TECHNOLOGY DIGEST
Timely Technology Transfer

Locating Lateral Track Irregularities Which Cause Excessive Vehicle Loads

by
Semih Kalay
and
W. P. O'Donnell

TD93-004

Summary

Recent tests using the AAR's paint-spotter car have led to a better understanding of the effects of lateral track irregularities which can input damaging forces into the carbody structure. Results indicate that railroads using a vehicle such as the paint spotter car in conjunction with a track geometry car would realize substantial benefits in both equipment and track maintenance. These tests are part of a Vehicle Track Systems Research Program to develop improved track geometry guidelines and recommendations for improved track geometry detection.

Unlike vertical track surface irregularities, the effects and occurrence of lateral track irregularities are not well understood. The tests showed that track irregularities which caused large lateral loads, could be categorized into two different groups. The first group was characterized by a discrete track irregularity in the lateral direction such as the switch or frog point at a turnout. The second group was characterized by multiple track irregularities which caused yaw, or a combination of upper center roll and sway type car body motions which resulted in large lateral bolster loads.

The Association of American Railroads has instrumented a 70-ton box car to measure and identify the high load producing lateral track surface anomalies. The test vehicle, called the "Paint-Spotter Car," was first tested over perturbed track sections at the Transportation Test Center (TTC) to quantify its lateral load environment. The paint-spotter car was then operated over 1,000 miles of high speed track on three railroads, to identify the location of track irregularities which cause high car body loads. Several track locations were identified using a paint spray system operated in conjunction with the measurement of the bolster lateral load.

Future work includes the development of recommendations for performance based track geometry standards accounting for the effect of vehicle response and standards.

Association of American Railroads
Research and Test Department

July 1993

INTRODUCTION AND CONCLUSIONS

The dynamic interaction between freight car and track is an important area of study in railroad research. Uncontrolled, this interaction can result in damage to the track, the freight car, and its contents. The need to control this dynamic interaction is not a new endeavor, but it has been emphasized with the increase in car speed and axle loads.

An important element of the Vehicle Track Systems program is to determine the effects of track irregularities on railway vehicles. It has been shown in the past by the paint-spotter car tests that vertical track geometry irregularities cause vertical bolster loads in excess of 3 to 4 times the static load. (See AAR Report R-694).

Effects and frequency of occurrence of lateral track irregularities are not as well understood. In the lateral plane, peak loads occur not only by the unsprung mass of the vehicle encountering a discrete track irregularity but by vehicles running out of secondary suspension travel. Particularly, on track with repeated alignment irregularities, bolster gib contact results in a significant force transfer from vehicle body to wheels. The resulting car body lateral forces can be high enough to cause fatigue damage on the car body structure. The truck-side lateral forces reacted by wheel flanges may be large enough to cause rail rollover derailments on weak track.

In order to investigate the frequency of occurrence of lateral and combinations of lateral and vertical track irregularities, the leading truck of the paint-spotter car was instrumented to measure the lateral and vertical loads. A paint spray system, operated in conjunction with the measurement of the bolster lateral load, was used to locate the high load producing track locations. During revenue track testing, the lateral bolster load trigger level was set at 30,000 pounds to establish a truck side L/V ratio of 0.6 (current Chapter XI safety limit), above which the propensity for rail rollover derailment substantially increases. The paint-spotter car was tested on over 1,000 miles of track on three railroads. Based on recorded data, the following conclusions can be reached:

* The paint-spotter car identified two types of lateral track irregularities that caused excessive loads on the vehicle.
* The first type, characterized by a discrete irregularity such as the switch or the frog point on turnouts, caused lateral bolster loads slightly above 30,000 pounds.
* The second type, multiple track irregularities, excited one of the vehicle's rigid body resonance modes in the lateral direction and caused car body loads in excess of 50,000 pounds.
* At most of the sites identified by the paint-spotter car, the track geometry car did not indicate any problems. In order to identify multiple track irregularities, a track geometry car should look at the interaction of several defects in sequence, and not only at single defects.
* In 1993, further experimental and analytical studies are planned to investigate the vehicle response to track defects found by geometry cars. Information obtained from these studies will be used to develop guidelines and recommendations for performance based track geometry standards accounting for the effect of vehicle response and standards.

PAINT-SPOTTER CAR TESTS

The test vehicle is a standard 70-ton box car with truck center spacing of 41 feet. It is equipped with standard three-piece, Barber S2, trucks that have variable column damping with roller side bearings. The paint-spotter car is instrumented to measure the vertical and lateral bolster loads, secondary suspension displacement, and lateral bolster acceleration on the leading truck. In addition, car body lateral and vertical accelerations are measured at both ends of the car.

Before revenue track tests, a series of preliminary tests were conducted at TTC to quantify the effects of lateral track irregularities on vehicular response.

During testing over the twist and roll section, lateral loads on the bolster exceeded 28,000 pounds, at the vehicle's critical roll speed of 20 mph. The vehicle was tested over a test track with multiple irregularities in the lateral direction; the yaw and sway test section at TTC. Multiple type irregularities are usually associated with a series of periodic track irregularities. These irregularities which excite one of the vehicle's resonance modes in which maximum loads and displacements occur. Lateral bolster loads of more than 50,000 pounds were measured on tangent track constructed with five 39 foot long sinusoidal alignment perturbations with maximum amplitudes of 1.25 inches. This lateral bolster load was measured at a speed of approximately 60 mph, which appears to be the critical speed that excites the vehicle's sway mode.

During high speed stability tests, lateral bolster loads in excess of 30,000 pounds were measured at the full flange-to-flange hunting speed of 70 mph. Finally, the vehicle was tested over a 10 degree curved track segment with crosslevel and high-rail alignment perturbations. The lateral load on the bolster reached 27,000 pounds at 30 mph. Exhibit 1 shows the maximum lateral bolster loads measured in response to various Chapter XI test tracks at TTC.

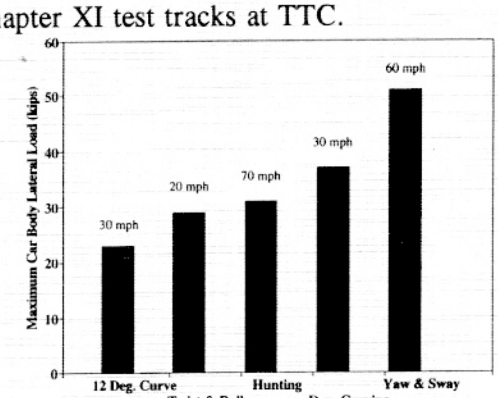

Exhibit 1. Effect of Track Geometry on Car Body Lateral Loads.

The paint-spotter car was operated on over 1,000 miles of revenue track, on three railroads in 1992, in conjunction with the participating railroad's track geometry car. Several locations were identified on each railroad and spotted with a deposit of yellow paint on the track.

The analysis of the test data indicated that the sites which triggered the paint-spotter car fell into two broad categories: those which were characterized by a single track irregularity and those with multiple track irregularities.

Single track irregularities caused large increases in loads and accelerations throughout the freight car, as well as on the track, and were usually associated with turnouts, and joints or welds in the track. One such example of a single irregularity in the lateral direction was found at a turnout where the lateral load on the bolster exceeded 30,000 pounds. Inspection of the track did not reveal obvious problems but it was inferred from the paint spray on the track and from examination of the lateral load time trace (Exhibit 2), that the exceedance started at the entry into the switch.

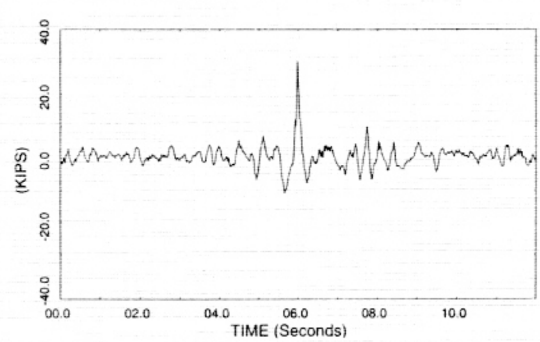

Exhibit 2. Car Body Lateral Load Exceedance at a Turnout.

Occasionally, excessive lateral loads are experienced on the car body that are not associated with any special track installation. One such example was experienced during tests on revenue track. As seen in Exhibit 3, a lateral load in excess of 30,000 pounds was experienced, at approximately 8 seconds, while negotiating a moderate curve through a reverse spiral at only 30 mph.

The center plate load represents the force that the car body applies to the truck. Examination of the corresponding vertical bolster load time history showed that when the lateral load increased dramatically, the center plate unloaded up to 60% of its static load level. This indicates that the car body was rocking off the center plate, and onto the side bearing, a potentially undesirable situation.

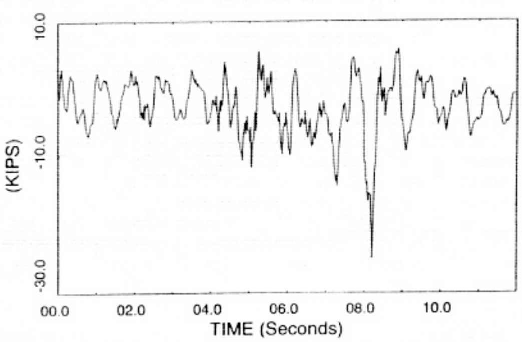

Exhibit 3. Lateral Car Body Load due to Alignment Defect.

Inspection of data obtained from the track geometry car over this track location offered some insight into the cause of this response. Alignment, as measured at the midpoint of a 62 foot chord, deviated at this location by more than 1 3/4 inches from the design curvature. Consequently an urgent defect was reported by the track geometry car.

A number of multiple track irregularities caused a high speed yaw or sway response in the test vehicle. At speeds near 60 mph, the vehicle experienced large lateral car body motions on tangent track in which the lateral forces exceeded the 30,000 lb threshold level periodically. The load exceedance was sporadic but continued over long stretches of track which appeared to provide enough energy to sustain the forced response. The vehicle became stable again when the track conditions and/or speed changed. The sensitivity of the vehicle's response to speed was apparent from the ensuing resonance phenomenon or hunting.

In Exhibit 4, the frequency of the bolster lateral motion was about 2 Hz, corresponding to the frequency at which the vehicle travels over a 39 foot rail length at 60 mph. Since the track input is oscillatory, the test vehicle is forced to vibrate at this frequency. If the frequency of excitation coincides with the yaw or sway natural frequency of the vehicle on its suspension system, resonance is encountered. As a result, large carbody motions accompanied by frequent gib contact may occur as seen in Exhibit 4. Results of the track inspection were inconclusive, however, several of the sites showed that the exceedances had occurred in open track and were associated with a series of parallel lateral alignment waves on continuous welded rails. At one site, the track had alignment waves coincident with square plant welds.

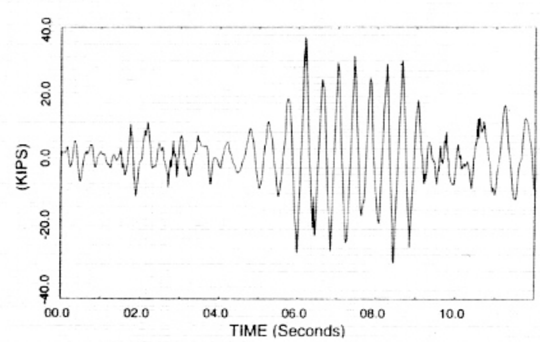

Exhibit 4. Lateral Car Body Loads due to Multiple Track Irregularities.

Note: Contact Semih F. Kalay at (312) 808-5840 with questions or comments about this document.