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Testing and Modeling: Revenue Service Coal Gondola Response to Track Geometry

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Summary

This digest summarizes the results of a third test in a series of vehicle/track interaction tests that will lead to a performance-based track geometry inspection system. The test was conducted on a Union Pacific revenue route in Colorado between Alamosa and Denver during July 31 to Aug. 3, 2000. Similar to the previous two tests, engineers with Transportation Technology Center, Inc. (TTCI) simultaneously measured track geometry conditions and the resulting vehicle performance. For this test, the vehicle used was a typical loaded coal gondola. The results of two similar tests conducted on CSX Transportation (in August 1998) and Burlington Northern Santa Fe (in August 1999) revenue service were reported in *Technology Digest 99-013* and *Technology Digest 99-022.*

Similar to the first two tests, the results from this test have been used to train neural networks relating track geometry inputs to vehicle response for the loaded coal gondola. Results show that the neural networks can be successfully applied to predict vehicle response of a loaded coal gondola to given track geometry inputs. This confirms the results previously found with testing of a covered hopper car and a tank car.

The results obtained from this test bring us closer to the goal of developing a performance-based track geometry inspection method and the corresponding geometry maintenance guidelines. As such, it would be more efficient and cost effective to prioritize track geometry maintenance based on vehicle/track interaction and geometry characteristics that lead to poor vehicle responses. This will in turn lead to improved vehicle performance and better derailment prevention.

Suggested Distribution:
- ☐ Maintenance of Way
- ☐ Car Department
- ☐ Track Maintenance
- ☐ Safety

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INTRODUCTION AND BACKGROUND

Railroads are particularly interested in improving safety and quality standards on their tracks. Tremendous costs of track renewal and maintenance combined with high derailment costs make performance-based track geometry inspection a high priority. An improved geometry inspection system with the ability to account for vehicle/track interaction would benefit railroads by identifying adverse track geometry conditions responsible for poor vehicle performance.

Research is under way to develop a "real-time" expert system or black box that can be installed on a regular geometry car and will relate measured geometry conditions to likely vehicle response. This expert system will produce vehicle response information, which, with conventional track geometry data, will enable track maintenance decisions to be made on vehicle performance as well as geometry exceptions.

The development of such a system will be based on real-world vehicle/track interaction data. Therefore, three tests using three typical freight vehicles have been conducted under various revenue service conditions. The first test was performed using a loaded covered hopper over 400 miles of CSX revenue tracks in July and August 1998. The results of that test were reported in *Technology Digest 99-013*. The second test with a tank car was conducted on a Burlington Northern Santa Fe revenue service route in August 1999. During that test, track geometry and vehicle response data were collected over approximately 470 miles of track. The results of the tank car test were summarized in *Technology Digest 99-022*.

The third revenue service test was conducted on a Union Pacific revenue route in Colorado between Alamosa and Denver on July 31 to Aug. 3, 2000. The test vehicle was a 110-ton coal gondola. About 450 miles of vehicle/track interaction data was collected. In the following sections, the test and neural network modeling results based on this test will be summarized.

UNION PACIFIC REVENUE SERVICE TEST

Similar to the first two tests, the coal gondola was instrumented with four load-measuring wheel sets and a portable track geometry system. Via the load-measuring wheel sets, vertical and lateral forces, and L/V ratios for each individual wheel were recorded. Track geometry information was recorded via a non-contact system using laser/camera and inertial compensation package. In addition, eight accelerometers were installed on the car body to define its rigid motion modes (such as roll, pitch, bounce, yaw, and/or sway).

Exhibit 1 shows the test consist used for the Union Pacific (UP) revenue service test. In this consist, the loaded UP coal gondola and TTCI's instrumentation car were operated in a UP revenue train. This 110-ton coal gondola was equipped with S-2-HD trucks (variable damping). During the test, track geometry and vehicle responses (both forces and accelerations) were recorded continuously.

The test run started at Pueblo, went to Alamosa, and then returned to Pueblo. The second leg of the run was from Pueblo to Denver and back to Pueblo. Most of the round trip consisted of double tracks owned by either UP or Burlington Northern Santa Fe (BNSF) except for the portion between Alamosa and Walsenburg. The tracks under test and the measured vehicle responses, showed a wide range of variations. Sharp curves up to 16 degrees were tested. The train speed varied between 10 and 50 mph. All these variations led to a very diverse vehicle/track interaction test database for the training of various neural networks.

Exhibit 1. Test Consist for UP Vehicle/Track Interaction Test

NEURAL NETWORK MODELING

As already demonstrated during the previous two tests, neural network technology is a powerful tool in both modeling and recognizing complex relationships between track geometry and vehicle response. However, its effective use is highly dependent on feature extractions of the test data for neural network training. A significant amount of effort has therefore gone towards understanding the input conditions that are likely to relate to the changes in vehicle output. The key steps in building neural networks for the coal gondola are the same as the ones utilized in the past two tests on a covered hopper car and a tank car. The data was processed such that the statistical features (average, min, max, 95th percentile, 50th percentile, 5th percentile and standard deviation) were extracted for every 0.1 mile of track segments. These features were then used to train and build neural network models. Once trained, these models for each of the output parameters of interest (i.e., wheel loads, L/V ratios, etc.) were validated by comparing the actual observed values to predictions made by the models.

Exhibit 2 illustrates the validity of the trained neural network for the prediction of L/V ratio. The prediction was made for the coal gondola operation between Alamosa and Pueblo. In training the neural network, only 40 percent of the data was used. The rest of the test data was used for testing the validity of the model. Also shown in Exhibit 2 are some of the major inputs to the neural network including train speed, curvature, gage, alignment, and surface.

As shown, despite a wide range of operating conditions, L/V magnitudes predicted by neural networks match closely with the actual observed values from the test. The higher magnitudes of L/V ratio occurred at La Veta Pass, where the tracks in the sharp curves show somewhat wide gage and somewhat large misalignment (as indicated by standard deviation values).

WORK IN PROGRESS

As mentioned earlier, the ultimate goal of this research is to develop a “real-time” expert system or black box that will be installed on a geometry car. The output of a geometry car; i.e., measured track geometry conditions, will be used as input to the black box. Vehicle type, operation speed, and pre-determined vehicle/track interaction criteria will be used as the other required inputs. The neural networks trained for the specific car types will constitute the basis of the black box. To date, preliminary networks have been trained and tested for the covered hopper car, tank car, and coal gondola.

Exhibit 3 illustrates how this research will lead to a system that will help to prioritize track geometry maintenance. For a track segment about 20 miles (near Walsenburg), a geometry car has measured its geome-

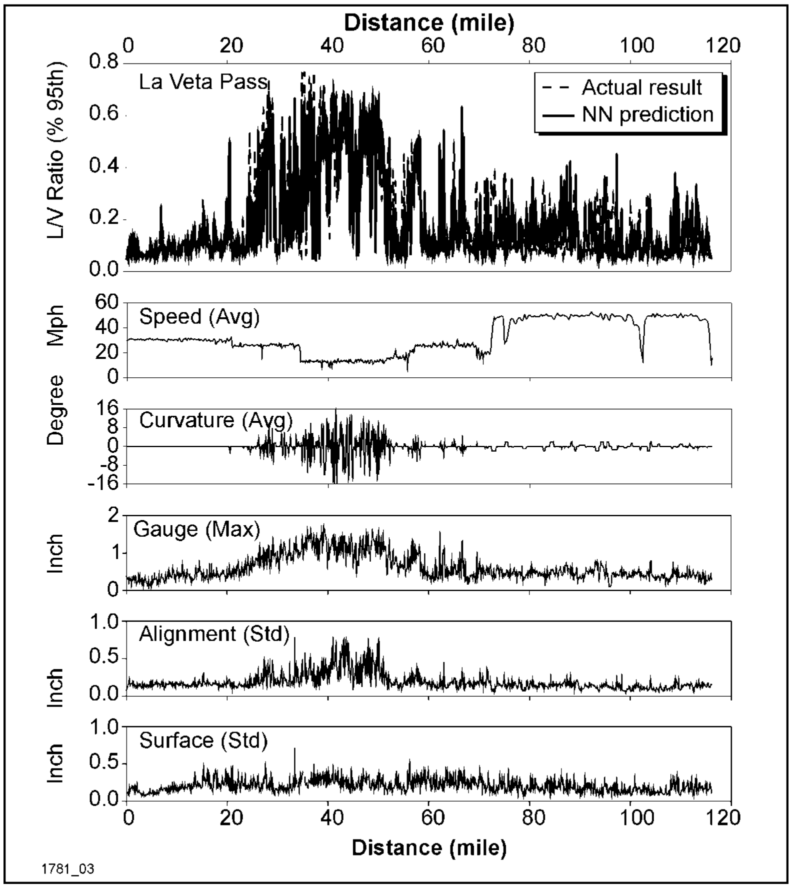

Exhibit 2. Comparison of Neural Network Prediction and Test L/V Results

try condition, some of which is shown in this exhibit. The measured geometry condition and train operation speed are used as inputs to the trained neural networks for the coal gondola and tank car. The predicted vehicle performance (i.e., L/V ratio) for these two vehicles is also given in this exhibit. Based on the vehicle performance and geometry results, it is obvious that the maintenance effort should be focused on locations A, B, and C, where the tracks at the three curves showed not only larger gage variations, but also higher magnitudes of L/V ratios.

ACKNOWLEDGMENTS

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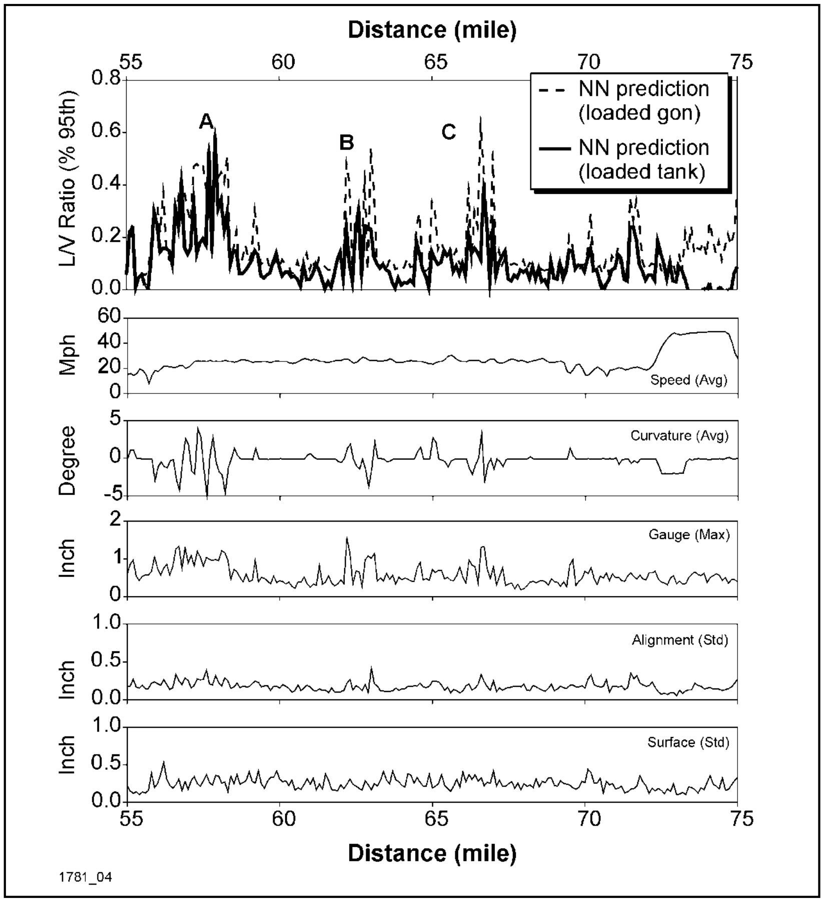

Exhibit 3. Performance Results for Coal Gondola and Tank Car together with Geometry Conditions

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.