TECHNOLOGY DIGEST

Timely Technology Transfer

# "FREIGHT CAR ROLLER BEARING FAULTS IDENTIFIED WITH A LASER VIBROMETER AT THE CONRAIL WHEEL SHOP"

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**Summary**
The Association of American Railroads (AAR), Transportation Technology Center (TTC) recently conducted a test using a laser vibrometer to measure vibration signals associated with freight car roller bearing defects. Results of testing indicate that a performance evaluation of mounted bearings is possible under wheel shop conditions. Advantages of the laser vibrometer as a roller bearing diagnostic tool also are presented.

This digest provides a simple graphic comparison of vibration spectra collected from 22 roller bearings. The most severely damaged bearings yielded spectra with the largest vibration amplitudes. A three-dimensional spectral plot developed from the laser vibrometer measurements was used to identify and rank order the bearings based on the severity of internal damage. Advanced classification of damage assessment, beyond the visual approach, is available from other AAR research[1,2] and will be added to enhance the diagnostic capability.

The vibration data was collected from new, special re-assembled, and bad ordered freight car bearings at the Conrail wheel shop in Hollidaysburg, Pennsylvania. All bad ordered bearings were taken directly from rail service hot bearing set-outs. In addition, there was a new bearing, and a reconditioned bearing.

One objective of AAR's bearing research program is to improve defective freight car roller bearing detection technology. Part of the research effort is directed toward evaluating advanced detection techniques for use in wheel repair shops. Identifying and assessing the extent of internal bearing component damage without disassembly is a viable goal of AAR's bearing research efforts.

A detection scheme capable of identifying damaged bearings could pay for itself in many ways. In particular, a detector located in a wheel repair shop could (1) reduce the need to fully handle every bearing entering the facility, (2) provide the opportunity to return good bearings directly to service without disassembly (if rules allowed), and (3) provide dynamic performance verification that shop bearings are defect-free before they are distributed for use.

**Suggested Distribution:**
- ❑ Car Department
- ❑ Research and Development
- ❑ Communications and Signal
- ❑ Equipment Maintenance

Association of American Railroads
Research and Test Department
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## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) recently conducted a field evaluation to measure freight car roller bearing defects using a laser vibrometer. Results of the in-shop vibration inspection study indicate that a performance evaluation of mounted bearings is possible under wheel shop conditions. Advantages of the laser vibrometer as a roller bearing diagnostic tool also are presented.

At present, whenever a railroad freight car bearing trips a hot bearing or acoustic detector, the train must be stopped for immediate inspection. The suspect bearing is checked by the train crew to determine if the train can safely go on. If not, the car containing the bearing in question must be set-out. The suspected wheel set is removed from service and sent to a bearing rework shop where the bearing is removed and fully disassembled.

In many instances, the damage to the suspect bearing and/or its mate is minimal or non-existent, allowing for continued safe operation. However, at the present time there is no approved procedure that can fully evaluate a mounted bearing's condition. Disassembly is presently required for both set-out bearings and wheelsets that come in for retruing. As a result, perfectly good bearings continue to be removed prematurely from active service and are needlessly reworked. Subsequently, the average uninterrupted service life of today's bearings is less than it might be otherwise.

It is roughly estimated that 20 percent of mounted bearings entering a wheel shop are candidates for reuse without tear down or reconditioning. Industry currently experiences $72 million per year in bearing reconditioning costs. If a thorough and reliable means of inspecting the mounted bearings can be established, significant savings can be realized.

During operation, all bearings generate and emit vibration energy. Vibration output from a bearing is normally maximized at certain frequencies. These frequencies coincide with the rotational rate of the axle as well as the rotational rates of the internal bearing components. Worn or damaged bearing components typically generate vibration outputs that are greater in magnitude and/or modified substantially in character. These changes in vibration can be detected by modern sensors and processed to reveal the bearing's operating condition.

Bearing vibration spectra obtained with a laser vibrometer can be used to identify and rank the severe defects commonly found in overheated roller bearings removed from service.

A detection scheme capable of identifying internal bearing damage while the bearing is still mounted on an axle could prove to pay for itself in a very short time. The realization of this potential could come when the performance-based inspection procedure discussed in this report is approved and implemented by the rail industry.

## TEST SETUP

Exhibit 1 shows the laser vibrometer as it senses a vibration signature and thus the bearing's operating condition at the Conrail wheel shop. The acoustic and surface vibration output from 22 bearings was collected in the Conrail shop for further evaluation.

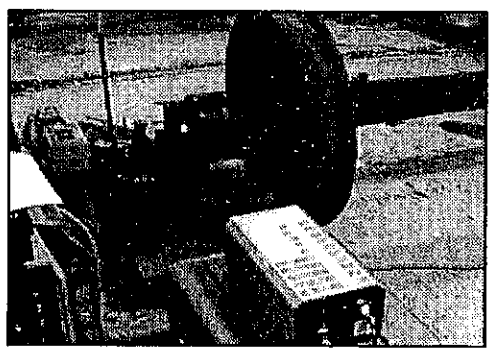

**Exhibit 1. Laser Vibrometer**

The majority of test bearings were pulled from service as a result of overheating. Two wheel bearing sets were assembled specifically for control purposes. One was new, the other was reconditioned.

All test bearings were spun at 350 RPM with a rig that supported the outer bearing cup on a pair of rubber rollers. The laser beam was focused on the non-rotating end-cap.

The laser vibrometer produces a velocity output measured in millimeters per second (mm/s). The bandwidth settings of the vibrometer can range from 5 kilohertz to 1.5 megahertz. Full-scale sensitivities were selected at either 5 or 25 mm/s of velocity amplitude. The vibration signature of each bearing was recorded on a portable digital/analog tape recorder.

## RESULTS AND ANALYSIS

All overheated test bearings were disassembled and visually examined for defects in the repair shop. A standard inspection sheet was generated for each bearing. Both 100-ton and 70-ton capacity bearings were tested. Exhibit 2 indicates the type of defects found in the 22 bearings tested.

A variety of defects were found. Spalls on the inner and outer races, as well as on the rollers were observed in some bearings. Others contained brinells, water etching, worn surfaces, indented surfaces, cracks, and discolored surfaces which indicate previous overheating. Several revealed that their cones had spun on the axle.

Spectra were generated from the collected vibration signatures. No filtering was used to generate the spectra. The first review of the spectra revealed the presence of vibrations that were undoubtedly associated with components of the drive system rather than the bearings themselves. This suggested normalizing the data to minimize the appearance of these signals. All spectra were normalized by the ratio of each test spectrum to that of the new test bearing.

**Exhibit 2. Inspection Report**

| Brg # | General Comments |
|---|---|
| 1 | Repaired Cup Spall |
| 2 | Loose Cap Screws |
| 3 | Good |
| 4 | Spalls, Indentations, and Heat |
| 5 | Heavy Spalls |
| 6 | Good |
| 7 | Brinell |
| 8 | Good |
| 9 | Reworked Good Bearing |
| 10 | New Bearing |
| 11 | 4 Spalls in Cup |
| 12 | 4 Spalls in Cone |
| 13 | Barline Spall in Cup/Broken WR |
| 14 | Indentations and Wear |
| 15 | Heavy Spall, Wear, Spun, and Water |
| 16 | Spalled, Cracked, Heated, and Spun |
| 17 | Spalled, WR Cracked, Spun, Worn |
| 18 | Water Etched |
| 19 | Could not Pull Bearing off Axle |
| 20 | Broken Roller, Spalls, Heat, Spun |
| 21 | Heavy Spalls, Water Etch, and Spun |
| 22 | Spalled, Brinelled, Spun |

Since test rig vibrations are present during each data collection cycle, the procedure sets all rig vibrations to a comparison level of "1." A display of the spectra from all three of the test bearings is shown in Exhibit 3.

Exhibit 3 is a plot showing two of the test spectra relative to the spectrum obtained from the new test bearing. The vertical axis displays the ratio of the amplitudes. From the new bearing they are "1" at all frequencies. New bearing amplitudes are displayed along the front edge of the plot. Note that test Bearing 5 was heavily spalled, whereas, test Bearing 1 contained a single reworked cup spall.

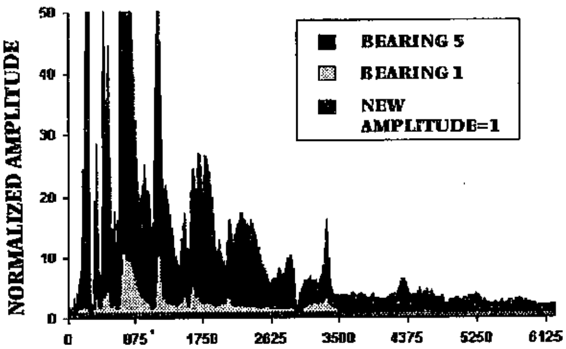


**Exhibit 3. Frequency Spectrum of all Test Bearings**

Exhibit 4 shows a set of three-dimensional average frequency spectrum for the two sizes of test bearings. As shown, the defective bearings generate more vibration energy output than the new bearing over the frequency range displayed.

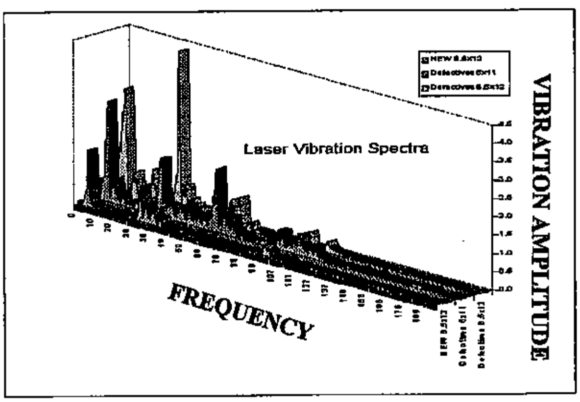


**Exhibit 4. Defective Bearings Normalized to New Bearing**

Actual bearing component rotational frequencies are all below 200 Hz for the test set-up used. Exhibit 5 displays the relative output spectra over the 200-Hz range for the same three bearings displayed in Exhibit 4. Shaft rotation signals for these tests would be at or near the frequency labeled "A." Frequency peaks at "B" are associated with the bearing rollers. Signal peaks at outer race (OTR) or inner race (INR) correspond to defects on either the outer or inner races of the bearings.

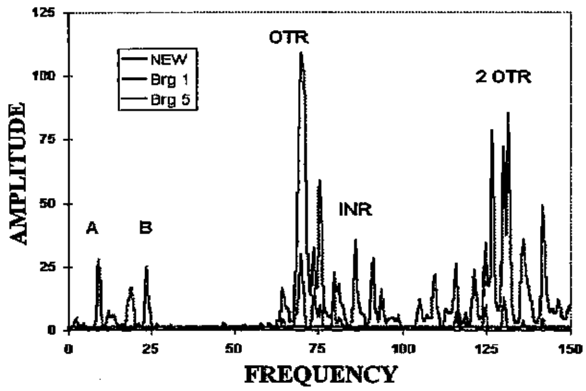


**Exhibit 5. Defect Frequencies**

## FUTURE PLANS

- To build a data base of bearing defect signatures
- To publish a performance specification for in-shop inspection systems
- To develop a neural network algorithm to identify type and severity of roller bearing defects
- To test and evaluate a turn-key bearing defect inspection system

## REFERENCES

[1] Wang, John M., Gerald Anderson, Richard Smith. "A New Detection Technique to Identify Defective Railroad Bearings," *Technology Digest* TD96-004, January 1996, R&T Dept., Association of American Railroads, Transportation Technology Center.

[2] Wang, John M., Gerald Anderson, Richard Smith. "Burn Off Simulation Analysis of a Railroad Roller Bearing," *Technology Digest*, TD96-005, R&T Dept., Association of American Railroads, Transportation Technology Center.



*A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON, D.C.,20001*