TECHNOLOGY DIGEST

TD-07-024
©SEPTEMBER 2007

TIMELY TECHNOLOGY TRANSFER

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

Acoustic Bearing Detectors and Bearing Failures

Russell Walker, James Cline, Elizabeth Smith, Jeremy Dasher

Summary

Implementation of acoustic bearing detectors (ABDs) has led to the development of a large number of alarms that, if acted on, would overwhelm current maintenance capacity and prematurely remove bearings from service. Consequently, railroads have requested Transportation Technology Center, Inc. (TTCI) to develop a method to identify the highest risk bearing within the alarmed population. TTCI's ABD, Trackside Acoustic Detection System® (TADS), uses an alarm called a growler—named for the sounds made by bearings with severe defects. The TADS growler alarm was introduced in October 2005. TTCI developed the TADS Growler Algorithm with internal funds. Association of American Railroads Strategic Research Initiatives Program funds were used to evaluate the effectiveness of ABD technology.

An economic analysis of the benefits of ABD technology requires information on the performance of ABD systems. Some of the important factors are the number of bearings that will alarm in a given period of time and the number impending hot bearings that a detector can identify. The objective of this *Technology Digest* (TD) is to answer these questions. TTCI used TADS data as being indicative of current ABD technology. The work described here indicates that:

- Current traffic and detector patterns indicate that about 1.5 percent of axles have a bearing with some type of acoustically detectable defect.
- About 0.05 percent of axles have growler defects.
- On average, for all detectors, there are about 8,200 new defects identified each month and about 660 new growlers identified each month.

TTCI studied a set of bearings that became hot or seized in service. The results showed:

- About 45 percent of these bearings had some type of ABD defect in the previous year.
- The growler alarm was present in about 13 percent of the bearings analyzed.

The results in this TD show that the rate of bearing removal by an ABD using a worst case alarm, such as the growler alarm, results in a removal rate that is in the same magnitude as that of the current hot bearing removals. ABDs can likely reduce the number of train stops due to hot bearing alarms and the number of accidents due to burned-off roller bearings by as much as 35 percent as the technology improves and as detectors become more prevalent.

This analysis should be repeated after more experience with ABD technology is gained. The algorithms for the growler alarm are being improved. New suppliers of ABD technology are installing equipment in North America. These technical changes, combined with more data will improve the analysis.

Please contact **Russell Walker (719) 584-0505** with questions or concerns regarding this *Technology Digest.* E-mail: Russ_Walker@ttci.aar.com.

INTRODUCTION

ABD systems have been in use in North America for several years. Application of this technology is still in development. Initially, ABD technology was geared to identify defects in specific parts of the bearing according to the sounds they made. This method found large numbers of defects, but it was not useful to prioritize the defects found so that the worst defects could be removed from service. Most of the defects found by the system at this time could continue in service until the axle was removed for another reason.

Algorithms used to identify specific defect types are often not able to identify them when they become large or occur on multiple races. Users of ABDs noticed that as bearings began to degrade, the systems were often not able to classify the defect as cup, cone, or roller and were labeling them as unknown or not labeling them as a defect at all. These types of bearings came to be known as growlers.

Consequently, new algorithms were created by TTCI to find these bearings. A new algorithm and the corresponding growler alarm code were introduced during October 2005. This algorithm has had success identifying bearings with a significant amount of damage. Results of the inspections to verify the performance of the growler alarm will be published as a research report.

A new section in AAR Interchange Rule 36 to implement ABD technology in the industry was adopted by the Association of American Railroads (AAR). The 2007 AAR Field Manual rule requires that an ABD Level 1 alarm represents a specific minimum amount of bearing damage corresponding to at least one of the following:

- Two square inches or more of spalled area on any one cup or cone running surface
- One square inch of spalled area on any one cup or cone running surface and 1/2 square inch or more of spalled area on any one other cup or cone running surface
- Any orange peel surface. An orange peel surface resembles the look and texture of an orange, as Figure 1 shows
- Any roller spall or seam
- Any loose component indication
  - Cone race backface wear greater than 0.010 inch
  - Indication of spun cone on the corresponding axle journal
  - Oversize cone bore from dynamic growth and evidence of turning on axle journal
- Two square inches or more of heavy water etched area, with indented surface(s), on cup or cone running surfaces

Figure 1. Example of an Orange Peel Surface Defect

Rule 36 in the AAR Field Manual requires that ABDs be validated through bearing teardowns to prove their capability to find Level 1 defects. Validation requires that 90 percent of 50 bearings, minimum, must exhibit Level 1 defects during the teardown inspection and any remaining bearings must exhibit internal defects consistent with bearing reconditioning requirements.

If an ABD shows a Level 1 alarm on a bearing, the car can be sent to a repair track. A hand roll inspection will be performed. If the bearing fails the hand roll inspection, the bearing will be removed as a Why Made Code 96 (i.e., the reason for removing the roller bearings from service). If the bearing does not fail the hand roll inspection, it can be removed as a Why Made Code 91. Why Made Code 91 bearings will be inspected.

Although ABDs can detect bearings with less damage than that described, the AAR Interchange Rule does not address other alarm levels.

To help quantify the benefits of this rule, several pieces of data are required:

- The number of ABD alarms in a given period, and more specifically, the number of growler alarms in a given period
- A correlation of ABD histories and hot bearing alarms

NUMBER OF ALARMS

The rate of bearing alarms was analyzed in two ways:

- The number of alarms over the first 6 months of 2006 was tabulated by alarm type and normalized by the number of axle passes.
- The number of new alarms in a given time was calculated. This is expected to be a better indicator of the long-term alarm rate.

The number of bearings with ABD alarms was counted for the North American ABDs reporting to *Inte*RRIS® over the first 6 months of 2006. Figure 2 shows these counts were normalized by 10,000 axle passes and are plotted by defect type. Summed together, the ABDs indicate that about 1.5 percent of axles have a bearing with some type of defect. About 0.05 percent of axles have growler defects.

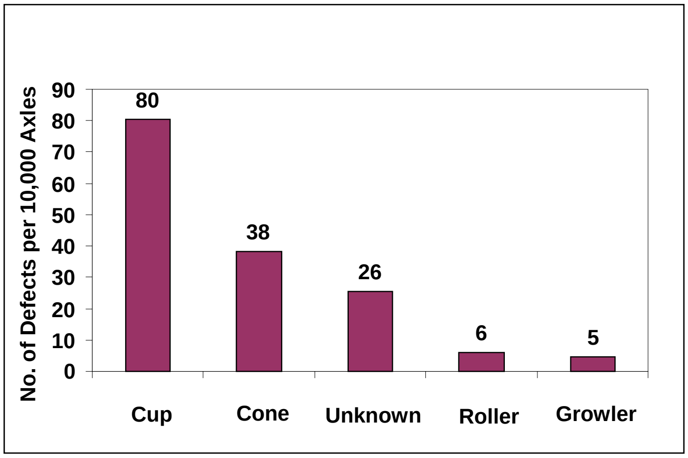

Figure 2. Number of Bearing Defects Identified by an ABD per 10,000 Axles

Although Figure 2 shows the state of the fleet at the current time, once alarmed bearings are removed from the system the rate of new bearing alarms will be the factor that determines the alarm rate.

To estimate the new alarm rate, an algorithm was developed that looked at all the alarms for a given ABD site in a month. The history of those bearings was examined for any defect in the previous year of operation. If none was found, it was counted as a new alarm. The analysis was done for a few months through the year to account for any seasonal variation. Table 1 shows the results of this analysis. The data was analyzed in two groups, one for any alarm and another for the growler alarm.

Table 1. Number of ABD Alarms at One Site

	Number of New Alarms of Any Kind	Number of New Growler Alarms
April 2005	4,386	[redacted]
August 2005	7,411	[redacted]
December 2005	8,815	539
March 2006	12,354	783

The results of the analysis show that the number of new alarms of any kind is relatively high, over 12,000 per month for March 2006. The trend seems to be increasing with time from April 2005 to March 2006. No obvious reason for this was found, and it is expected that over time this number would likely hover around the average of about 8,200 new alarms per month on the North American railroad network. The results for the growler alarm average to about 660 new growler alarms per month on the system. These alarm rates are dependent on average ABD observations of a car for a given period of time; so they will change as ABD coverage increases.

CORRELATION OF ABD HISTORY AND HOT BEARING ALARMS

To correlate ABD records with actual failures, bearings with Why Made Code 50 (hot bearings) and Why Made Code 95 (seized bearings) were listed for the period from January 2006 to September 2006. The ABD histories for these cars were obtained.

The Why Made Code 50 and Why Made Code 95 lists were analyzed together. A subset of these bearings, those with more than 24 ABD records in the year before the repair, was analyzed to correlate ABD alarms to failed bearings.

The AAR Car Repair Billing Data Exchange System showed 3,247 bearings listed for Why Made Code 50 or Why Made Code 95 in the period from January 2006 through September 2006. This represents a rate of 4,357 bearing failures per year. Only 2,137 (about 66 percent) of these bearings had been recorded at an ABD site in the year before the repair date. A subset of these bearings with 24 or more ABD visits in the year before the repair date was chosen for analysis. This left 384 bearings, or about 12 percent of the original sample.

One railroad has been actively using ABDs to manage its fleet. This activity affects the number of bearings with ABD alarms that go on to failure. For this reason, failed bearings with records on that railroad's ABD systems were removed from the analysis. This left 92 bearings to be analyzed.

Figure 3 shows the percentage of cars that produced alarms on a given percentage of axle passes in the year preceding their repair date. For example, 24 percent of the cars produced an alarm on 10 percent of the ABD passes in the year before the repair date. The percentage of axle passes over a year that produces an alarm will vary depending on the rate of degradation of the bearing. If the bearing degrades quickly, the ABD might only record alarms on the last few passes before some type of failure occurs. Fifty-five percent of the bearings had no alarm at all.

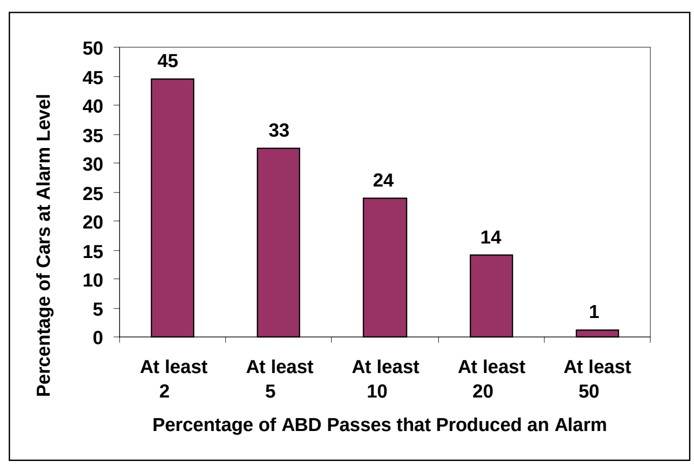

Figure 3. Percentage of Cars with a Given Alarms Rate. Cars had Why Made Code 50 or Why Made Code 95 Bearings and 24 or more ABD Passes in the Year before Failure

Of the 92 bearings analyzed, 12 bearings, or 13 percent of the sample, had growler alarms. It is interesting to note that 26 bearings, or 28 percent of the sample, had alarms labeled as unknown. It is possible that some of the bearings labeled as unknown should have been labeled as growler defects. Improvements in the growler alarm are being pursued as part of TADS development by TTCI. This development is separate from the AAR Strategic Research Initiatives Program.

CAPABILITIES OF ACOUSTIC DETECTION

The high number of unknown alarms incurred in the sample of failed bearings indicates that current ABD technology can still be improved. It is important to estimate how many bearing failures might be detected acoustically and thereby prevented with improved technology.

In 2005, TTCI published *Technology Digest* TD-05-009 "Roller Bearing System Failure Analysis." It presented the percentage of hot bearings attributable to various failure progression modes (FPM):

- Adapter – 5.8 percent
- Application – 1.7 percent
- Bearing destroyed – 12.3 percent
- Displaced seal – 2.0 percent
- Loose – 21.8 percent
- Lubrication – 3.3 percent
- Manufacturing defect – 0.3 percent
- Mechanical – 6.7 percent
- Fatigue spalling – 13.3 percent
- Truck related – 0.8 percent
- Wheel defect – 9.9 percent
- Water etch – 22.1 percent

Of these FPMs, it is assumed that at a minimum the mechanical spalling and water etch FPMs should be able to be detected acoustically. If detected, such bearings have the potential to reduce, by 35 percent, the number of train stops due to hot bearing alarms and prevent some accidents attributed to burned-off roller bearings. With time and additional development, some percentage of the other failure progression modes may also be detectable acoustically.

CONCLUSIONS

The results in this TD show that the rate of bearing removal by an ABD using a worst-case alarm, such as the growler alarm, results in a removal rate that is in the same order of magnitude as that of the current hot bearing removals. ABDs can likely reduce the number of train stops due to hot bearing alarms and the number of accidents due to burned-off roller bearings by as much as 35 percent as the technology improves and as detectors become more prevalent.

FUTURE WORK

ABDs are an evolving technology. Research is in progress to improve the effectiveness of the growler alarms. New suppliers are introducing equipment. As these technologies come on line, it will change both the rate that bearings are identified, and the ratio of bearings that can be caught before they overheat or seize in service. This type of analysis should be repeated as the technology changes.