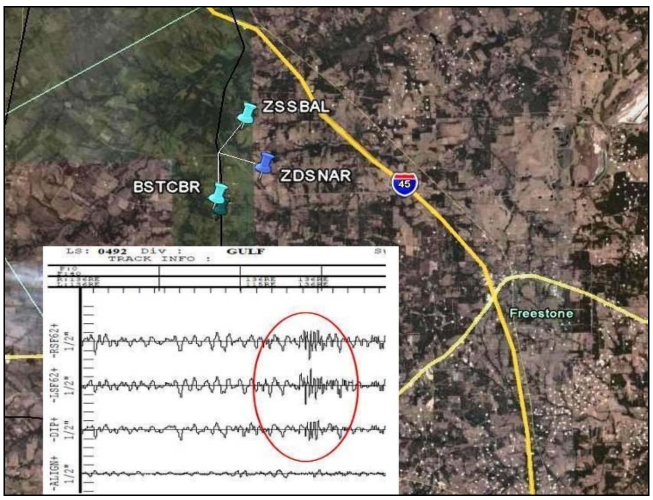

Figure 2. Muddy Track Location Identified by IFC

BUCKLING EVENT

Another illustrative case was a track location that the IFC identified on two separate occasions. On January 23, 2009, the IFC top chord axial stresses on the left side of the car exceeded the threshold limit by about 1,000 psi, while operating at a speed of 49 mph, signaling the track location was producing an adverse vehicle response. On April 23, 3 months after the January 23 event, the IFC flagged the same location as an exception, but with unfortunate consequences this time. Both IFC top chords severely buckled. They bulged at the same spot near the chord center. Figure 3 shows two photos of the buckled IFC.

The presence of in-phase surface deviations (1.25 inches maximum) and the operating speed excited the car into a bounce mode, which produced large compressive stresses that led to failure of the top chords. The top chord stresses on the left side of the car read -41,031 psi, which is about twice as high as the threshold limit for safe operations. An operating speed of about 55 mph was recorded at the time the exception occurred. The surface deviations did not constitute maintenance exceptions as defined by current track geometry standards. Table 2 shows the two exception reports on two separate occasions. Figure 4 displays the geometry data recorded on the day the top chords buckled. This type of car is slow ordered to 40 mph by one operating railroad to avoid top chord failures.

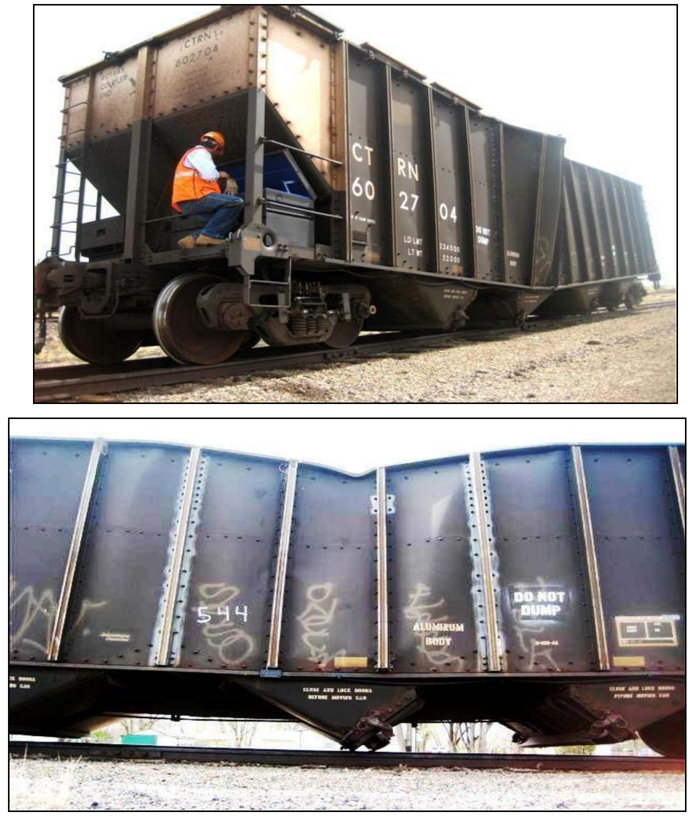

Figure 3. Buckled IFC

Table 2. Same Track Location Identified on Two Occasions for Channel Axial Top Chord Stress B-End Left Side

Date	Value	Criteria	Units	Longitude	Latitude	Speed (mph)
23 Jan.	-20,956	-20,000	psi	—	—	48.8
23 Apr.	-41,031	-20,000	psi	—	—	55.3

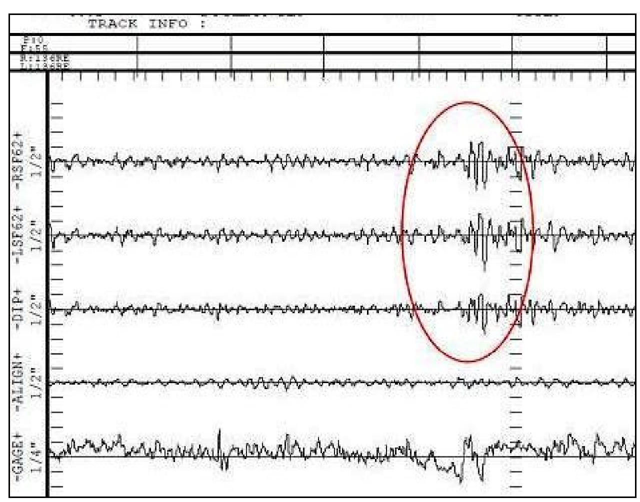

Figure 4. Surface Deviations Present Where IFC Buckled

DETECTION REPRODUCIBILITY OF TRACK LOCATIONS

Information about the exact routes the IFC traveled during revenue service testing was not available; thus, it was not possible to determine the reproducibility of the IFC measurements under similar operating conditions over the same track locations. However, an examination of the exception reports revealed 13 track locations that were identified by IFC on more than one occasion. Table 3 shows three exception reports the IFC produced at the same track location on three different occasions. The three reports present a strong concurrence in identifying the same location that caused the undesirable vehicle response. The track location was identified by multiple sensors on the IFC. The difference in the number of sensors exceeding the threshold on each occasion may be attributed to operating speed and direction of travel.

Table 3. Same Track Location (Longitude 102.33/ Latitude 35.77) Identified on Three Occasions

Date Identified	Channel Description	Value	Criteria	Units	Speed (mph)
7-Feb.	Vertical Accelerometer B-End	1.0	0.7	Gs	52.5
	Bending Top Chord Stress B-End Left Side	-2,123.1	-2,000	psi	52.5
	Bending Top Chord Stress B-End Right Side	4,578.6	2,000	psi	52.5
	Vertical Spring Nest Displacement A-End Right Side	1.4	1	inch	52.6
	Axial Top Chord Stress B-End Left Side	-21,189.7	-20,000	psi	52.6
	Lateral Accelerometer B-End	1.0	0.5	Gs	52.6
	Vertical Stress A-End	273.4	200	µE	52.7
6-Mar.	Bending Top Chord Stress B-End Right Side	3,415.8	2,000	psi	50.9
	Vertical Spring Nest Displacement A-End Right Side	1.1	1	inch	51.0
	Lateral Accelerometer B-End	0.7	0.5	Gs	50.7
	Vertical Stress A-End	229.6	200	µE	51.0
22-Apr.	Vertical Accelerometer A-End	0.8	0.7	Gs	52.1
	Vertical Stress A-End	257.1	200	µE	51.9
	Vertical Accelerometer B-End	0.9	0.7	Gs	51.6
	Vertical Spring Nest Displacement A-End Right Side	1.2	1	inch	52.1

IFC SENSOR CONFIGURATION

The IFC exception reports included statistics of activated channels, screen captures of raw data graphs, and debugging statements so as to pinpoint problem areas with the IFC data system when they occurred. Continuous scrutiny of the health of the IFC measurement system and performance was intended to help optimize the configuration of the IFC measurement system and to evaluate the sensor configurations for a production version of this technology.

Depending on measurement needs, the number of sensors could be reduced. The use of numerous sensors enabled the IFC to capture the main vehicle dynamic modes of vibration, such as pitch and bounce and twist and roll. This translates into more predictive power to identify track locations generating adverse vehicle responses. Multiple sensors exceeding allowable limits would be indicative of poor vehicle response, reflecting track conditions that may require more attention than other locations identified with only a single sensor. However, it should be noted that some vehicle performance issues, such as vehicle top chord damage, could be identified by the top chord strain gages alone.

Not all the track locations the IFC identified were verified in the field; thus, it was difficult to relate all the IFC exceptions to the track conditions present at the time they occurred. During 3 months of revenue service testing, the IFC generated the following exceptions:

- Top chord bending stresses — 173
- Vertical carbody accelerations — 129
- Vertical spring nest deflections — 80
- Lateral carbody accelerations — 53
- Vertical bolster load — 43
- Top chord axial stress — 21
- Side bearing load — 19
- Vertical side frame accelerometer — 7
- Lateral bolster to side frame displacement — 3

Truck warp exceptions, characterized by side frame lateral displacement relative to the bolster, were very uncommon with just three exceptions on both sides of the truck throughout the entire 8,000 miles the IFC traveled.

CONCLUSIONS

The IFC technology is designed to assess track conditions in real time by identifying track locations that have long- and short-wavelength defects. It relates poor vehicle dynamic behavior to track geometry parameters and operating speeds, produces exception reports, and relays them to the maintenance personnel via e-mail. It is configured to be operated just like other freight cars, and no human interaction is required to run it while in service. The IFC technology aims to optimize track maintenance practices in order to help prevent derailments and reduce failures related to track and car components.

ACKNOWLEDGEMENT

Wil Lundberg and Steve Luna of TTCI contributed significantly to the results presented in this TD.

REFERENCES

1. Li, D, A. Meddah, and W. Lundberg. July 2008. "Instrumented Freight Car For Performance-based Track Inspection," *Technology Digest* TD-08-028, AAR/TTCI, Pueblo, Colorado.