[E8.03]

An investigation into wayside hot-box detector efficacy and optimization

C. Tarawneh*, J. Aranda, V. Hernandez, C. Ramirez
University of Texas Rio Grande Valley, USA

Introduction (300 words)

Wayside hot-box detectors (HBDs) are devices that are currently used to evaluate the health of railcar components including bearings, axles, and brakes by monitoring their temperatures. HBDs are usually placed 24 to 40 km (15 to 25 mi) apart alongside the track, but some may be spaced as far apart as 65 km (40 mi). As each freight car passes, the wayside HBD measures the temperatures of the railroad bearings along with the ambient temperature. Wayside HBDs are configured to alarm whenever the operating temperature of a bearing is 94.4°C (170°F) above ambient conditions. Additionally, a wayside HBD will trigger an alarm if there is a 52.8°C (95°F) temperature difference between the two bearings that share the same axle. Another method of processing the HBD temperature data involves averaging all the bearing temperatures along one side of a railcar and comparing each bearing temperature to the mean value. A bearing that runs hotter than the mean value as determined by several wayside HBDs is termed a “warm-trended” bearing. Bearings that trigger a HBD alarm or exhibit signs of warm-trending are removed from service for disassembly and inspection. In cases where no discernable defects can be found in any of the bearing components, the bearing is labeled as “non-verified”. While wayside HBDs have been instrumental in reducing train derailments in the past few decades, the number of non-verified bearing removals has increased significantly. Although non-verified bearings resulting from the overprediction of bearing temperature may be a cause of inefficiency in the rail industry, the underprediction of bearing temperature can have disastrous consequences. In the United States and Canada, from 2010 to 2016, wayside HBDs have failed to detect 119 defective bearings which have led to costly derailments. Inaccuracies of HBD temperature readings may be caused by many factors including bearing class and infrared sensor misalignment. This study outlines the work done to examine the efficacy of the wayside HBD system in field service.

Methods (300 words)

A field test was performed to investigate the warm bearing trending phenomenon occurring in freight rail service. The data obtained was used to investigate the accuracy and efficacy of wayside HBDs. The test was conducted along a path of more than 483 km (300 miles) of track, utilizing 21 different wayside HBDs. Two hopper-type freight cars, one fully-loaded and one empty, were employed during the test and were pulled by a locomotive. The train traveled over the 21 HBDs with a total of 16 tapered-roller test bearings: 14 were Class F and 2 were Class K. These bearings were instrumented with two onboard K-type spring-loaded bayonet thermocouples.

The research team at the University Transportation Center for Railway Safety at the University of Texas Rio Grande Valley has designed and manufactured a dynamic test rig that can simulate the travelling speeds and loading conditions of a freight car in service. A system that mimics a wayside HBD was also implemented using an IR sensor fixed on a small cart that travels on a track. The cart is powered by a pneumatic cylinder to carry the IR sensor underneath the bearing and take a measurement of the bearing surface temperature. An infrared temperature measurement was taken at four different locations on the bearing and compared to onboard thermocouple temperature measurements. Additionally, a two-point calibration was conducted on the IR sensor by placing the sensor underneath a static bearing that was at room temperature and a bearing that was operating under fully-loaded conditions and a speed of 85 km/h (53 mph). Using these two points, a linear correlation between the IR sensor temperature and the thermocouple temperature located at the bottom of the bearing was then used as the calibration for all data acquired in the laboratory. Supplementary calibration points were also identified at various speeds and loads using the laboratory wayside HBD and the onboard thermocouple temperatures.

Results (300 words)

Analysis of the results revealed that the HBDs were biased toward Class F bearings where the temperatures were underestimated by as much as 47°C (85°F). The HBDs tend to overestimate the temperatures of the Class K bearings 36% of the time, and underestimate Class F bearings by more than 17°C (31°F) almost half of the time. Moreover, the HBD temperature data exhibited false trending events that were not present in the onboard bayonet thermocouple temperature data. According to data collected from laboratory experiments, it was concluded that the top hemisphere of the bearing has higher operating temperatures than the bottom surface of the bearing. Comparing the field test data to the laboratory data revealed very similar trends in that both systems tend to under-predict the bearing temperature, in general. However, the results also indicate that the laboratory wayside HBD was more accurate and more precise than its field service counterpart. Additionally, it was determined that the inboard raceway region was the most precise and most accurate scanning location of the four laboratory HBD scanning configurations. Table 1 provides the RMSE and R^2 values for the acquired data, which represent a generalized measurement of accuracy and precision, respectively.

Table 1. Root-mean-squared-error (RMSE) and coefficient of determination (R^2) values for laboratory and field data

Data Description			**RMSE**	$\mathbf{R^2}$
Lab Data	**Class K Unloaded**	**OB Raceway**	11.1	0.81
		Spacer	8.9	0.89
		IB Raceway	8.8	0.94
		IB Seal	10.0	0.83
	Class K Loaded	**OB Raceway**	22.7	0.51
		Spacer	25.8	0.53
		IB Raceway	17.1	0.79
		IB Seal	18.3	0.75
	All Class K	**OB Raceway**	19.9	0.68
		Spacer	22.1	0.67
		IB Raceway	15.1	0.87
		IB Seal	16.2	0.83
Field Data	**Unloaded Class F**		25.8	0.17
	Loaded Class F		33.4	0.46
	Unloaded Class K		22.9	0.13
	Unloaded and Loaded Class		30.4	0.45
	Unloaded Class K and F		25.1	0.19
	All Class K and F		29.6	0.39

The calibration procedure of the wayside HBD was also investigated. Different calibrations were compared and analyzed including two-point, three-point, and multi-point calibrations. The results demonstrate that three-point and multi-point calibrations performed on the laboratory-acquired data were superior to the simple two-point calibration. Furthermore, a calibration performed on the field test data using its best-fit trendline resulted in much improved temperature accuracy as measured by the field service HBDs.

Conclusions and Contributions (300 words)

An investigation into the efficacy of wayside HBDs that are currently used in rail service was carried. Data was collected from field service HBDs as well as in the laboratory utilizing a pneumatic system that traverses an infrared (IR) sensor that scans a specific region under the bearing. The laboratory-fabricated HBD is supposed to mimic the functionality of HBDs in rail service. Numerous experiments were performed in the laboratory using both healthy and defective bearings at various speeds and loading conditions. The acquired data was compared to data that was obtained during an on-track field test.

Analysis of the results revealed that field service HBDs are affected by the bearing class since the IR sensors scan different regions of the bearing depending on its class. Laboratory testing validated by field test data indicates that scanning the inboard raceway region of the bearing outer ring (cup) will yield the most temperature data. In general, HBDs tend to underestimate bearing temperatures in both field service and in laboratory testing, which is not surprising considering the simple two-point calibration method that is used to calibrate these devices. The latter can lead to disastrous consequences if a defective bearing goes undetected by these HBDs; a scenario that occurred on numerous occasions over the past two decades and resulted in catastrophic derailments. Hence, an optimized calibration technique along with proper IR sensor alignment can markedly improve the accuracy and precision of HBD temperature measurements, which in turn, can reduce: (a) costly delays and train stoppages associated with false warm bearing trending events, and (b) catastrophic bearing failures associated with HBDs underestimating the operating temperature of a defective bearing.

Keywords: Wayside Hot-Box Detectors (HBDs), Defect Detection, Condition Monitoring, Bearing Health