

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Characterizing Fleet Performance with TPD Technology

by Chris Pinney and Dio Yoshino

Summary

Continuous performance measures are critical for fleet managers to plan, design, and implement the most efficient operating programs for their fleets. Well managed fleets are designed or retrofitted with components that may extend their service life, improve safety, and provide the best return-on-investment relative to expenditures incurred during operation. The process of selecting the most efficient maintenance and car design programs may be improved with new developments in wayside detection technology. Research conducted by Transportation Technology Center, Inc. (TTCI), suggests that data collected from the truck performance detector (TPD) may be useful in characterizing fleet performance to benchmark optimal car designs or retrofits based on curving performance.

The primary goal of this research is to develop a design of experiment that will illustrate analysis techniques for assessing optimal freight car designs. This was done using TPD data from the Transportation Technology Center's (TTC) High Tonnage Loop (HTL), in Pueblo, Colorado. Another goal of this research is to develop a methodology that will allow consistent comparison between cars under evaluation and detect differences in behavior displayed in TPD data based on selected car groups. Finally, the research may determine if these differences are due to freight car design or component differences.

Developing a process for collecting data and turning it into useful information to support the planning, design, and implementation of fleet operations is an important part of any fleet management program. TPD data is emerging as a tool that may support fleet managers in assessing optimal freight car designs, configurations, and maintenance policies. This technology is enhanced with TTCI's InteRRIS™ database query engine.

Significant TPD findings at TTC:

- TPD technology was successful in measuring the performance characteristics of component modifications to truck suspension systems (conventional three-piece truck versus trucks with frame brace application and primary suspension pads) tested at the Facility for Accelerated Service Testing (FAST) at TTC.
- TPD technology was successful in distinguishing car design groups within the population at TTC.
- Under dry (un-lubricated) rail conditions, close average lateral loads resulted with very close standard deviations for similar car types and truck designs. Therefore, repeatable behaviors with consistent analysis techniques were achievable under dry rail conditions in a controlled test environment at TTC.
- Under lubricated rail conditions, selected car design groups showed significantly higher measurement variation. Car design performance characteristics, however, were still achievable with consistent analysis techniques at TTC.



INTRODUCTION

The objective of this research is to identify analysis techniques using truck performance detector (TPD) technology that may allow fleet managers to benchmark optimal car designs. The benchmarks derived from characterizing their fleet may provide information to improve safety at the wheel/rail interface and optimize maintenance and component designs. Decreasing the number of truck related derailments and extending wheel life are key issues related to this research.

According to the 2004 Federal Railroad Administration safety statistics, the industry experienced a number of truck component related train derailments as a result of truck bolsters that were stiff from improper lateral or swiveling car body stability (the specific cause code is E46C, “truck bolster stiff, improper lateral, or improper swiveling”).”

On the maintenance expense side, Class I railroads and the Association of American Railroad’s (AAR) car repair data indicates that the industry spends approximately \$1.5 billion annually in car related maintenance expenditures. Approximately 37 percent is spent on wheel repair and replacement, constituting an expenditure of approximately \$555 million per year.¹ Car owners and suppliers have conducted extensive research in the past several decades exploring modes of wheel failure and means to increase wheel life.

TPD’s are designed to measure freight car performance in curves where component wear resulting in undesired truck warp and poor truck-to-car body rotation may be present. These anomalies contribute to high lateral loads that may cause track degradation and in extreme cases gage widening derailments and excessive component wear. Car design, car design configurations, and mechanical condition affect issues related to these undesired lateral loads.

DATA CONSISTENCY

In order to accept new information into an existing operating process, it must first be validated. The first objective of this research is to measure the consistency of TPD data in a controlled test environment. TPD sites are designed to measure steady-state curving under dry rail conditions. TTC maintains a TPD on their HTL which was used to measure the performance of sample test cars under dry rail conditions. TPD measurements were taken in a 5 degree, left hand curve for the high rail at speeds averaging 40 mph. Identical car types with the same truck design were used to compare the consistency of TPD technology.

Data in Figure 1 shows repeatable behavior for individual cars over multiple passes and similar performance between identical car designs. The average lateral load for car 1 was 11.7 kips with a standard deviation of 0.61. Car 2 varied slightly from Car 1 with an average lateral load of 12.1 kips and standard deviation of 0.56. Similar results were found with multiple car observations under dry rail conditions.

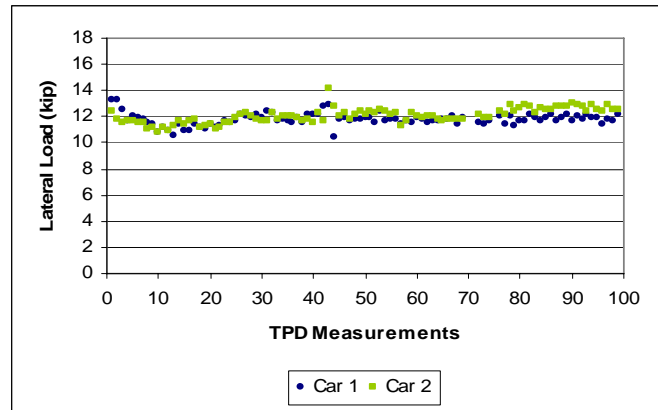


Figure 1. Curving Performance Comparison for Similar Car Designs

Close average lateral loads resulted with very close standard deviations for identical car types and designs. Therefore, repeatable behavior was obtained under dry rail conditions with the sample car designs.

DATA ANALYSIS TECHNIQUES

Data measurement techniques are vital to achieving a consistent comparative analysis between car designs. Filtering data and considering dynamic issues related to freight car curving are also important factors in refining data into useful information. There were several data analysis techniques used when evaluating vehicle performance using TPD data.

These include:

- Measure only lead axle from lead truck.
- A and B trucks in a car may behave differently, so car performance should be measured individually for both A and B trucks when leading.
- Truck performance is evaluated based on high rail values.
- A truck may behave differently based on direction of travel. If possible, performance information should be gathered for both left and right hand curves.
- There should be sufficient agreement between adjacent cribs in a curve. Otherwise the data for the curve should not be used (may be due to a TPD calibration issue or track geometry).

CAUSES OF VARIATION FOR TPD DATA

Assignable causes such as track condition (track strength and lubrication) and TPD site calibration play significant roles in the consistency of TPD data. These conditions should be controlled to accurately compare the performance of freight car types and or designs.

Lubrication and the resulting coefficient of friction have a significant effect on curving forces and thus, on TPD measurements. It is desirable that rail be in a dry condition in order to evaluate the consistency of vehicle performance. Figure 2 illustrates the effect lubricated and dry rail conditions have on TPD measurements for two car design groups. Group 1 and 2 are each represented by five cars with similar truck designs. Each TPD measurement represents the average lateral load (kips) for each group by train pass.

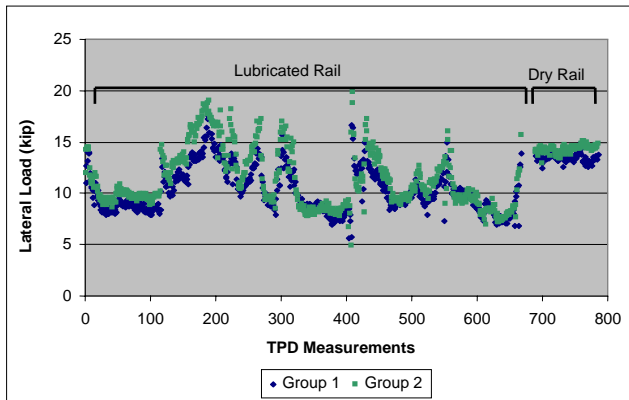


Figure 2. Curving Performances under Lubricated and Dry Rail Conditions

Under lubricated rail conditions data variability was significant when analyzing individual car groups. Although individual TPD measurements for selected car groups were variable, the performance between car groups followed a similar trend. That is, they showed a similar pattern of variability based on the coefficient of friction at the wheel/rail interface. From measurement 1 to 667, on lubricated rail, the average lateral load was 10.31 kips for group 1 with a standard deviation of 2.6. Group 2 averaged 11.3 kips with a standard deviation of 2.8. Occurrences of peaks under lubricated rail are a result of dry rail conditions at the beginning of each operating cycle on the HTL.

At the 668th measurement in Figure 2, track conditions were consistently dry and data variation became controlled. Consistent behavior was observed with average lateral loads for group 1 at 13.4 kips with a standard deviation of 0.39. Group 2 averaged 14.3 kips with a standard deviation of 0.38. This transition from lubricated to dry rail illustrates the effect variation of the coefficient of friction may have on the force generated at the wheel/rail interface. It also suggests that dry rail conditions are desired for accurate TPD measurements.

TPD site curvature will also directly affect curving forces observed for a vehicle. Car performance should be evaluated based on like curvatures until a normalization algorithm can be established.

COMPARISON OF CAR AND COMPONENT DESIGNS

An analysis was conducted on the HTL to evaluate the consistency of TPD data and test the reliability of characterizing optimal car designs. The first approach was to evaluate fleet performance by assessing the target population. The second approach evaluates a specific group shown to have optimal performance characteristics relative to the population. The objective is to identify the design differences within the group (Barber S-2 trucks) and compare them to their modified sub-group with improved components (frame brace application with primary suspension pads [FBSP]).

Population Evaluation Comparison

The initial step of distinguishing optimal car designs is to evaluate the performance of a selected fleet. In revenue service fleet managers may want to first evaluate their entire fleet or specific sub groups based on their service. For this study we selected the car population active at the HTL under dry rail conditions. Using TPD technology with the InteRRIS™ database query engine, population distributions were developed as shown in Figure 3.

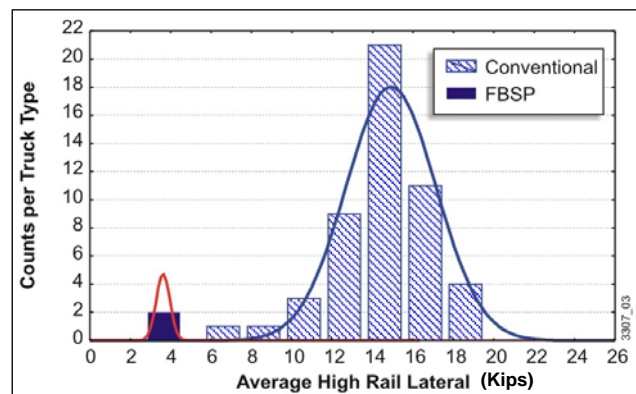


Figure 3. Characterized Fleet Population Distribution

The population average was 14.8 kips. This average includes various conventional three-piece trucks and a small group of frame brace trucks with primary FBSP. Each measurement (kips) represents the average of approximately 100 TPD observations per car in the population distribution graph. There was a significant difference in the group equipped with FBSP. Its average lateral loads were approximately 3.6 kips with a close standard deviation of 0.33. The group with FBSP achieved a performance 311 percent better than the average population lateral load (kips) as shown in Figure 3. The improved curving performance was due primarily to the use of primary suspension pads. This shows that differentiating car groups were achieved with TPD technology under dry rail conditions.

Truck Design Comparison

The car group with the best performance (the FBSP equipped cars) was compared to a similar car and truck design not modified with FBSP to characterize sub group performance. For a design change to be recommended, similar car groups with modifications should be evaluated. Therefore, Figure 4 compares the performance of four coal gondolas with Barber S-2 trucks.

Two similar car design groups, one with conventional three-piece trucks and the other modified with FBSP, were tested for curving performance at the HTL under dry rail conditions. Car set A's (conventional three-piece truck) data was very consistent resulting in a standard deviation of 0.60 for car A1 and 0.86 for car A2 in Figure 4. The average lateral loads were also very similar with car A1 at 10.6 and car A2 at 10.5. This represents only a 0.95 percent difference in average lateral load performance.

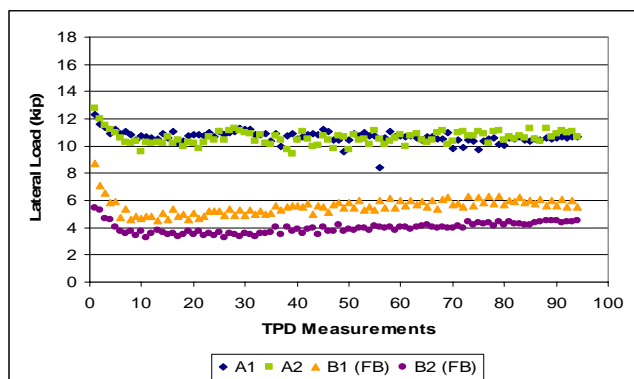


Figure 4. Frame Brace with Suspension Pads (FBSP) versus Conventional Three-Piece Truck Curving Performance

Car set B, modified with FBSP, also showed very consistent behavior. The standard deviation for car B1 was 0.61 with B2 at 0.54. Average lateral load results for both B1 and B2 performed very well averaging 5.6 kips and 4.0 kips respectively.

Test data at the HTL shows that cars modified with improved components consistently performed better than the conventional three-piece truck design. The average lateral load performance for car set A was 10.6 kips, while car set B achieved an average of 4.8 kips. The results of the sample car sets are significant and result in a performance difference of approximately 120 percent. Previous testing at TTC using instrumented wheelsets data also showed that improved suspension trucks produced significant performance benefits of low lateral force and reduced rail wear.² These tests conclude that differentiating component designs by sub group were achieved with TPD technology under dry rail conditions.

CONCLUSION

The InteRRIS™ database query engine, TPD technology, and analysis techniques developed by TTCI engineers may be used to benchmark optimal car designs based on preliminary test results at TTC. Testing at TTC was conducted under controlled conditions with the HAL test fleet. Selected car designs were tested to validate consistent performance differences. Test results provided information confirming consistent performance differences between sub-groups.

However, this analysis technique was only feasible for selected car groups at TTC. Therefore, it is important to acknowledge that fleet characterizations may only be practical for selected revenue service fleets. Based on TPD related revenue service analysis conducted by TTCI engineers, some fleets show significant performance differences. These differences may be due to issues such as: fleet maintenance practices, TPD site location, or the effect various coefficient of friction conditions may have on the wheel/rail interface.

To validate these preliminary findings, evaluations should be conducted for selected revenue service fleets. Accurate statistical data with historical maintenance records, car mileage, and car design is required to evaluate a fleet or selected group of cars. In addition, fleets must operate consistently over TPD sites so sufficient volumes of data are generated for analysis. Selecting appropriate car groups and filtering TPD data were the key analysis techniques used by engineers at TTC to develop reliable results.

FUTURE WORK

The initial findings in this Technology Digest support the initiative for TTCI to develop a design of experiment for a revenue service fleet evaluation. The goal of this research is to evaluate a similar fleet over multiple TPD sites. The sample fleet will consist of identical car types with different designs or components such as modified truck types.

The objective is to differentiate curving performance between car designs and make recommendations of optimal car designs. Additionally, a safety and wear index will be used to compare car design performance. The safety index will be used to evaluate the effect different car designs may have on AAR Chapter XI performance measured with TPD technology. The wear index will be used as a key performance measure to identify optimal car designs.

REFERENCES

1. T. Guins, C. Pinney, and P. Little, "Weibull Analysis of Coal Car Wheel Life," TD-04-020, TTCI, November 2004.
2. H. Wu, J. LoPresti, K. Rownd, and C. Urban, "Effect of Eccentric Loading and Primary Suspension Pads on Vehicle Curving Performance," TD-03-002, TTCI, March 2003.

Visit our website at <http://www.tci.aar.com>