TECHNOLOGY DIGEST
TD-16-021
©JUNE 2016
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.

Bearing Defects and High Impact Wheels

Tony Sultana and Demet Cakdi

Summary

As part of the Association of American Railroads' (AAR) Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI) analyzed acoustic bearing detector (ABD) defects to identify if bearings on wheels with high impacts have an increased risk of producing bearing defects detectable by an ABD. A relationship of wheel impact load detector (WILD) to acoustic bearing defects could indicate the ability to identify at risk bearings with WILD solely of an event – an acoustic bearing defect in this case – compared to a control group of good bearings in revenue service.

Results of the analysis did not indicate an increased risk of acoustically detectable bearing defects due to high impact wheels for cups, cones, and severe defects (RS1_e and Growlers with history). There was insufficient data for the analysis of roller and multiple acoustic defects.

- The percentage of bearings with acoustic defects and high impact wheels is not practically different from a control group of good bearings.
- The median WILD values, measured by peak, dynamic, kip-days and dynamic ratios are not practically different between the good and acoustic defect bearings.

Several factors may affect the results of the study.

- The number of high impact wheels in service has decreased over time while coverage with WILD detectors has increased
- The WILD setout policies of the Class I railroads remediate wheels quicker than prior years
- AAR *Manual of Standards and Recommended Practices* Section F, Standard S-6001 permits the removal of 70+ peak kip wheels with some heat on the bearing[1]
- ABDs may not detect the type of damage that occurs to bearings due to high impact wheels
- In addition, there are significant improvements with bearing technology, including fitted backing rings, polymer cages, and non-contacting bearing seals

WILD by itself is not a replacement to ABDs to identify acoustic bearing defects. Further research is planned to identify if damage occurs that is not acoustically detectable (e.g., cracked cages).

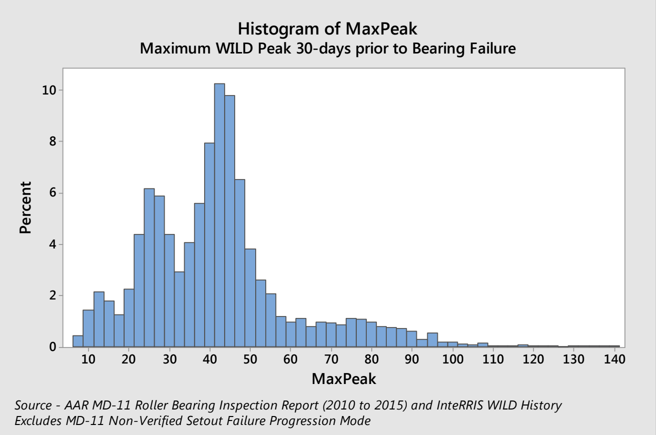
Please contact **Tony Sultana (719) 584-0559** with questions or concerns regarding this *Technology Digest.* E-mail: Tony_Sultana@ttci.aar.com.

INTRODUCTION

TTCI analyzed acoustic bearing detector (ABD) defects to identify if bearings on wheels with high impacts have an increased risk of producing bearing defects detectable by an ABD. This was completed using frequency analysis and risk assessment, a method of quantifying the risk of an event – an acoustic bearing defect in this case – compared to a control group of good bearings in revenue service.

ABD systems have been in use in North America for several years. ABD technology identifies defects in specific bearing components by the sounds produced at higher train speeds in revenue service. Severe bearing defects can result in overheating or a burned-off journal.

Some of the defective bearings experienced high wheel impact forces within the prior 30-days to failure measured by wheel impact load detectors (WILD). Since less than 2 percent of reporting data from the AAR MD-11 Roller Bearing Defect Inspection Report[2] contained prior WILD peak kips, InteRRIS® WILD data used in the ABD analysis was merged with the reporting data for verified bearings from 2010 through 2015. Verified bearings are reported distressed and assigned a failure progression mode by its symptoms.[2] The number of bearings with WILD peak kips after the data merge increased to 41 percent as shown in Figure 1.



Source - AAR MD-11 Roller Bearing Inspection Report (2010 to 2015) and InteRRIS WILD History
Excludes MD-11 Non-Verified Setout Failure Progression Mode

Figure 1. WILD Maximum Peaks for Verified Bearings[2]

The study looked at acoustic bearing alerts from Track IQ's RailBAM® – Bearing Acoustic Monitor and TTCI's Trackside Acoustic Detection System (TADS®). The study included the following bearing alert types:

- RailBAM
  - RS1_p (Cup), RS1_n (Cone), RS1_r (Roller), RS1_m (Multiple), and RS1_e (Extended)
- TADS
  - Cup, Cone, Roller, Multiple with repeated alerts, and Growlers with history
- Good Bearings (control group)
  - Good bearings were identified and used as a control group that had no defects of any level with at least five to ten clean detector passes

The bearing alert date was taken from the first occurrence of the alert type and merged with WILD data for the wheelset up to the alert date. Summary WILD information was calculated for each bearing/wheel using seven calculations as follows. Each bearing defect type was analyzed for each WILD calculation and compared to the control group of good bearings:

1. The maximum peak vertical force up to the bearing alert date
2. The maximum dynamic vertical force (dynamic force is the impact energy above the weight of the wheel [maximum peak minus wheel weight])
3. Peak kip-days (cumulative maximum peak forces)
4. Dynamic kip-days (cumulative maximum dynamic forces)
5. Count of dynamic ratio detector passes that are 3 or greater (dynamic ratio is calculated by dividing maximum peak by the wheel weight)
6. Count of dynamic ratios of 4 or greater (as above)
7. Count of dynamic ratios of 5 or greater (as above)

Kip-days are calculated starting when the wheel initially meets or exceeds 30 dynamic vertical force. The peak or dynamic for the wheel is the initial total kip-days. Each day thereafter without a WILD pass the kip-days are increased by the original amount. When a new WILD pass occurs, the peak or dynamic at the pass is used thereafter only when the value exceeds the original. Kip-days accumulation continues until the wheelset is replaced. Table 1 is an example of the peak kip-day calculation.

Table 1. Peak Kip-day Calculation Example

WILD Date	Peak Kips	Dynamic Kips	Peak Kip-Days	Notes
2/1/2015	37	0	0	
2/5/2015	72	37	72	Started
2/6/2015	No WILD pass		144	Add 72
2/7/2015	No WILD pass		216	Add 72
2/8/2015	35	25	288	Not higher, add 72
2/9/2015	100	68	388	Increases rate

ANALYSIS

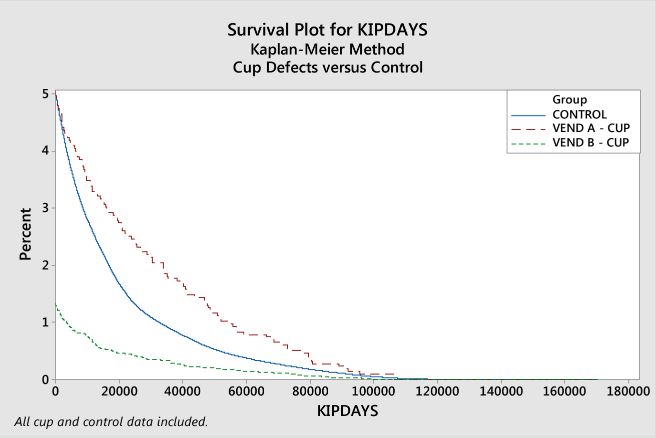
Nine months of ABD data totaling 91.3 million bearing passes was merged with four years of WILD data totaling 1.49 billion wheel passes on 765,071 unique cars. Four years of WILD data was used to calculate peak and dynamic kip-days for wheelsets that were in service for an extended period.

The statistical method applied in the study is a frequency analysis that measured how often high measured values occurred in a dataset. Nonparametric survival testing was used to perform the frequency analysis with the right tail (highest values) of the WILD calculated values. The analysis tested two conditions to determine if high impact wheels resulted in bearing defects detectable by an ABD.

1. The dataset of defective bearings should have a higher proportion of bearings with high impact wheels than the control group of good bearings.
2. The dataset of defective bearings should have a higher typical WILD calculated value than the control group of good bearings.

The nonparametrical survival technique compared the proportions and the overall WILD calculated values between the defective bearings and the control group.

The following analysis of cup defects compared them to the control group for peak kip-days. The results were typical of the other WILD calculated values, and cones and severe (RS1_e and Growlers with history) defects. Figure 2 shows the peak kip-day frequency distributions of the cup defects and control data for all the included data. Vendor A and the control have about 5 percent of the data (y-axis) with calculated peak kip-days while Vendor B has less than 2 percent (highlighted yellow in Table 2). At least 95 percent of the bearings with cup defects did not have elevated WILD readings. Differences between vendors for a specific defect type may be due to their filtering and detection algorithms.


Survival Plot for KIPDAYS
Kaplan-Meier Method
Cup Defects versus Control

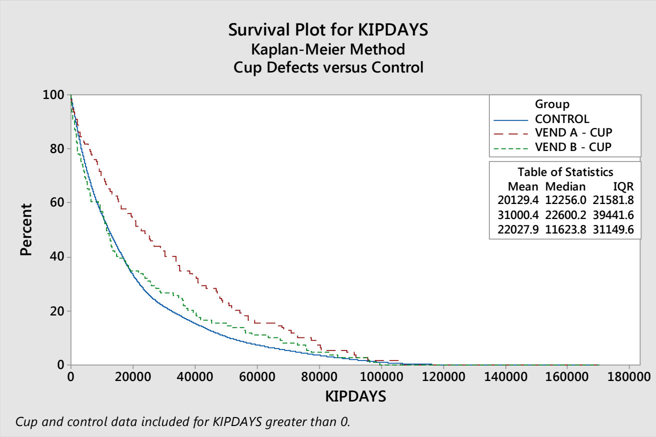
All cup and control data included.

Figure 2. Peak Kip-Day Frequency of Cups and Control

Figure 3 examines only the cup defect bearings with calculated peak kip-days from Figure 2. The distribution of the control and Vendor B cup defects with peak kip-days are almost identical, while Vendor A has a slightly higher median peak kip-days (highlighted blue in Table 2). In addition to a higher expected percentage of bearings with high impact wheels it was also expected to have higher calculated WILD values. The number of bearings above 50,000 peak kip-days for both groups are as follows:

- Control has 0.53 percent representing over 10,000 out of 1.9 million bearings in sample
- Cups from both vendors has 0.40 percent representing 41 out of 10,748 bearings with cup defects in sample

If all of the elevated WILD bearings were removed from service, then up to only 5 percent of the bearings with acoustic defects would be removed from service and an equal percentage of good bearings would also be removed. This indicates that WILD combined with ABD does not identify a proportion of acoustically defective bearings different from the general population.


Survival Plot for KIPDAYS
Kaplan-Meier Method
Cup Defects versus Control

Cup and control data included for KIPDAYS greater than 0.

Figure 3. Analysis of only Bearings with Kip-Days

Tables 2 through 4 summarize the results for the control group and each vendor for cups, cones, and severe defects and peak kip-days. The results are typical for the six other WILD calculation methods examined. The percent of population (% Pop) and median peak kip-days are shown as the confidence interval ranges, or what is expected from another similarly taken sample of bearings. The percentage of the population of defects varied statistically by defect and vendor, but still identified a small proportion of bearings with acoustic defects. The percent population for severe defects for Vendor A (Table 4) was wide due to the much smaller sample size. There was insufficient data for roller and multiple defects (not shown). Severe defects in Table 4 include RS1_e (Extended) and Growlers with history of each vendor.

Table 2. Cup Defects versus Control Group

Group	% Pop with Peak Kip-days	Median Peak Kip-days
Control	4.4–4.5	12,109–12,401
Cup – Vendor A	4.2–6.0	16,053–30,384
Cup – Vendor B	1.0–1.5	9,478–14,701

Table 3. Cone Defects versus Control Group

Group	% Pop with Peak Kip-days	Median Peak Kip-days
Control	4.4–4.5	12,109–12,401
Cone – Vendor A	3.0–5.7	11,372–36,122
Cone – Vendor B	0.6–1.1	5,714–23,875

Table 4. Severe Defects versus Control Group

Group	% Pop with Peak Kip-days	Median Peak Kip-days
Control	4.4–4.5	12,109–12,401
Severe – Vendor A	6.3–19.8	9,066–44,643
Severe – Vendor B	2.3–3.6	4,563–11,323

CONCLUSION

The results of the analysis did not indicate an increased risk of acoustically detectable bearing defects due to high impact wheels for cups, cones, and severe defects (RS1_e and Growlers with history) when compared to the control group of good bearings. Removal of wheels with elevated WILD would capture a small portion (about 5 percent) of bearings with acoustic defects, but also would remove an equal percent of good bearings. There was insufficient data for the analysis of roller and multiple acoustic defects.

- The percentage of bearings with acoustic defects and high impact wheels is not practically different from a control group of good bearings.
- The median WILD value, measured by peak, dynamic, kip-days and dynamic ratios are not practically different between the good and acoustic defect bearings, in that a small percentage of bearings with acoustic defects would be included.

Several factors that did not exist years ago may account for the results in the study:

- The number of high impact wheels in service has decreased over time while the coverage of WILD detectors has increased
- The WILD setout policies of the Class I railroads remediate wheels quicker than prior years
- MSRP Section F, Standard S-6001 permits the removal of 70+ peak kip wheels with some heat on the bearing
- ABDs may not detect the type of damage that occurs to bearings due to high impact wheels

In addition, there are significant improvements with bearing technology, including fitted backing rings, polymer cages, and non-contacting bearing seals.

WILD by itself is not a replacement to ABDs to identify acoustic bearing defects.

NEXT STEPS

Further research is planned to identify if damage occurs that is not acoustically detectable (e.g., cracked cages). By identifying high impact wheels in service for a long period of time with no acoustic indications and low bearing temperatures, wheelsets can be removed from service for examination. These bearings can have an AAR MD-11 bearing teardown inspection to identify any undetected defects.

REFERENCES

1. Association of American Railroads. 2012. *Manual of Standards and Recommended Practices*, Section F Sensors, Standard S-6001, “Bearing Temperature Performance.” Washington, DC
2. Association of American Railroads. 2015. *Manual of Standards and Recommended Practices*, Section G-II Wheel and Axle Manual, Paragraph 2.7, “MD-11 Reporting–Failure Progression Modes and Fig. 4.76 Roller Bearing Inspection Report.” Washington, DC