TECHNOLOGY DIGEST

Timely Technology Transfer — 99-013

VEHICLE/TRACK INTERACTION: REVENUE-SERVICE TESTING OF AN INSTRUMENTED COVERED HOPPER

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Summary

Engineers with the Transportation Technology Center, Inc., have simultaneously measured track-geometry conditions and the resulting performance of a loaded 100-ton covered hopper in revenue service. These tests were performed in July and August 1998, in railroad operations conducted by CSX Transportation. The test data was recorded for a round trip from Cincinnati, Ohio, to Corbin, Kentucky, and to the Sarah Coal Mine, yielding more than 400 miles of both track-geometry data and vehicle responses. These tests were performed to better understand the relationships between the track geometry and its effects on railcar behavior, especially in terms of combination of surface and alignment errors, important wavelengths of disturbance, and effects of periodically repeated track deviations.

Results of the analysis show that track and vehicle loads increase with increased geometry-defect amplitude. Multiple geometry surface, cross-level, and alignment defects can produce higher vehicle/track loads than single defects. As the project continues, certain features (or statistics) will be extracted from this data, and neural networks will be trained to predict and evaluate vehicle performance based on track-geometry patterns.

The long-term goal of this AAR-funded research is to develop an improved method of prioritizing track maintenance with regard to geometry. In other words, additional smoothing of track that does not currently cause undesired vehicle responses (e.g. forces and accelerations) may not reflect the best investment of limited maintenance resources. In the shorter term, this project aims to use pattern-recognition techniques to recognize segments of track-space curves which are likely to correspond to more active vehicle response than neighboring sections of the track. As such, this technique could help prioritize track maintenance beyond current railroad classification rules for track-geometry maintenance.

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

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April 1999©

INTRODUCTION AND CONCLUSIONS

North American railroads use modern, high-speed inspection vehicles to take accurate measurements of track geometry. Track-geometry data taken by inspection vehicles is primarily used for finding exceptions to specific standards. This procedure is designed to locate, for immediate correction, defects that are currently present in the track. These include instances that exceed FRA Track Safety Standards, and instances, which exceed the railroad's own standards, and are sometimes set one track class higher than the FRA limits.

The former FRA geometry limits (in effect from 1971 to 1998) were mostly based on mid-offsets of a 62-foot chord. New geometry limits were drafted using the industry-wide experience of the Railroad Safety Advisory Committee (RSAC) in 1997 and adopted by FRA in 1998.[1]

The new limits for track classes 1 through 5 expand the use of a 31-foot chord length and address vehicle harmonics on jointed track. However, the new limits do not specifically link the response sensitivity of individual freight vehicles (in terms of truck spacing, suspension characteristics, or body torsional stiffness) to various geometry wavelengths.

The AAR Track Geometry project has been undertaken to improve the safety of railroad operations, as well as to improve the efficiency of track maintenance. This Technology Digest presents results from a vehicle/track interaction test conducted on revenue-service track owned by CSX Transportation. Preliminary conclusions from this test and other test operations at the FRA's Transportation Technology Center (TTC) are listed below:

- On the TTC Transit Test Track which has light 100 lb./yard rail, the loaded hopper experienced sustained hunting at 65 mph. The resulting lateral wheel forces caused more than 1 inch (peak-to-peak) railhead movement.

- In revenue service, analyses to date have indicated that dynamic wheel-force amplitudes were larger on track segments having multiple deviations at once (combined lateral and vertical directions) than for track deviations in one direction only. In addition, for lateral and vertical variations of similar amplitude, large car responses occurred at lower speeds when encountering lateral deviations rather than when encountering vertical deviations.

- Significant gage-widening forces appeared in curve negotiation with the hopper car (even on smooth track). These forces were further increased in locations of rougher track.

TEST VEHICLE INSTRUMENTATION

The covered hopper was instrumented to acquire both track-geometry data and car responses. The track geometry was recorded by a vendor-supplier, non-contact, inertial-geometry system. This system uses laser light (infrared), video-arrays, and an inertial compensation package to allow space-curve recording between transient wavelengths of 3 to 63 feet. The geometry system was suspended from a standard three-piece freight truck, using elastomeric mounts and various pivot joints in order to ensure that the truck-steering properties were not compromised.

The lead truck of the hopper car was also instrumented using Transportation Technology Center, Inc.'s (TTCI), load-measuring wheel sets. These continuously measure tri-axial (vertical, lateral, longitudinal) forces at the wheel-to-rail interface during travel. This lead truck was also instrumented with several string potentiometers to measure truck warp, as well as the interaction of bolster and side frames. The trailing truck was instrumented with a load-measuring bolster as well as several displacement transducers. The car body was instrumented with nine accelerometers to fully describe the car-body motion at any time during the test.

CSX REVENUE-SERVICE TEST AND PRELIMINARY RESULTS

In the revenue track test of this vehicle, the covered hopper was pulled in a normal train behind the AAR-112 instrumentation coach. Train speeds ranged from 0 to 50 mph, with timetable speed achieved whenever possible. The track was commonly class 4, with curvatures up to 11 degrees. Mainline track was traversed from Cincinnati, Ohio, to Corbin, Kentucky, and side track was encountered when en route to the Sarah Coal Mine.

More than 400 miles of track-geometry and car-response data were recorded. To date, approximately 80 segments (each 0.1 mile in length) have been identified as having active vehicle responses. Initially, these segments have been examined in detail to intuitively understand the track input to the car, as well as the resulting active responses. A number of these segments will be included here as examples. All of these examples will show track-spaces curves (wavelength limited to between 3 and 63 feet), and lead-axle wheel forces in the lateral and vertical directions (frequency limited to between 0 and 30 hertz).

For tangent tracks recorded with little roughness, minimal dynamic wheel forces were measured at all speeds (up to 50 mph). However, the vertical-forces mean for the left and right wheel differed by approximately 10 kips, due to uneven weight distribution caused by pre-exisitng carbody twist.

Exhibit 1 was recorded at 21 mph in a 5-degree curve, and reflects the change in lateral wheel forces when encountering this curve. The primary effect is an increase in the lateral forces at the wheels. In this case, both the left and right lead-axle wheels indicate approximately 7 kips of mean gage-spreading force. The dynamic characteristic of both vertical and lateral wheel force is minimal, because this track segment is relatively smooth. In fact, the vertical-surface space curve shows some in-phase (bounce) input of approximately 0.5 inch peak-to-peak. However at this speed, the deviations were encountered at 1.3 cycles per second, a rate that produces little or no vehicle bounce since the vehicle bounce natural frequency is 2.1 hertz.

Exhibit 2 shows data recorded on a tangent track at 39 mph. This data is a very good example of a track-space curve which could indicate geometry maintenance would be beneficial. As shown in the lateral alignment trace of the track, this segment has significant periodic lateral deviations of more than 1 inch (peak to peak). In the track vertical surface trace, a single vertical deviation of about 0.5 inch is also seen, which has both bounce and roll characteristics. This is due to each rail showing in-phase vertical activity, but somewhat more severe on the left rail. The wheel lateral force recordings show the undesired effects of such a track-space curve, with lateral deviations of up to 18 kips (peak-to-peak). These track inputs and responses are very similar both in amplitude and frequency to the AAR Chapter XI Trackworthiness specification for Yaw and Sway input (10 cycles of 0.75-inch lateral in-phase deviations at 40-foot wavelength). As with Chapter XI testing, this track perturbation causes significant gage-widening forces at one-half the wavelength of the track perturbations.

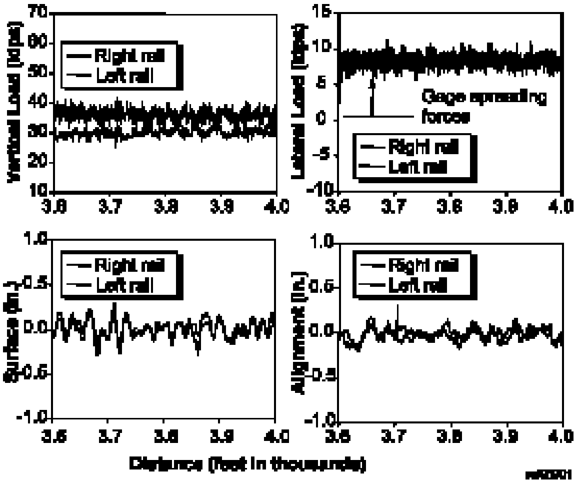

Exhibit 1. Gage-Widening Lateral Forces Due to Curving (21 mph, 5-Degree Curve)

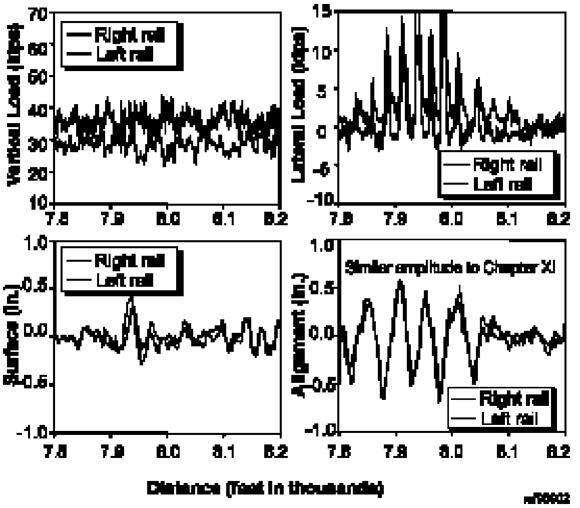

Exhibit 2. Yaw Action Due to Lateral Deviations (39 mph, Tangent Track)

Exhibit 3 shows data recorded at 45 mph on tangent track. This is primarily a vertical event, with vertical space-curve deviations of 2 inches (peak-to-peak). In response, the vertical reaction forces of the wheel increase to approximately twice the static reaction loads. Both the lateral track deviations and lateral car responses are relatively insignificant during this bounce activity.

In addition to these examples, which are rather easily interpreted, many other events have been identified with more complex track-space curves and car responses. These data are being prepared for analysis using neural-network methods in order to recognize patterns too complex for the subjective evaluations described above. The results of such analyses will be presented in a future *Technology Digest*, as well as a full Research Report.

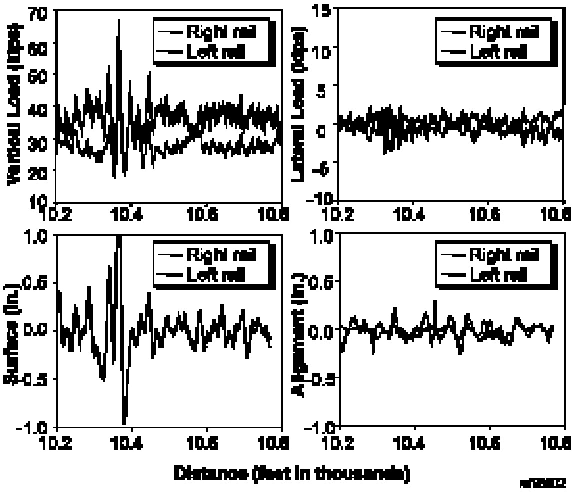

Exhibit 3. Pitch/Bounce Action Due to Vertical Deviation (45 mph, Tangent Track)

FUTURE STEPS

This project has thus far shown the ability to simultaneously measure loaded track-space curves, as well as real-time vehicle responses in the form of tri-axial wheel forces and car-body accelerations. Integral to this is a working inertial-based track-geometry system.

Preliminary data analysis has shown that the vehicle responds in a complex manner, due to the multi-axis inputs coming from the rail. Some data relationships have been easily identified, usually when a particularly periodic and uniaxial rail shape coincide with a wavelength near the vehicle natural frequencies. More complex responses, involving cross-coupling between many vehicle response modes, must be analyzed using pattern-recognition methods such as neural network or multiple-input/output methods.

This work continues into 1999, and another test is planned using a tank car over a similar route. In the long term, TTCI expects to demonstrate the calculation of a car-response index given only the track-space curve information. A high value for such an index would indicate greater predicted car responses, and therefore a higher priority for track-geometry maintenance.

Reference

1. El-Sibaie, Magdy et.al., “Engineering Studies in Support of the Development of High-Speed Track Geometry Specifications,” ASME, RTD-Vol. 13, 1997.

ACKNOWLEDGMENTS

TTCI would like to thank CSX Transportation for the loan of the covered hopper, and for providing the opportunity to gather data in revenue service. The assistance of Mr. Ken Davis and Mr. John Roland of the CSX Test Laboratory in Waycross, Georgia, is most appreciated. Also, TTCI would like to acknowledge Pandrol-Jackson for permission to adapt the company’s fixture design to the inertial geometry system.

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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.