TECHNOLOGY DIGEST

Timely Technology Transfer — 02-007

Canadian National Railway

Warm Bearing Trend Analysis

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Summary

The Canadian National Railway (CN) has developed a communication network of hot bearing detectors (HBD). In addition to monitoring traditional hot bearings that require a mandatory train stop, the network also tracks warm bearings, which fall below traditional alarm levels. This network includes operating rules and procedures that allow corrective action to be taken on trains experiencing abnormal journal bearing performance.

Preliminary data analyzed from the HBD network suggest that a prediction can be made, within limits, on how bearings may behave in service. Mechanical officers use real time data analysis of bearing temperature along with automatic car identification (AEI) readers to track warm bearings at HBD sites. Transportation Technology Center, Inc. (TTCI) is presently determining the feasibility of tracking warm bearings to make operational predictions. This project is part of the Association of American Railroads' (AAR) Strategic Research Initiative (SRI) Wayside Detection Program.

Bearing failure from overheating is the leading mechanical cause of derailments in North America. Therefore, enhancing safety is the primary objective for researching wayside detector networks. The CN Railway has tracked the predictive characteristics of journal-bearing performance since April of 1997. Since that time, the CN has shown significant improvements in safety and operational efficiencies.

CN Network Operation Today

- Mechanical staff (RTCMech's) manually track suspect bearings using an HBD network based on established alarm criterion and operating policies.
- The HBD network has significantly reduced hot bearing alarms and burned-off journals per 2.5 million axles scanned since its inception in April of 1997.
- Bearing teardowns confirm significant number of suspect bearings (warm) having internal defects.

CN Network Operation in the Future

- Develop a virtual system to track cars between AEI readers to improve accuracy in tracking car histories.
- Automate trending analysis for repeated warm bearings, requiring additional algorithms for improved operating policies.
- Extend automated trending to look at earlier car and bearing history to predict hot bearing alarms and risk of failure.

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Suggested Distribution:

- ❑ Maintenance of Way
- ❑ Mechanical Officers
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

INTRODUCTION AND CONCLUSIONS

Hot bearing detectors (HBD) have played a major role in keeping the number of bearing-related derailments at a relatively constant level over the past several years. Although they have contributed greatly to the prevention of derailments, they have also contributed significantly to train delays. Solutions to these problems require the identification of bearings in their earliest stages of deterioration, well in advance of the bearing running in a dangerous condition forcing a train stop or causing a derailment. Early detection would provide a railroad with the opportunity to repair or replace the defective bearing at optimal locations before problems occur. Improvements in predictive detection systems can reduce bearing failures in service, increase track capacity, and potentially decrease train delays on North American railroads.

Predictive or condition detection systems detect degrading conditions of critical components during system operation and allow operators to plan corrective action before an in-service breakdown. Predictive component failure requires complex information systems as well as accurate measurement technology. Predictive component failure represents a relatively recent technological development in operating strategies. As this work has shown, the nature of the new technological developments and the resulting complexities associated with the decision process make applying the corrective action regimes especially advantageous.

CN bearing data was analyzed using time histories of bearing temperature at sequential HBD sites on cars set out by a warm bearing alarm. Preliminary results show that the other bearings are in control when the suspect bearing is identified as exceeding a warm bearing threshold. The process used to analyze bearing performance was three sigma statistical process control (SPC) charts to determine if each bearing on the suspect truck was in control relative to the suspect bearing. The standard deviation of the normal bearings on the suspect truck showed close dispersion, while the suspect bearings maintained a wide dispersion that consistently exceeded the average control limits set by the normal bearings. This is an important result because it shows that the process is in a reasonable degree of statistical control independent of the suspect bearing. CN has observed warming trends on most suspect bearings. The experience is that most cars identified with a suspect bearing are tracked and show warming trends. Therefore, preliminary results suggest that developing algorithms based on warm bearing trends is feasible at this point.

BEARING TREND ANALYSIS

As Exhibit 1 shows, three of the four bearings on the suspect truck display normal temperature displacement variation. The average is around 6.0 millimeters (mm) and the upper natural process limit is around 8.5 mm. Typically speaking then, normal bearings have an average of approximately 6.0 mm of temperature displacement and rarely have more than 8.5 mm.

The suspect bearing displays a behavior that is different in several ways. It has an average that is significantly higher than normal. Early in its history, the displacement exceeds the average at five consecutive sites. Next, the displacement exceeds the maximum expected level (8.5 mm) five consecutive times. This trend is consistent with other samples analyzed thus far, in terms of normal bearing behavior. One observation from Exhibit 1 is that four successive readings above the average may indicate that the bearing will continue to increase in temperature. The implication of this example trend is that the next site may trigger a mandatory train stop at 15 mm HBD deflection (174°F above ambient). Therefore, by observing patterns of suspect trucks, policies may be developed based on warm bearing trends using SPC charts.

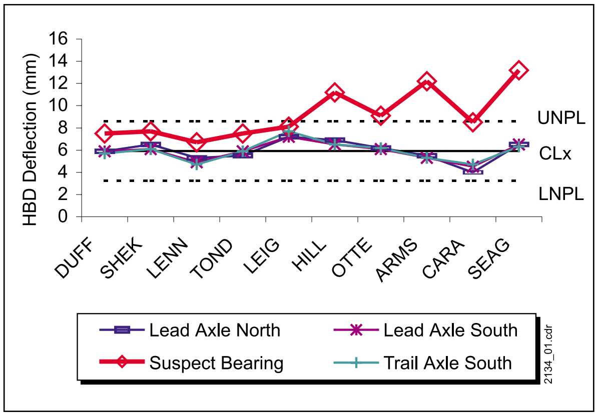

Exhibit 1. Normal Temperature Displacement Variation on 3 of the 4 Bearings on the Suspect Truck

Normalizing bearing temperature by speed may improve our ability to detect suspect bearings. Once again, the three normal bearings display normal displacement variation, as Exhibit 2 shows. The average is around 0.13 (mm/mph) and the upper natural process limit is around 1.9 (mm/mph). If this is typical, then we can say the normal bearings averaged approximately 0.13 (mm/mph) and rarely have more than 1.9 (mm/mph).

The suspect bearing here also displays a behavior that is different in several ways. It has an average that is significantly higher than normal. It exceeded the upper natural control limit early on, deviating by nearly 0.08 from the average at the LENN HBD site. The displacement decreases slightly, then begins to exceed the upper control limit five consecutive times. One observation from Exhibit 2 is that any value that exceeds the maximum upper control limit may continue to increase in temperature. Journal bearing temperature relative to speed may play an integral role in determining trends.

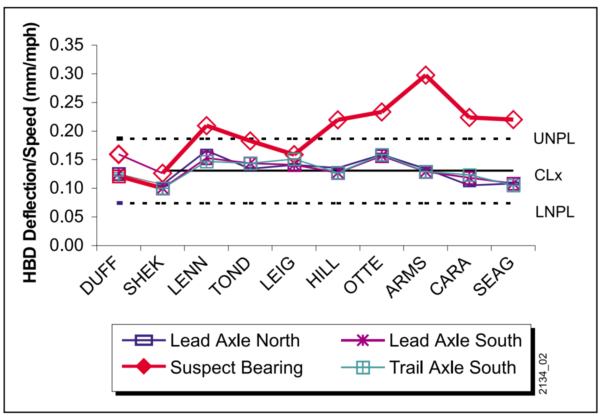

Exhibit 2. Normal Temperature Displacement Variation Normalized by Speed

BEARING BURNOFF TEST RESULTS AT TTC

As part of the AAR Bearing Research Program to improve wayside bearing detection technology, a bearing burnoff test was conducted at TTC. Results indicated that warm bearing trends may be detected early in the deterioration process of a defective bearing (TD 96-005, Wang, Anderson & Smith). Data analysis techniques used on the test showed promise toward providing an early warning of bearing deterioration and failure. Exhibit 3 shows the maximum temperature variation during the course of thermal failure of a spun cone defect along with the observed torque response. The heat generated depends in part on the fluctuation of friction coefficient with temperature. The fluctuation of the friction coefficient represents operational conditions and how a bearing component may fail in service.

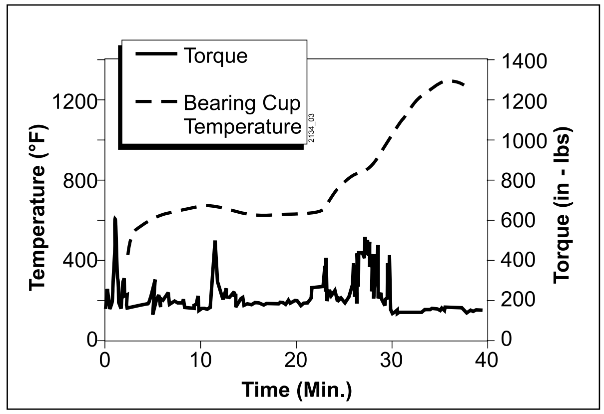

Exhibit 3. Maximum Temperature and Torque Variation during Burnoff Test

OPERATING TRENDS

Replaying and studying significant warm bearing events has proven to be a powerful tool in adding more improvements to CN's system. Exhibit 4 shows an example of a bearing tracked over 10 HBD sites with spacing approximately 15 miles apart. The north axle became a suspect bearing at the DECIMAL site (Exhibit 4), when it exceeded a pulse to train side warm bearing alarm (W2). It then reached an absolute warm bearing threshold (WB) at the next HBD site and then increased over the next three sites, reaching a mandatory hot bearing train stop at JONES site. The train averaged typically 4.0 to 6.0 mm of HBD deflection. The bearing on the north axle (bearing #140) was found to be extremely hot at the time of inspection and was set out on a mainline siding for repair.

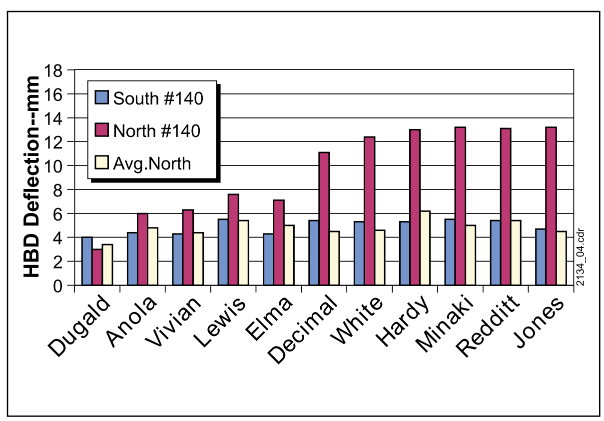

Exhibit 4. Warm Bearings Tracked over 10 HBD Sites

TTC = Transportation Technology Center; FAST = Facility for Accelerated Service Testing

HBDs on the Canadian System

The current CN system is comprised of 437 HBDs; 326 are GE-Harmon-Servo (Model DHP-2000) and 111 are from Southern Technologies. A Devtronics display system is used for real time analysis of bearing problems. Traditional chart "tapes" have been eliminated by Devtronics PC displays. The HBD detectors are monitored 24 hours a day 7, days a week by mechanical staffers (RTCMech's). Although the Devtronics technology allows electronic monitoring of CN's wayside system, the RTC Mech's are the key to tracking warm bearings and making the decision to set out the car or recommend corrective action procedures. Tracking and set-out decisions are based on manual algorithms applied by the RTCMech's. The RTCMech's begin tracking warm bearings at about ½ the traditional field alarm levels. Exhibit 5 shows the alarm criterion for 2001. A bearing that exhibits temperatures at about ½ the normal alarm is then tracked over multiple sites for warm bearing trends. There are four main alarm criterion used by CN to identify a potential suspect bearing. Temperatures are expressed in millimeter of pen deflection, based on the original pen-type chart recorders. The computer screens today retain the old "mm" term.

- All measurements based on temperature scans above ambient
- All bearings get 1.6 mm "pedestal" pulse to show presence of axle
- Temperature calibration = 13^{o}F per mm extra deflection
- Temperature degrees F above ambient = (mm-1.6) x 13
- Typical running bearings scan at 3 to 7 mm = 18^{o}F to 70^{o}F above ambient

CN has significantly reduced the number of 'warm bearing' journals using this real time monitoring process.

AEI Integration

Most HBD systems in North America do not have the capabilities to identify a particular car; instead, locating defects by the axle count is the most commonly used method. One solution appears to be the integration of a wayside detection system with AEI, made possible by the sophisticated microprocessor-based technology now used in modern HBD systems. Manufacturers have developed and tested software that can integrate wayside detectors with AEI equipment. The integrated data, routed to a central computer, can be used in creating a database for developing railcar maintenance programs. As an alternative to integrating each wayside site with AEI technology, the CN is using existing equipment to reconcile train axle counts to previous AEI locations. Early detection of failing bearings, sticky brakes, and cars with poor braking effort could go a long way toward giving railroads additional information helpful in reducing delays and accidents.

Exhibit 5. 2001 Warm Alarm Bearings

Alarm Identifier	Comparisons	Alarm Setting	Temperature Above Ambient
WB	Absolute	12 mm	135F
WD	Differential (Axle)	6 mm	78F
W2	Pulse to Train Side	5 mm	65F
W3	Pulse to Car Side	4 mm	52F

FUTURE WORK

Next year's efforts will concentrate on populating a database with a representative sample of bearing data. The data will then be analyzed using SPC charts to determine repeatable trends that may be used to refine the process of setting out suspect cars. The data will also be analyzed to determine the probability of failure and system disruption as a result of hot bearing train stops.

ACKNOWLEDGEMENTS

Our thanks to the members of the mechanical staff of Canadian National Railway for their contribution to this project. They have put into practice and continue to refine an innovative predictive maintenance system geared toward improving safety and operating efficiency for its North America railway system.

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