TECHNOLOGY DIGEST

Timely Technology Transfer

"MODELING SIMULATIONS PERFORMED ON SERVICE WORN TRUCKS,"

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TD 94-024

Summary

This *Technology Digest* is a continuation of the work presented in TD 94-009 "Truck Characterization Test Performed on Service Worn Trucks," June 1994 and TD 94-023 "Track Tests Performed on Service Worn Trucks," November 1994.

Recent modeling predictions were conducted at the Transportation Test Center, Pueblo, Colorado, on a number of service worn trucks to investigate when truck maintenance should be conducted on the standard 100-ton three-piece truck. As with the track test results (TD 94-023), modeling predictions indicate that the truck designs tested should be reconditioned or rebuilt at 0.4 inch of wedge rise to ensure a proper level of truck performance.

The trucks were tested through a series of limited Chapter XI tests found in the Association of American Railroads' *Manual of Standards and Recommended Practices*. They were of a variable damped design and had wedge rise reading ranging from 0.0 to 1.7 inches.

Modeling simulations for lateral stability (hunting) indicate that by using the AAR-1B wheel profile there would be a delay at the onset as well as at the critical hunting speed by as much as 5-7 mph. Loaded pitch and bounce and twist and roll modeling predictions indicate that the trucks exceeded Chapter XI performance criteria at 0.4- to 0.35-inch wedge rise.

Modeling simulations were performed using the industry standard NUCARS to predict the performance of these trucks. Simulations of Chapter XI empty stability (hunting), loaded pitch and bounce, and twist and roll as well as empty twist and roll were conducted. Pass/fail criteria from Chapter XI were used to assess the performance of the vehicle/truck combination. Criteria were added to assess the truck performance issues not identified in Chapter XI.

Maintenance guidelines and procedures will be recommended as a result of these tests.

Association of American Railroads
Research and Test Department
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INTRODUCTION AND CONCLUSIONS

This research was conducted by the Association of American Railroads (AAR) at the request of the Mechanical Division Sub-Committee on Research. The research sub-committee directed the AAR to investigate 100-ton freight car performance and to recommend maintenance guidelines that would optimize and improve the standard three-piece truck's performance.

In 1989 and early 1990 the AAR developed an instrumented truck to investigate the relationship between wear and performance. A combination side frame truck was selected to allow either variable or constant damped designs to be tested. The truck was modified to test various levels of simulated wear by effectively reducing the column damping. In 1991, on-track tests were conducted over several perturbed track sections using the variable damped instrumented truck for two states of wear. The results from these tests were inconclusive indicating that the instrumented truck may not be simulating the worn truck condition typically seen in revenue service.

In 1992, five identical car sets of 100-ton variable damped truck designs with various wedge rise conditions were obtained from a member road to further the understanding of how truck performance is affected by wear. The trucks were characterized for vertical, lateral, and warp damping and stiffness parameters using the Mini-Shaker Unit (MSU) located at the Transportation Test Center's Rail Dynamics Laboratory. Friction wedge rise is a widely accepted common indicator of wear. The wedge rise for these trucks ranged from 0.4 inch to 1.7 inches. The manufacturer suggests that these trucks be reconditioned at 0.75 inches of wedge rise when approximately 50 percent of the friction damping remains.

From the track test results and modeling studies, the standard three-piece freight truck tested in this program should be rebuilt at 0.4 inch of wedge rise. These results primarily pertain to loaded vertical performance for a variable damped truck with double side coils. However, wear inspections and observations of constant damped trucks show similar trends.

The hunting predictions indicate that newer trucks with worn wheels would require additional rotational snubbing to control the unwanted oscillations. This could be in the form of constant contact side bearings or additional warp restraint.

In 1989, the AAR performed a wear versus mileage study at TTX's CALPRO facility in Ontario, California. The results of this study showed that both variable and constant damped trucks wear at a rate of 1.2 inches of wedge rise per million miles. Using this information in conjunction with the track test and modeling predictions from this study, we can conclude that the standard three-piece truck evaluated in this project should be reconditioned at 333,000 miles of service or 0.4 inch of wedge rise.

Please refer to **TD 94-023, November 1994**, for the results obtained from the track test conducted earlier this year. Only the track test results and modeling predictions will be presented in this *Technology Digest*.

NUCARS MODEL

AAR's NUCARS computer modeling simulation program was used to perform the analysis on the trucks. NUCARS can model any type of truck/car over a wide range of track inputs. It also has the capability of modeling all of the connections used in the standard three-piece truck. Of particular interest to this project, NUCARS is capable of modeling the friction connections. Loss of damping due to wedge rise or changes in friction can be studied.

All five car sets of service worn trucks were characterized on the MSU earlier in the test program. The data obtained from the truck characterizations was used as input to the models. A NUCARS MSU version was developed to match the modeling and characterization test results.

Empty and loaded vehicle models were then developed to investigate Chapter XI test regimes and wedge rise conditions. Rigid body frequencies were measured and verified using a hand excitation technique developed for the test program. All wheel/rail profiles as well as friction levels were measured during the track test and used as inputs during the modeling process. All wheel sets were machined to the worn instrumented wheel set profile.

MODELING PREDICTIONS

Hunting

Lateral instability (hunting) is initiated by lateral shifts of the wheel set. This induces a rolling radius difference between the wheels, thereby causing a yaw oscillation. The wheel set that is flanging has the greatest rolling radius which steers the wheel set toward the opposite rail. Eventually this sets up an uncontrolled dynamic oscillation that increases with speed.

Modeling predictions versus track test results for the no wedge condition and simulated zero wedge rise condition are shown in Exhibit 1. The data shown is car body root mean square (RMS) accelerations versus speed. Added to ease the interpolation of the plot are the onset RMS of 0.15 and the maximum Chapter XI limit for car body RMS accelerations of 0.26.

Hunting simulations matched the track test results for the worn wheel conditions; additional simulations investigating the performance of the trucks using the AAR-1B were conducted. The predictions indicate that using the 1B wheel profile would increase the performance of the trucks by approximately 5-7 mph.

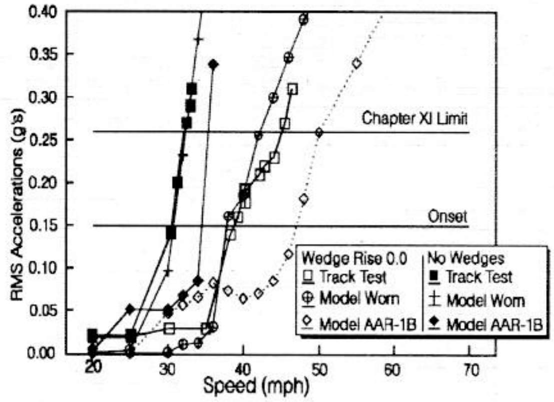

Exhibit 1. Hunting Track Test Results vs Modeling Predictions, RMS Car Body Accelerations and Wedge Rise vs Speed

Pitch and Bounce

NUCARS modeling predictions and track test pitch and bounce results for the simulated zero wedge rise and 1.5-inch wedge rise conditions are shown in Exhibit 2. Added to the plot to ease interpolation is the Chapter XI 10-percent vertical load limit and the proposed dynamic load factor limit for truck performance.

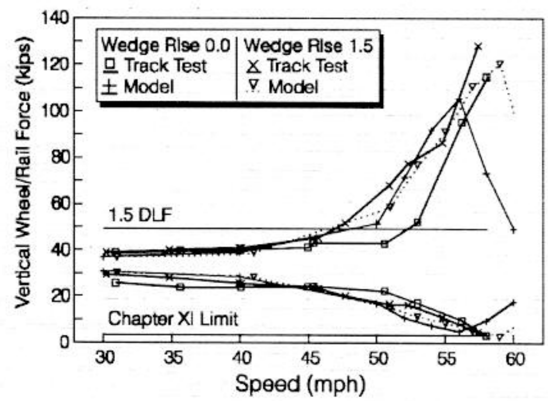

Exhibit 2. Pitch and Bounce Track Test Results vs Modeling Predictions Maximum and Minimum Vertical Wheel/Rail Forces and Wedge Rise vs Speed

Modeling predictions nearly matched the results obtained from the track tests. The track test results showed that the amplitudes of the Chapter XI perturbations are too severe to evaluate differences in the friction damping systems of the trucks. Further modeling investigations were deemed necessary to investigate the response of the trucks over a smaller range of perturbation amplitudes.

These modeling simulations showed that perturbation amplitudes from 0.75 to 0.70 were again too large to measure the differences in truck performance. At 0.6-inch amplitude, there were measurable differences in truck performance. The modeling predictions showed that trucks with 0.0 to 0.4 inches of wedge rise passed the simulation and all other conditions failed.

Twist and Roll

Twist and roll modeling predictions and track test results for the simulated zero and 1.5 inches of wedge rise are shown in Exhibit 3. Again, for ease of interpolation, the Chapter XI 10-percent vertical load limit and dynamic load factor limits have been added to the plot.

The 1.5-inch wedge rise twist and roll modeling predictions nearly matched the results obtained from the track test. However, the modeling predictions obtained for the zero wedge rise condition did not match the simulated zero wedge rise track test results as closely. This is primarily due to using a worn 0.5-inch wedge rise truck during the test, and shimming it to a "simulated zero wedge rise condition." The track test results show an improvement in performance but does not reproduce a "new" truck condition. The idealized modeling predictions show how a "new" truck would performed.

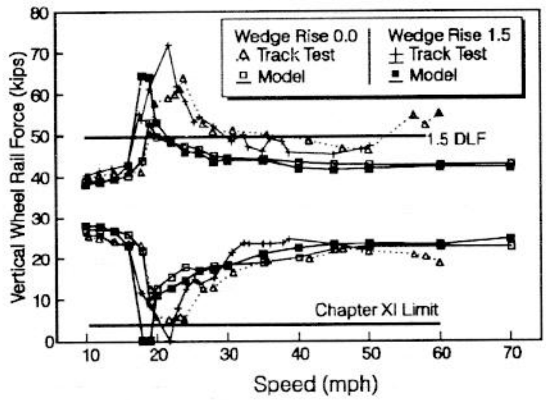

Exhibit 3. Twist and Roll Track Test Results vs Modeling Predictions Maximum and Minimum Vertical Wheel/Rail Forces and Wedge Rise vs Speed

Modeling simulation were made for wedge rise conditions ranging from 0.0 to 0.5 inch. At the 0.35-inch wedge rise condition, the truck failed the simulation indicating the maintenance should be performed prior to this level.

Note: Contact Curt Urban (719) 584-0574 or Huimin Wu at (719) 584-0533 with questions or comments about this document.

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, WILL BE AVAILABLE AT A LATER DATE THROUGH THE DOCUMENT DISTRIBUTION CENTER, CHICAGO TECHNICAL CENTER, 3140 SOUTH FEDERAL STREET, CHICAGO, ILLINOIS 60616. PHONE BETTY J. VAUGHAN (312) 808-5421. A REPORT LIST IS AVAILABLE UPON REQUEST.