TECHNOLOGY DIGEST

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Evaluation of Hot Bearing Detector Technology Used to Identify Bearing Temperatures

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Summary

In 2013, Transportation Technology Center, Inc. (TTCI) evaluated 16 configurations of hot bearing detectors (HBD) installed on the Railroad Test Track (RTT) at Transportation Technology Center (TTC), Pueblo, Colorado. The study was conducted to identify technologies that provide more accurate and precise measurements of class K and F bearing temperatures, while maintaining or improving on the current standard of effectiveness estimating class E and G bearing temperatures.

Test results showed that HBD configurations that use a near vertical scan angle and scan the bearing closer to the lateral center line of the bearing race are the ones that show greater accuracy of bearing temperatures.

Two phases of testing were conducted using railcars with various defective bearings, as well as with heated plates to simulate hot bearings, which operated at speeds up to 65 mph on TTC's RTT:

- Phase I identified configurations of the HBDs that will improve the accuracy of reported temperatures on class K and class F bearings.
- Phase II testing focused on ensuring the HBD configurations that produced the best results for class K and class F will also provide equivalent or improved readings of class E and G bearing temperatures. In addition to Phase I variables, Phase II included variations of emissivity, railcars with standard axle and bearing applications, and defects found by optical geometry detectors such as angle of attack variations, asymmetrically worn thin flanges, controlled worst of worst lateral positions, and railcars with a history of hunting.

Beginning in 2014, Phase III revenue service testing will be conducted at multiple locations. HBD systems that scan closer to the bearing center and/or use a more nearly vertical scanning angle will be installed adjacent to traditional HBD systems and evaluated with a full range of revenue service railcar types and trucks, and under diverse climate conditions.

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INTRODUCTION AND OBJECTIVES

North American Class I freight railroads, HBD system manufacturers, and Transportation Technology Center, Inc. (TTCI) have been studying the use of HBD technology to assess railcar bearing health. HBD is a proven and effective technology for reducing the population of defective bearings. Railroads provided the necessary railcars and wheelsets used and guidance on the experimental design for both phases.

This controlled test was conducted to identify technologies that provide more accurate and precise measurements of class K and F bearing temperatures, while maintaining or improving on the current standard of effectiveness for class E and G bearing temperatures. Here we use "technologies" in reference to both alternative devices and alternative alignment of common devices.

TTCI worked with HBD vendors and developed the diagrams in Figures 1 and 2.

In Figure 1, the white dot is centered at 7¼ inches from rail gage, which is the standard scan location. The current HBD technology measures an area of 1 to 1½ inches across. The scan area at which the bearing temperature is measured was selected because of older side frame obstructions that were common decades earlier. The target angle at 45 degrees, as the bearing approaches the detector, was established primarily because of the speed of the technology at the time.

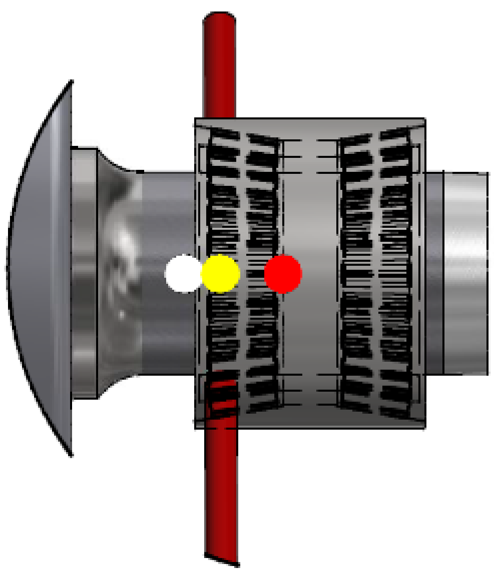

Figure 1. Class E Bearing Wheelset Tracking

The yellow and the red dots in Figure 1 were locations selected for Phase I testing. These two locations measure the temperature of the race of the bearing directly, as shown in Figures 1 and 2.

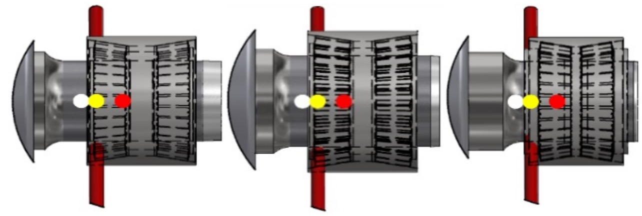

Figure 2. Diagram of Class F, G, and K Bearings (respectively) with Scan Locations

TESTING

In July 2013 (Phase I) and October 2013 (Phase II), testing was conducted at TTC on the RTT using detectors provided by vendors or railroads. The test consist was made up of three railcar types (rotary gondola, covered hopper, and 5-platform spine car) equipped with class E, F, G, and K bearings. The consist made over 70 passes through the established HBD test zone. To evaluate the HBD performance over a broader range of bearing distress, some of the bearings were provided from revenue service using TTCI's Trackside Acoustic Detection System (TADS®) and/or standard HBD system alarms. The bearing conditions ranged from new to worn out with severe defects. Those bearings observed to be highest risk for burn off were monitored real time by an onboard thermocouple system.

Table 1 shows the HBD configurations tested showing the numbers of inches from rail gage. Two target angles were tested, one at 45 degrees and the second at 90 degrees directly below the bearing. Configurations A–7.25 inches and B–7.25 inches and less commonly B–14 inches are the standard HBD system configurations used in Class I revenue service. The letters A, B, C, D represent different HBD vendors. Most vendors tested multiple configurations of their technologies.

Table 1. HBD Configurations for Phase I and II Testing

HBD Configuration	Target Angle (degree)	Testing Phase I	Testing Phase II
A–7.25 inches (current service)	45	X	
A–8.25 inches	45	X	X
A–9 inches	45		X
A–10 inches	45		X
A–11.25 inches	45	X	
B–7.25 inches (current service)	45	X	
B–8.25 inches	45	X	
B–8.5 inches	45		X
B–9.5 inches	45		X
B–9.5 inches	90		X
B–14 inches (current service)	45	X	
C–9 to 13 inches	90	X	X
D–6 to 8 inches	90	X	
D–7.75 to 9.75 inches	90		X
D–8.25 to 10.25 inches	90		X
D–11 to 13 inches	90	X	

Class E, F, G, and K bearings were instrumented for the test. Onboard thermocouple instrumentation was used as the control to evaluate HBD performance. Onboard data consisted of physical temperature measurements from thermocouples securely fixed to the bearing outer race on bearings of varying conditions. Some HBD systems reported temperature above ambient. For those cases, the vendor's ambient reading was included, so all the data was evaluated as actual temperature, not relative to ambient.

During both phases of testing, TTCI conducted preliminary runs to assess equipment performance, quality, and safety. No preliminary runs were included in the data analysis.

ANALYSIS

Scatter plots were used to illustrate the relationship between the HBD reading and the known temperature of the bearings from onboard instrumentation (Figure 3). Each scatter plot shows onboard data as the x-axis and one wayside HBD technology as the y-axis. One data point represents a single HBD reading on one bearing for one pass. The blue diagonal line indicates an ideal scenario where wayside HBD and the onboard thermocouple (control) provided the same values.

The analysis is performed with a Gage R&R to quantify the measurement system between the HBD and the control. The graph in Figure 3 demonstrates the variation in the measurement system for a standard HBD technology. An ideal measurement system would be when the HBD always provides the same reading as the control, as denoted with the blue line. The black dotted line is the variable bias of the HBD system and measures, on average, a lower temperature than the thermocouple control. The green dotted arrow line, perpendicular to the black line, represents the variation at a specific temperature. Both of these sources of variation reduce the measurement system accuracy with the control.

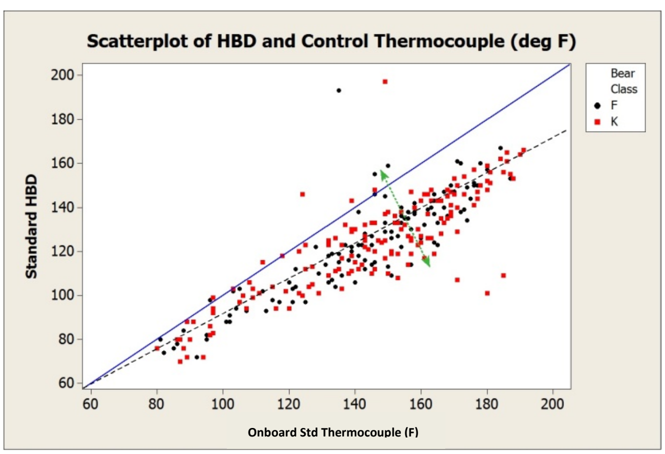

Figure 3. Class K and F Bearing Data vs. Control

Figure 4 consists of a series of scatter plots of the class K bearing data. For example, the data from HBD configurations A–7.25 inches and B–7.25 inches have considerable variation and do not follow the blue line well. Any point right of the blue line indicates HBD data that is lower than the actual temperature of the bearing. This trend is typical of a HBD that is aimed at the edge of the bearing whose backing ring, wear ring, end cap or seal is running at a lower temperature than the bearing itself. Any point left of the blue line indicates HBD data that is higher than the actual temperature. This trend is typical of a bearing seal that is running hotter than the bearing.

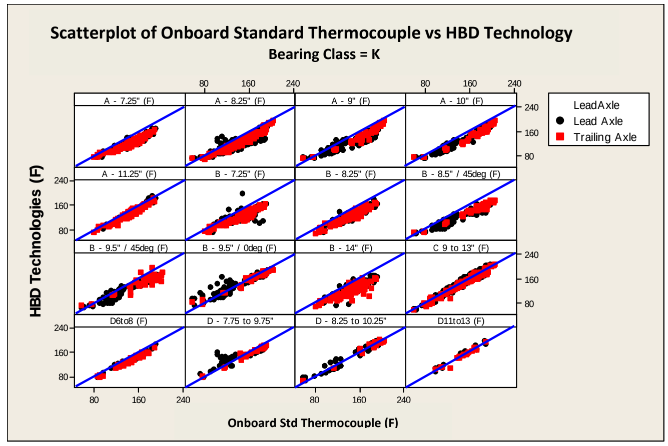

Figure 4. Class K Bearing Data Scatter Plots

The class F bearings in Figure 5 perform similarly to the class K bearings in Figure 4.

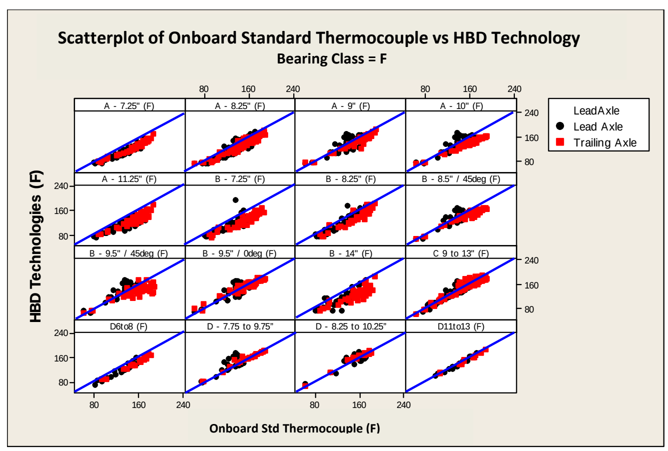

Figure 5. Class F Bearing Data Scatter Plots

Some HBD systems use other objects in the scan (not the bearings) to establish ambient temperature. Some railcar designs present difficulties, because they allow the HBD to intermittently view past all railcar and truck components and try to measure clear sky, returning a large negative value as the ambient temperature.

Figure 6 shows a difference between trends of leading axles and trailing for several HBD systems. For this unloaded spine car with class E bearings, the lead axle data lies near the blue line and the trailing axle data trends lower than the control.

The class G bearings were on railcars that had a heavy accumulation of dust on the truck components. Note that in Figure 7, several HBD configurations show the lead axle reading above expected and the trailing axle below expected

The data shows the HBDs are more in agreement with the onboard data when the bearing is at cooler temperatures, but produce a progressively exaggerated reading when the bearing is at higher temperatures. This indicates that the axles may have had an associated difference in emissivity.

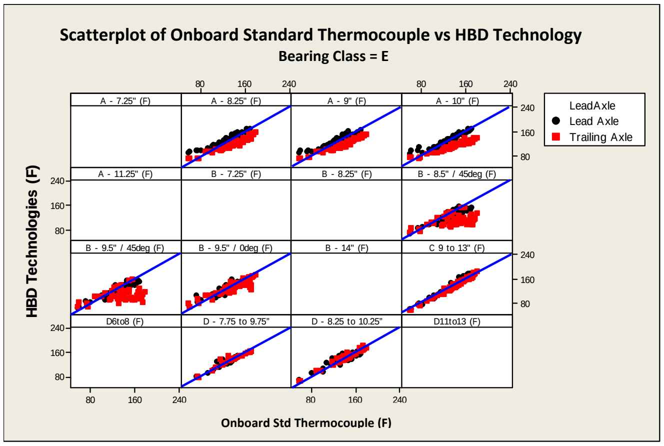

Figure 6. Class E Bearing Data Scatter Plots

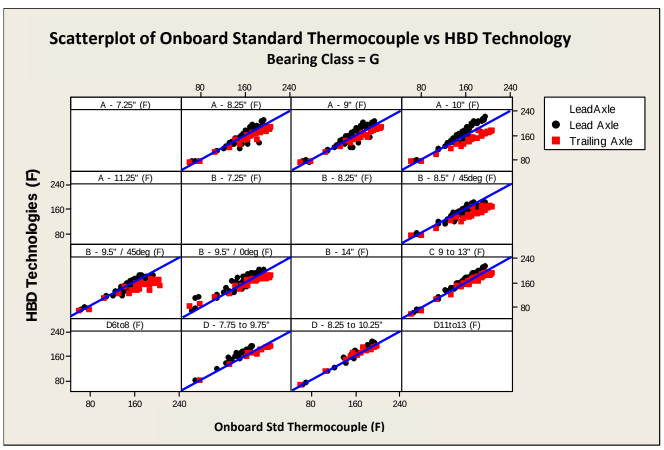

Figure 7. Class G Bearing Data Scatter Plots

Gage R&R Study

A Gage R&R study is an evaluation of the measurement system for HBD technologies and the control (thermocouple). Table 2 shows the rank ordered results (from 1 to 5) of the Gage R&R measurement system analysis. A lower ranking, and therefore a lower percent study from the Gage R&R, indicates a more accurate HBD configuration, in that temperatures are more consistent with the control. The testing and analysis of the HBD configurations identify improved measurement system accuracy, which may lead to a lower nonverifiable bearing detection rate.

Only the distances of 7.25 inches and 14 inches from rail gage are currently used in revenue service.

Table 2. Rank Ordered Performance of Gage R&R Study

HBD Configuration	Angle	Class E	Class G	Class F	Class K
A–7.25 inches (current service)	45	-	-	5	5
A–8.25 inches	45	5	2	4	5
A–9 inches	45	5	3	4	4
A–10 inches	45	5	4	4	3
A–11.25 inches	45	-	-	5	3
B–7.25 inches (current service)	45	-	-	5	5
B–8.25 inches	45	-	-	4	5
B–8.5 inches	45	5	4	4	4
B–9.5 inches	45	5	4	5	4
B–9.5 inches	90	3	3	3	2
B–14 inches (current service)	45	-	-	5	5
C–9 to 13 inches	90	1	2	2	1
D–6 to 8 inches	90	-	-	3	3
D–7.75 to 9.75 inches	90	2	3	4	3
D–8.25 to 10.25 inches	90	2	2	2	1
D–11 to 13 inches	90	-	-	1	1

CONCLUSION

Generally, measuring farther into the race of the bearing shows improvement with varying degrees of performance, depending on the vendor’s technology. Evaluation of HBD technologies showed that configurations that use a vertical scan angle have an improved measurement system; however, not all vendors tested a vertical scan system.

FUTURE WORK

Beginning in 2014, Phase III testing will be conducted in revenue service at multiple locations to evaluate the new HBD configurations with the full range of revenue service railcar types and trucks, and under diverse climatic conditions. HBD systems that scan closer to the bearing center and/or use a vertical aim will be installed adjacent to traditional HBD systems at the discretion of participating railroads. Alerts based on either configuration will be pursued to ascertain alert legitimacy and severity of the bearing condition.