Railway track and structures

vol. 100, n° 9, septembre 2004, pp. 21-25, fig., bibliogr. - *(REVUE) - S/C : 0610*

Inspection de la géométrie de la voie, fondée sur la performance. Ce que c'est et comment ça se passe.

TTCI R&D

Performance-based track geometry inspection: What it is and how it works

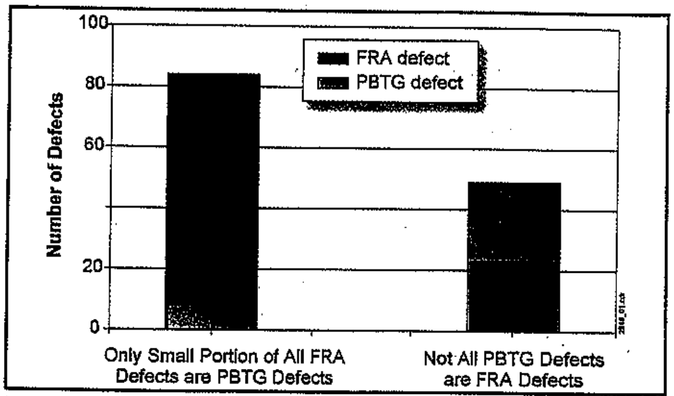
TTCI begins implementation of a new track inspection technology that relates track geometry to vehicle performance, resulting in better safety and maintenance actions.

A new "add-on" technology has been developed to relate measured track geometry to vehicle performance on a real-time basis. The technology can also be used on historic track geometry data to examine the effect of track geometry degradation on vehicle performance.

Following several years of research and development, the Transportation Technology Center, Inc., Pueblo, Colo., has started the demonstration and implementation of its performance-based track geometry, PBTG, inspection system.[1] The PBTG inspection system is a new add-on technology that can be implemented on conventional track geometry inspection vehicles.

The PBTG inspection method is an improvement over the current track geometry inspection method because track geometry defects, identified using current methods, do not always relate to vehicle performance (Figure 1). Implementation of the PBTG inspection method should lead to prioritized track geometry maintenance based on vehicle performance. As such, railroads can expect to reduce potential derailment incidents and the stress state of track structure caused by poor vehicle/track interaction.

The PBTG technology allows users to specify vehicle types sensitive to track geometry input (such as empty tank cars, loaded hoppers and gondolas), as well as a variety of operating speeds for vehicle performance analysis. On a real-time basis, this technology identifies track segments that may produce poor vehicle performance and generates recommended track geometry maintenance actions.



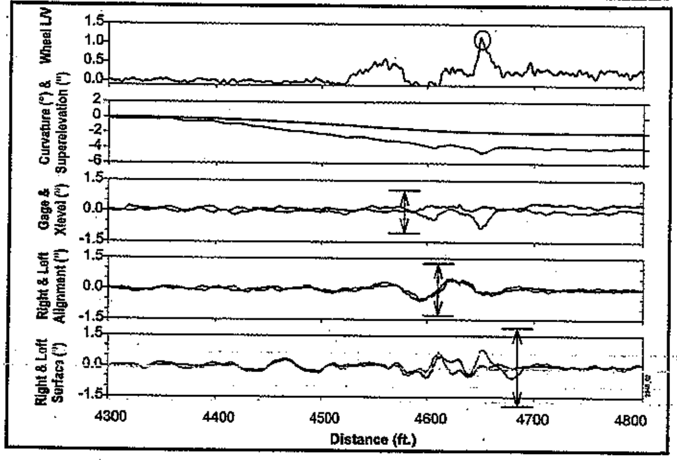


Figure 1, top, depicts the revenue service test results showing track geometry defects identified by current methods do not always relate to vehicle performance. Figure 2 is a test result showing how poor vehicle response (L/V ratio > 1.0) was caused by combined track geometry deviations in conjunction with an entry spiral (vertical arrows are FRA limits for individual track geometry parameters).

Vehicle performance and PBTG exceptions

Performance-based track geometry inspections relate measured track geometry to vehicle performance. Vehicle performance can be defined in terms of different vehicle response parameters relating to derailment potential, stress state of track structures and vehicle ride quality. These vehicle responses can be defined as follows:

- "Derailment potential" is often defined by L/V ratio (lateral/vertical wheel or axle load ratio) and "vertical wheel unloading" values with respect to allowable limits. The L/V ratio criterion is intended to prevent flange climb derailment and the vertical unloading criterion is intended to prevent wheel lift derailment.
- "Stress state" is often quantified by the "maximum vertical and lateral wheel loads" exerted on track.
- "Ride quality" is often quantified by "vertical and lateral accelerations on the car body."

The current version of the PBTG inspection system defines vehicle performance in terms of derailment potential and stress state, though it can be expanded to include ride quality analysis. More specifically, the current PBTG system can be used for vehicle performance analysis for the following parameters: single wheel L/V ratio, vertical wheel load and lateral wheel load.

"PBTG exception" is defined as a track geometry condition within a track segment that will likely cause an undesirable vehicle response. Unlike a track geometry defect, defined by the FRA Track Safety Standards[2] or railroad maintenance standards, which

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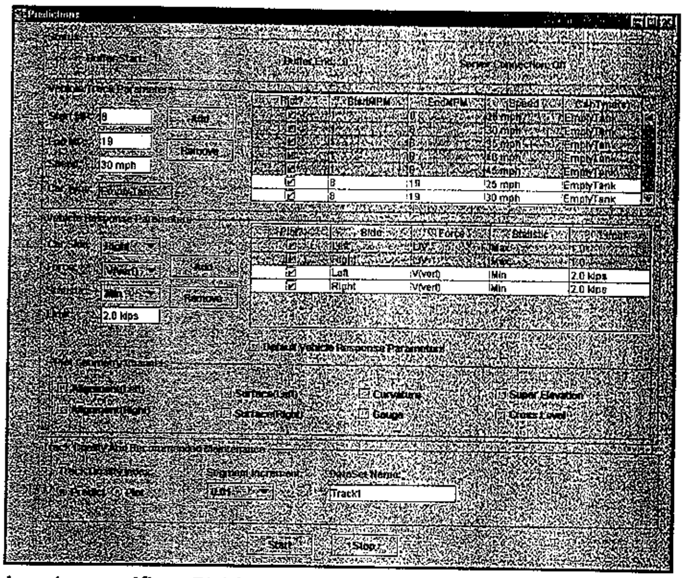

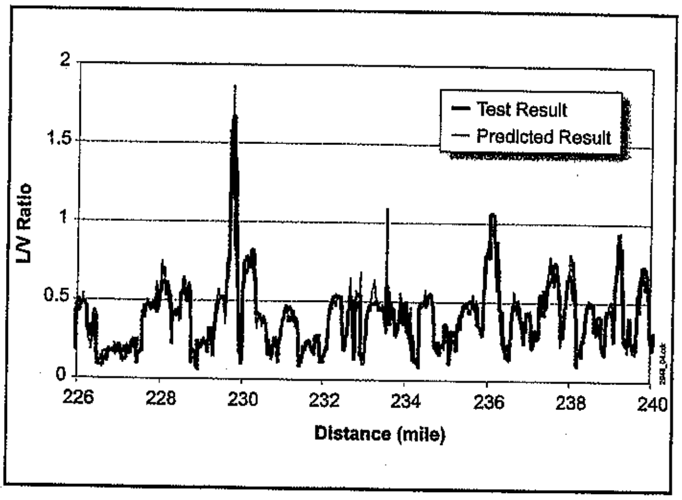

Figure 3, left, shows PBTG graphical user interface. Figure 4 is an example of PBTG analysis result and comparison with test result.

is point specific, a PBTG exception is segment specific. It includes combined and multiple geometry deviations within a segment and takes into account the effect of track features, such as curvature and spiral.

As an example, Figure 2 shows where a combined track geometry condition led to a poor vehicle response (L/V ratio above 1.0). As shown, the combined track geometry deviations (cross level, alignment and surface) were located between 4,500 feet and 4,700 feet. The presence of an entry spiral also contributed to the poor vehicle response.

The allowable FRA limits are also shown in the figure (vertical arrows) for the measured track geometry parameters. There were no individual exceptions that could be identified to relate to the poor vehicle performance. In the PBTG inspection, however, this segment would be identified as a PBTG exception.

A PBTG exception is also a "likely" defect, because an identified track segment causes poor vehicle performance (derailment potential) only under a certain vehicle operation condition. Unlike a con-

MP	Force	Side	Car Type	Speed	Value	Limit
229.9	L/V max	Left	Empty tank	35 mph	1.8	>1.0
233.4	V min	Right	Covered hopper	40 mph	3.0 kips	<3.5 kips
...	...	...	...	...	...	...

MP: 229.9 Curvature: 1.5 degree Geometry Parameter	PBTG Index = x.x (before) Maintenance Action
Cross-Level	YES
Surface	No
Gauge	No
Alignment	No
	PBTG Index = v.v (after)

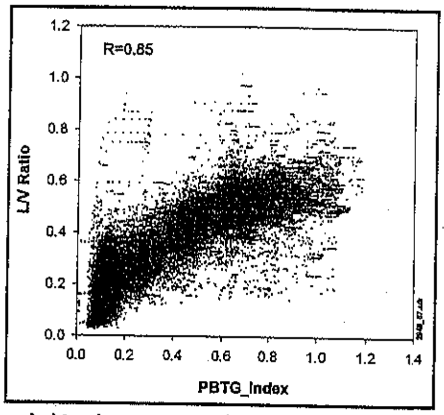

Figure 5, top left, is an example of PBTG exception report. Figure 6, bottom left, is an example of recommended track geometry maintenance action report. Figure 7 shows the correlation between PBTG track quality index and the actual vehicle performance.

ventionally-defined track geometry defect that can be measured repeatedly, vehicle response may not be the same due to the same track geometry input, if other conditions vary. Even for the same vehicle operating at the same speed, vehicle response can be different over the same track geometry, when wheel and rail contact conditions change. For example, rain or snow can reduce wheel and rail friction, leading to reduced lateral loads in curves.

Having pointed out the likely nature of a PBTG exception, it is important to understand that poor track geometry within a segment will always cause "undesirable" vehicle responses, although their magnitude (or sensitivity to track geometry input) can be different. In other words, the trends of vehicle responses due to the same track geometry inputs would be similar, regardless of vehicle type and operating conditions.

Nevertheless, realizing possible variation of vehicle responses to the same track geometry inputs, TTCI engineers have employed a statistical approach in the development of the PBTG technology. The approach required conducting actual vehicle and track interaction tests under a wide range of track and operating conditions in revenue service. Then, based on the database created from the actual tests, many neural networks were trained to relate track geometry and operating speed to "most likely" vehicle responses.

The PBTG system also uses the following statistical outputs to characterize vehicle performance: (1) maximum and the 98 percentile for L/V ratio, lateral and vertical wheel loads; and (2) minimum and the second percentile for vertical wheel unloading. The maximum value represents the most-likely maximum responses over a given track segment, and the 98 percentile represents a magnitude greater than 98 percent of likely vehicle response occurrences over a given segment.

To identify PBTG exceptions, the vehicle response limits need to be established. For example, the following AAR Chapter XI criteria can be used: (1) single wheel L/V ratio > 1.0 and (2) vertical wheel load V < 10 percent of static wheel load.[3]

PBTG inspection system

As mentioned, when used on a track geometry inspection vehicle, the PBTG technology is an add-on technology for real-time vehicle performance analysis. The basic functions of the PBTG system include:

- Interface with a conventional track geometry inspection system to accept and process measured track geometry so track geometry data can be used as inputs to the PBTG system
- Carry out real-time vehicle performance analysis, based on measured track geometry and given operating speeds
- Identify track segments that may produce vehicle responses above the pre-determined performance limits (PBTG exceptions)
- Generate recommended maintenance actions to the track segments identified with PBTG exceptions
- Output PBTG track quality index values before and after the recommended maintenance

Figure 3 shows one of the graphical user interfaces of the PBTG system. As illustrated, users can enter an array of operating speeds for a given track and for a given vehicle. They can select vehicle response parameters for real-time analysis and enter their corresponding performance limits. The system also plots (strip charts) measured track geometry parameters together with vehicle response results.

Figure 4 shows an example of predicted vehicle response for single wheel L/V ratio (max.), based on actual track geometry measurements and vehicle operating speeds for an empty tank car. The actual test results recorded using instrumented wheelsets are also included in this figure for comparison. As shown, the predicted results were consistent with the measured results. In the example, poor vehicle responses (L/V >1.0) occurred at MP 229.9, 233.8 and 236.0.

Exception report and maintenance

From real-time vehicle response results, the PBTG system will generate a PBTG exception report (Figure 5). The report will list the locations of PBTG exceptions identified, vehicle responses that exceed the pre-determined performance limits, magnitudes of likely vehicle responses, vehicle types and operating speeds.

From this report alone, for the identified track locations, railroads can examine the actual track geometry measurement results and decide what maintenance actions need to be taken. However, the PBTG inspection developed by TTCI has also incorporated preliminary performance-based maintenance guidelines for correcting the PBTG exceptions. To do so, the track geometry condition for an identified PBTG exception segment is categorized into four maintenance parameters: cross-level, surface, gauge and alignment. Each maintenance parameter is calculated based on maximum deviation, number of repeated deviations and whether it is a segment in curve, spiral or tangent.

There are also weights associated with each maintenance parameter. These weights are developed based on the effect of each geometry parameter on vehicle performance. The calculated result of each geometry maintenance parameter indicates the contribution of that particular parameter to poor vehicle performance. Depending on the ranking for the results of these four maintenance parameters, track geometry maintenance actions are recommended for surfacing, lining and/or re-gauging activity. Figure 6 shows a simplified report of the recommended maintenance actions.

Note in this report that a PBTG track quality index is calculated before and after recommended maintenance action. The PBTG track quality index is a single parameter developed to sum the combined effect of all track geometry maintenance parameters. Unlike track quality indices developed by others, the PBTG track quality index is a performance-based quality index and is developed based on the effect of track geometry parameters on vehicle performance. It gives an overall quantification of track geometry condition for a given track segment, in terms of how it may affect vehicle performance.

Figure 7 shows the correlation between the calculated PBTG index values and actual vehicle response test results (L/V ratio) for many segments in revenue service. As shown, use of the PBTG index gives a reasonable indication of track geometry quality as it relates to actual vehicle performance.

Demonstration, implementation

The prototype PBTG system has been demonstrated on test tracks at the Federal Railroad Administration's Transportation Technology Center and in revenue service. The demonstrations were conducted to check if the system would perform as designed in a real-time manner. To do so, the PBTG system was set up on TTCI's track geometry measurement system, TGMS, and the interface was established between each system. Overall, the PBTG system performed as designed and was capable of doing vehicle response analysis onboard at the same pace as the track geometry measurement vehicle ran. The PBTG system was stable and satisfactorily performed its functions.

TTCI is presently completing its first commercial PBTG system on track geometry vehicles for Burlington Northern and Santa Fe.□

Footnotes

1. This project was funded by the Association of American Railroads.

2. *Track Safety Standards*, Part 213, Subpart A to F, Class of Track 1-5, DOT, FRA, Office of Safety.

3. AAR's *Manual of Standards and Recommended Practices*, Chapter XI, Service-Worthiness Tests and Analyses for New Freight Cars, Adopted 1987, revised 1993.