TECHNOLOGY DIGEST

Timely Technology Transfer

Wheel Impact Acceleration Detector Performance Tests

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<u>Summary</u>

Results from the performance testing of an acceleration-based wheel surface defect monitoring system showed that the detector reliably identifies wheels with tread defects. However, the repeatability of the measurement of impact accelerations is questionable for longer wavelength out-of-round wheels. An optimum impact threshold level which will identify out-of-round wheels (long wavelength defects with large divots) appears to be between 200 and 300 gs. The optimum train speed at which the maximum number of defective wheels is detected appears to be near 50 mph, for most long wavelength defects.

The rail impact acceleration measurement system was tested in August, 1991 at the Transportation Test Center in Pueblo, Colorado, to develop a statistical data base of the measured impact accelerations from a variety of wheel types. The primary objective of these tests was to evaluate the performance of wayside wheel impact detector systems to measure and identify those wheels exceeding specified excessive levels of impact loads and accelerations on track at typical freight train speeds.

Two radically different types of impact detectors - a rail load and a rail acceleration measurement system - were utilized in the test program. A total of 48 test wheel sets with various tread defects were installed under 70, 100, and 125 ton cars, and the resulting consist was operated over the detector site back and forth at various test speeds. A previous Technology Digest (92-004) presented results with the rail load measurement system. That system also operated reliably during the test and successfully identified wheels with tread defects. This Technology Digest covers only the acceleration moving system.

An alternative wheel removal criterion based on impact acceleration detectors could be utilized to identify out-of-round wheels, as they are not covered under current AAR wheel removal criteria. It also seems possible from the data, that a statistically significant level of acceleration threshold can be set using an impact detector to identify wheels with tread defects only. The percentage coverage at the optimum impact acceleration threshold increases with speed. However, as train speed increases, the probability of misidentifying good wheels also increases.

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Research and Test Department

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INTRODUCTION AND CONCLUSIONS

Recently the railroad industry has begun to recognize the limitations of the current AAR Rule 41a criteria for condemning wheels due to wheel tread defects. Starting with wheel-defect-induced concrete tie problems found on the Northeast Corridor's high speed passenger route, it was discovered that Rule 41a permitted continued operation of certain types of wheel defects which could generate very high impact loads on the rail. Further work by the Canadian National showed that these high impact loads were not limited to high speed passenger routes, but could also be found in freight service. Since then, several railroads have installed wheel impact detectors to monitor high impact load producing wheels.

In 1989, AAR staff reviewed the current industry experience with wheel impact load detectors and wheel tread irregularities. The results of this survey published in AAR Report R-754 emphasized the urgent need to review current AAR wheel removal criteria. The survey data also showed that significant questions remained about the information obtained from the impact detectors. In particular, issues about speed sensitivity and repeatability of this type of measurement need further research if impact detectors are to be used as supplementary tools for condemning wheels due to tread defects.

A series of tests were performed to address these concerns and to develop a statistical data base of the measured impact load and accelerations from a variety of wheel defect types. The results from tests with the acceleration measuring impact detector system are presented herein. The preliminary analysis of the test data supports the following conclusions:

- *The impact acceleration detector system operated reliably during the full duration of the test program. A very attractive feature of this system is its ease of installation which involves only simple clamping of accelerometers to the rail base.*
- *The detector system clearly identifies wheels with tread defects, although the repeatability of the measurement of impact accelerations is questionable for longer wavelength out-of-round wheels. Also, unlike the impact load measurement system, the accelerations are transmitted from the defective wheel to the good wheel on the same axle.*
- *Rail accelerations due to impact increase with depth of wheel defects and speed. The scatter found in the measured data also increases with defect size and speed.*
- *The variability in the impact load was the highest for longer wavelength defects with large divots, especially at higher speeds.*
- *An optimum impact threshold level which will identify out-of-round wheels appears to be between 200 and 300 gs.*
- *The percentage coverage at the optimum impact acceleration threshold increases with speed. However, as train speed increases, the probability of misidentifying good wheels also increases. The optimum train speed at which the maximum percentage defective wheels is detected appears to be near 50 mph, for most long wavelength defects.*
- *The detector system occasionally reads very high acceleration levels, however, occasional measurement of a very large acceleration under a given "bad" wheel does not effect the reliability of the system to detect a given anomaly.*
- *Surprisingly, the tests show that empty cars equipped with the same defects show almost as high impact accelerations as loaded cars. This feature of the detector may enable the user to monitor wheels under both loaded and empty cars at a single acceleration threshold level.*
- *The measured impact loads show a directional bias due possibly to the non-symmetrical shape*

of the defects, however, this variation does not influence the detector's ability to identify the defective wheels.

IMPACT LOAD DETECTOR TESTS

The impact detector system used during this test program is based on an array of accelerometers (seven on each rail) mounted to the rail base. This type of detector is utilized by several European railways.

The wheels utilized in the test series included a number of condemnable and non-condemnable wheels, supplied by six major North American railroads. Defects present included slid flats, shells and spalls, out-of-rounds, and tread build-up. The defective wheels were mounted under cars with axle loads ranging from 25 to 39 tons. A total of 48 test wheelsets were included in the program. A limited number of runs were made with empty cars. The test consist (Exhibit 1) was operated past the detector site a minimum of 20 times in each direction, at each test speed. The test speeds ranged from 20 to 70 mph in 10 mph increments.

Exhibit 2 shows repeatability of the peak impact acceleration measured under a 36-inch diameter out-of-round (O.O.R.) wheel with a long wavelength defect, 20 inches in arc length and 140 milli-inches in depth.

This wheel set was originally identified at a revenue service detector, and the defects found were non-condemnable. It was also one of the most difficult wheels to measure, and represents the *worst case scenario*.

The peak impact acceleration data shown in Exhibit 2 represents: 1) fifty (50) individual loaded car runs, 25 in the northbound and 25 in the south bound direction at each of the six the speeds; and 2) ten (10) empty car runs, 5 in the northbound and 5 in the southbound direction at each of the 3 test speeds. As seen in this exhibit, a large scatter in impact acceleration is found, especially at speeds above 20 mph, when more than one measurement is taken at each speed. Rail accelerations due to impact increase with speed, and the scatter found in the measured data also increases with speed.

Theoretically, the detector system is designed to provide 100 percent coverage for all wheel diameters. However, this feature does not guarantee a high degree of repeatability, as the impact acceleration measured during each repeat run can further be affected by vehicle dynamics, variation in wheel/rail contact geometry, and variability in track support conditions.

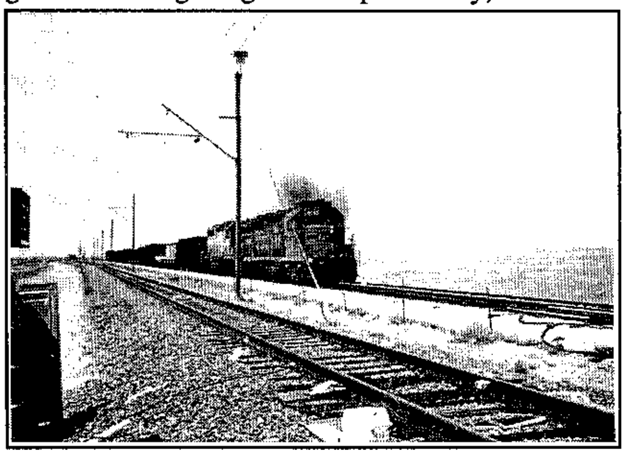

Exhibit 1. Test Consist Comprising 70-, 100- and 125-ton Cars used in Impact Detector Repeatability Tests.

The data also shows a few suspect observations which are only present on the high side of the readings. This problem was a common occurrence in most of the acceleration data collected under defective wheels only.

In Exhibit 3, the variability of this measurement is compared with that of a "good" wheel in terms of the mean value and standard deviation at each test speed. A close examination of the data reveals that the peak impact accelerations produced under the "good" wheel do not exceed 90 gs at speeds up to 65 mph. In this speed range, the average impact acceleration measured

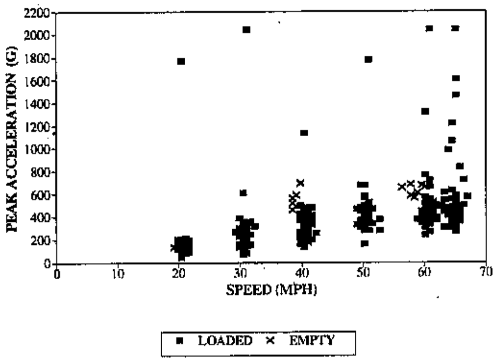

Exhibit 2. Impact Acceleration Scatter Plot for the 36" Diameter O.O.R. Non-condemnable Wheel.

under the defective wheel remains above 140 gs, indicating that the detector system successfully identifies the "bad" wheel. The mean value and standard deviation of the impact acceleration increases with speed, even for the "good" wheel, due largely to increased vehicle dynamics.

Exhibit 4 shows the percent coverage of impact accelerations exceeding a given threshold level at various speeds for the same wheel. The percentage of the measurements producing greater than 200 g impact acceleration ranges from 65 percent at 30 mph to 100 percent at speeds above 60 mph. At the 400 g impact acceleration threshold level, this coverage ranges from 2 percent at 30 mph to 80 percent at 65 mph.

Shortly after these tests, the vendor released a new version (Version 3) of this detector system. In Version 3, the measurement zone is extended to detect the impact acceleration over four wheel revolutions (as opposed to one wheel revolution in the version tested). This should improve the measurement repeatability and detection accuracy of this detector system.

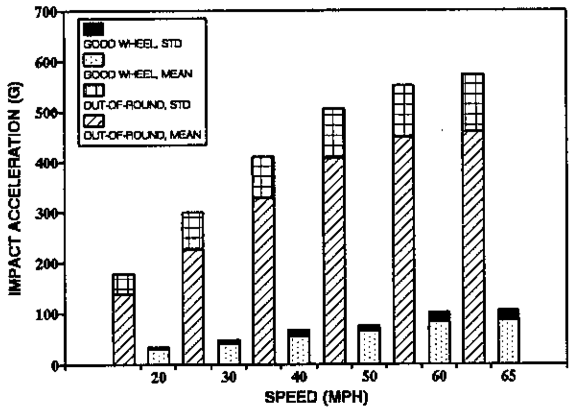

Exhibit 3. Comparison of Impact Acceleration Statistics for Defective and "Good" Wheels, 100-ton Car.

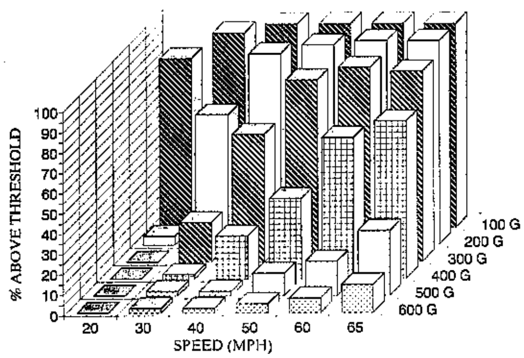

Exhibit 4. Impact Detector's Coverage of Wheel Impact Accelerations at Various Threshold Levels and Speeds, O.O.R Wheel.

Note: Contact Semih F. Kalay at (312) 808-5842 with questions or comments about this document.