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TEMPERATURE PROFILES OF RAILROAD TAPERED ROLLER BEARINGS WITH DEFECTIVE INNER AND OUTER RINGS

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Outline

- Introduction and Background
- Objective of Study
- Experimental Setup and Instrumentation
- Experimental Procedure and Methodology
- Research Results
- Conclusions and Future Work
- Acknowledgements

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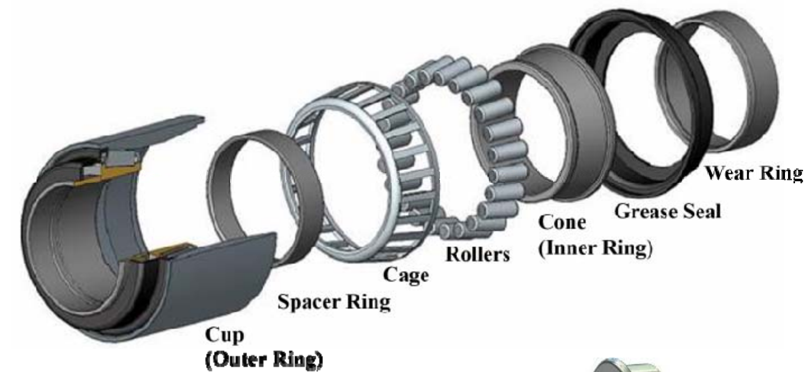
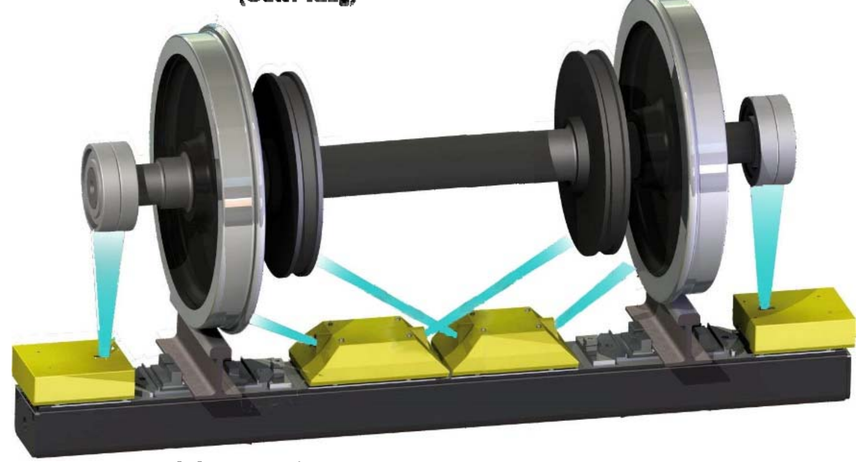
Introduction and Background

- Conventional monitoring systems:
  - Wayside infrared devices called Hot-box detectors (HBDs)
  - Discrete Data [25-40 miles apart]
  - Trigger if bearing temperature is 170°F (94.4 °C) above ambient conditions
  - Non-verified bearings – Trended bearings found to be non-defective upon teardown and inspection.
  - Costly removals of non-verified bearings. According to data collected by Amsted rail from 2001 to 2007, nearly **40%** of bearing removals are non-verified.



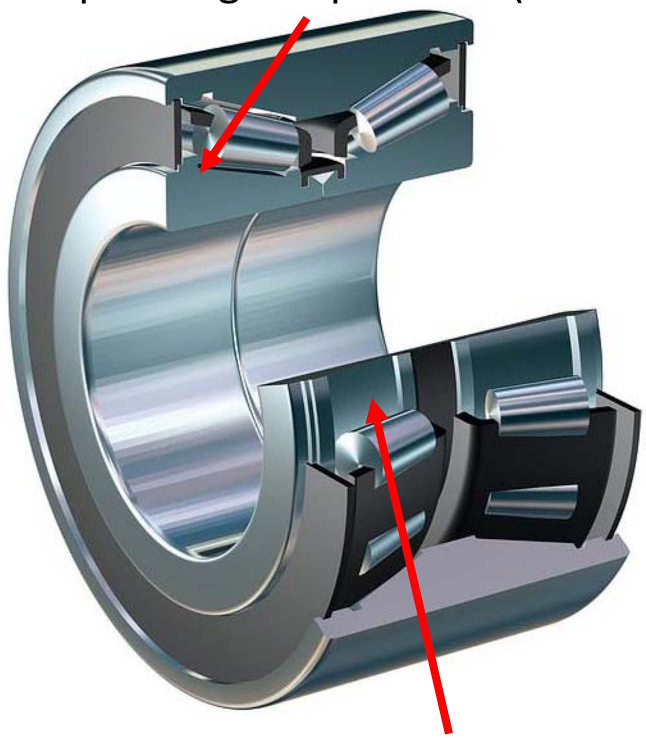


[1] Tarawneh, C.M., et.al. Thermal Modeling of a Railroad Tapered-Roller Bearing Using Finite Element Analysis. ASME. *J. Thermal Sci. Eng. Appl.* 2012;4(3):031002-031002-11. doi:10.1115/1.4006273.

[2] NEM Solutions,. Http://Www.Nemsolutions.Com/Images/Product-Images/Rail/Hot-Axle-Box-Detection/Laser-Hot-Box-Detection.Jpg. 2016.

Introduction and Background

Highest operating temperature (rib-roller)



Highest contact pressure (roller-inner race)

- Conduction is the main heat transfer mechanism [3].
- Abnormal operating conditions may not significantly raise the bearing cup temperature [1].
- **Bearing seizures and their consequences occur too rapidly for conventional monitoring systems of detection** [4,5].

[6] A. Zagouris, et.al., 2012, “Experimentally validated FEA of railroad bearing adapter operating temperatures,” Proceedings of the 2012 ASME IMECE Conference
[7] GNK Land Systems, Powertrain Systems and Services. Http://Www.Gknservice.Com/Typo3temp/Fl_Realurl_Image/Double-Tapered-Roller-Bearing-A5.Jpg. 2016.

[3] K. Cole et.al.2010, “Thermal models of railroad wheels and bearings,” Int. J. of Heat Mass Transfer, Vol. 53, pp. 1636-1645.
[4] S. Karunakaran, et.al., 2007, “Bearing temperature performance in freight cars,” Proceedings Bearing Research Symposium
[5] H. Wang, et.al., 1996, “Effects of cone/axle rubbing due to roller bearing seizure on the thermomechanical behavior of a railroad Axle,” J. of Trib., Vol. 118, pp. 311-319.

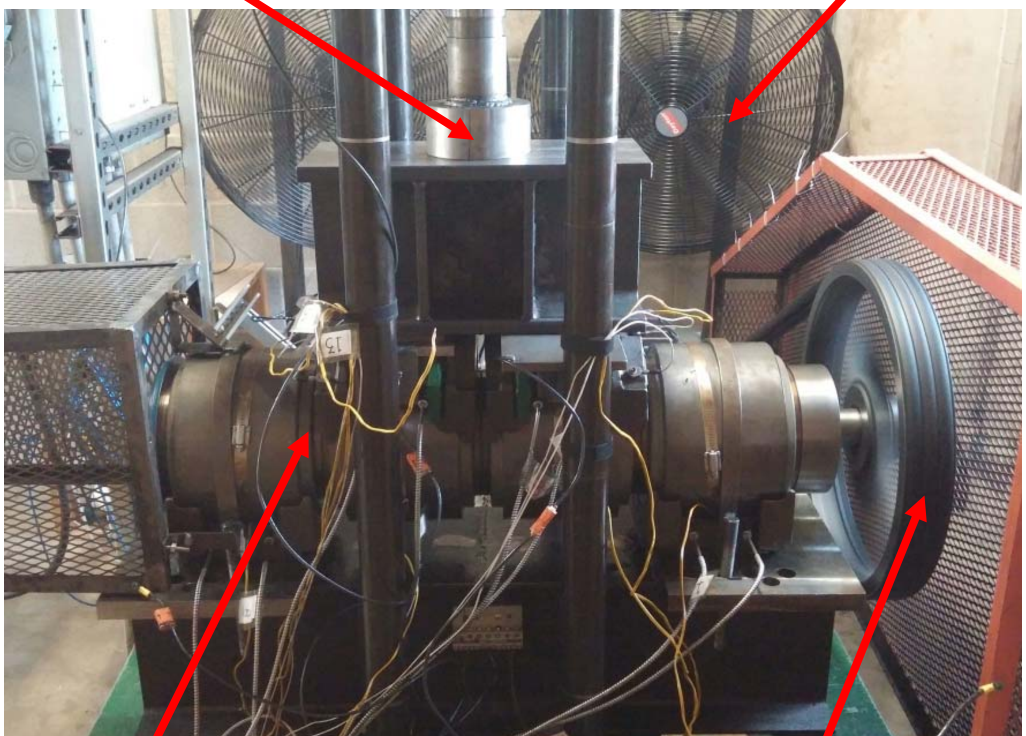
Objective of Study

- To investigate the correlations between railroad bearing defect severity, as measured by the size of spalls present in inner (cone) and outer (cup) rings, and the bearing operating temperatures.

Experimental Setup and Instrumentation

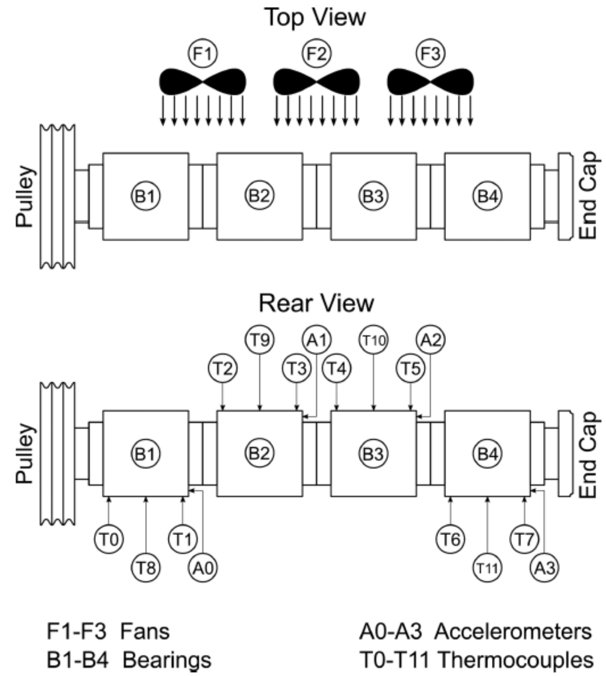
Applied Load
(from Hydraulic cylinder)

Fans



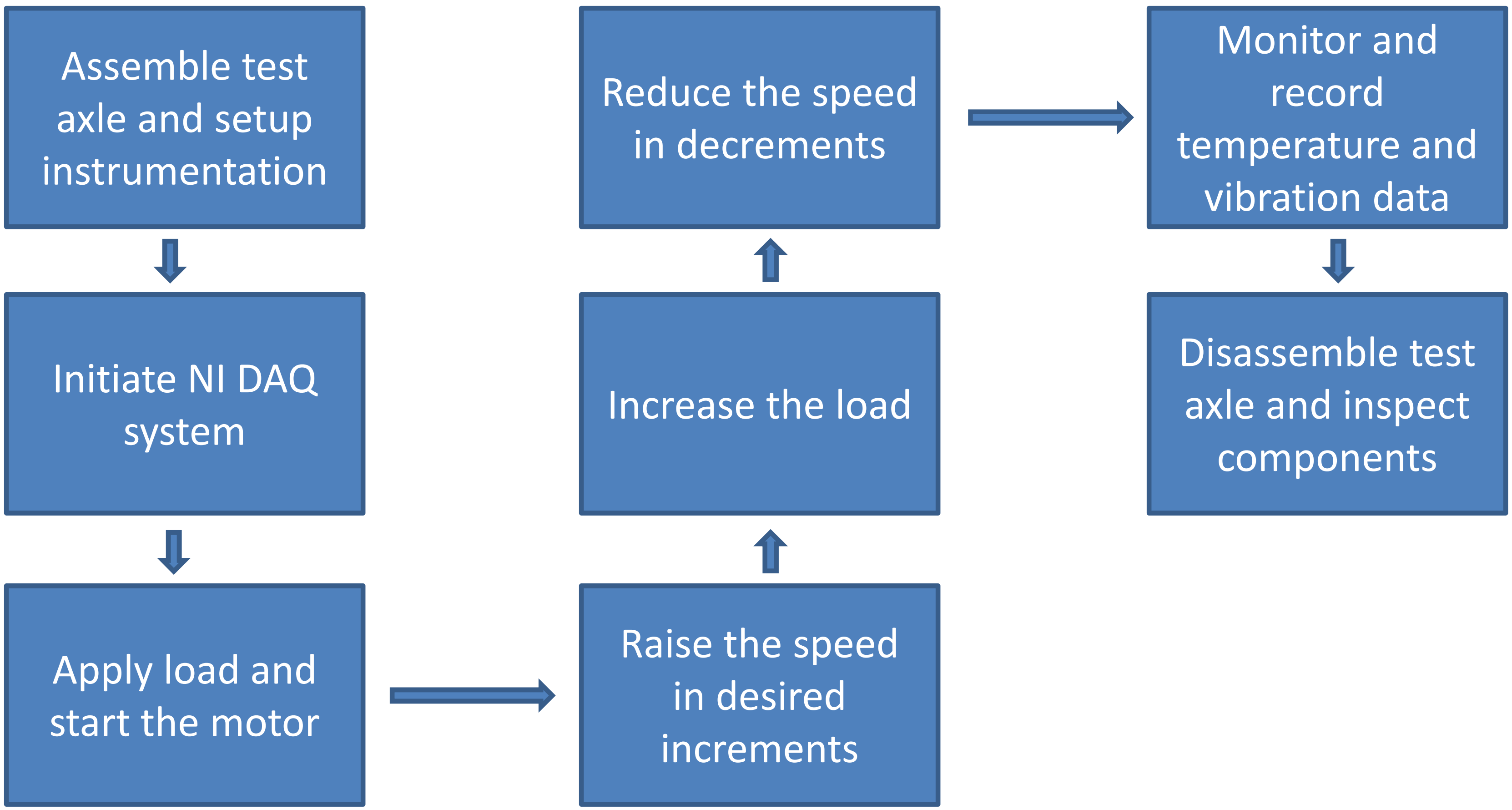
Axle assembly

Motor pulley



- Four class K or F bearings
- 14 K-type thermocouples
- Four 500g accelerometers
- LabVIEW™ operated by NI DAQ

Experimental Procedure



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Experimental Procedure

- A full railcar (100% load) is simulated by applying 34,400 lb of force through a hydraulic cylinder. An empty railcar is simulated by applying 17% of the load.
- The speeds used in these experiments are listed in the table.
- The bearings are run long enough to ensure that steady state operation is achieved at every load and speed combination.

Speed [rpm]	Speed [mph]	Speed [kph]
140	15	24
187	20	32
234	25	40
280	30	48
327	35	56
374	40	64
420	45	72
498	53	85
560	60	97
618	66	106
699	75	121
799	85	137

Methodology

- Only data from top loaded bearings were considered for this study.
- The data was acquired from more than 70 experiments.
- The temperature data presented in this study is that collected from the two K-type bayonet thermocouples located at each bearing.
- The analysis was performed using the mathematical software MATLAB™.
- The defects were classified as shown in the table below.

Defect Classification	Defect area range [in^2]
Small	0 - 0.25
Medium	0.25 - 1
Large	> 1

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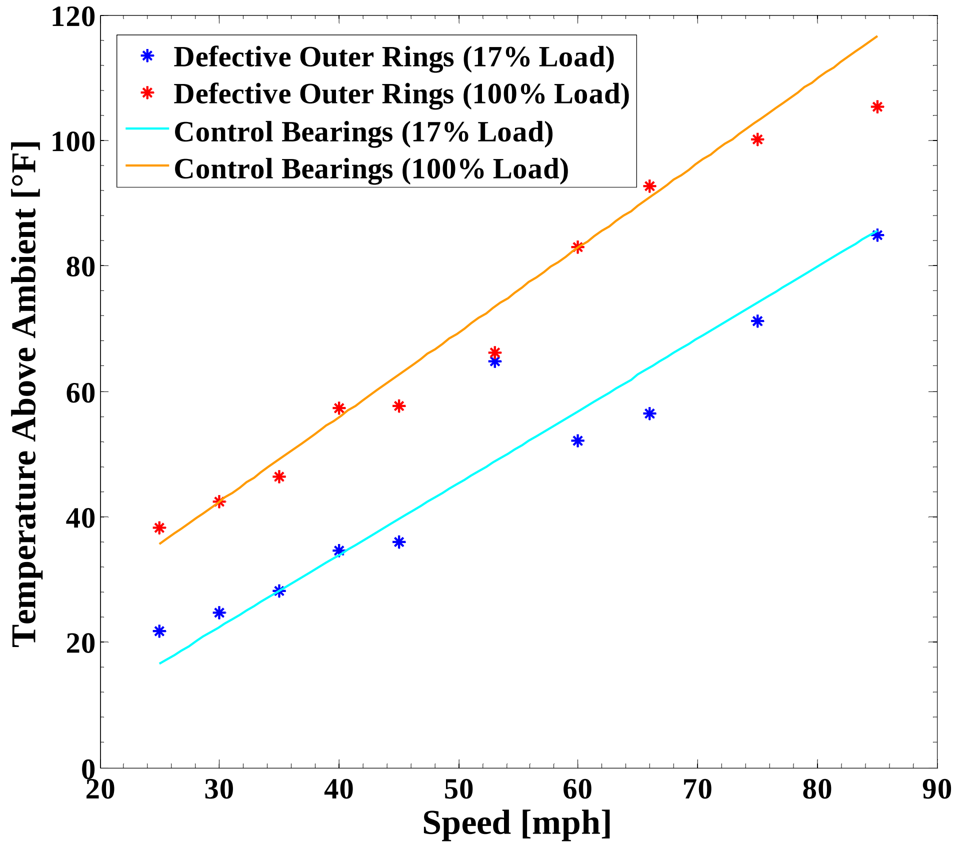
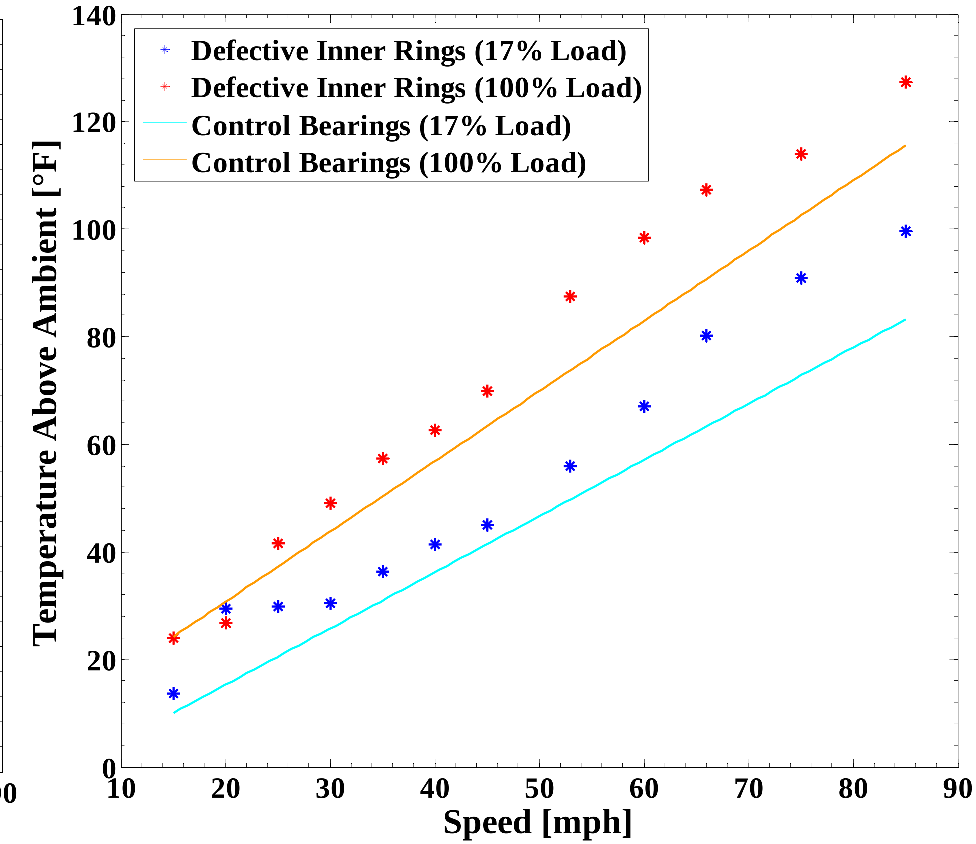
Experimental Results





Average temperature above ambient (78°F) of bearings with defective outer (cup) and inner (cone) rings, as compared to healthy (control) bearings, for unloaded (17% load) and fully-loaded (100% load) conditions.

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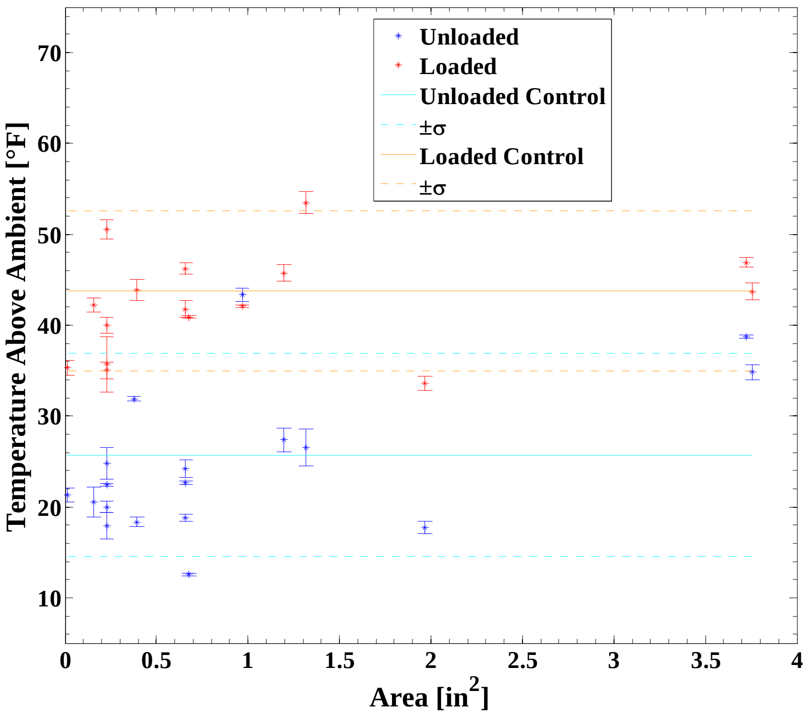
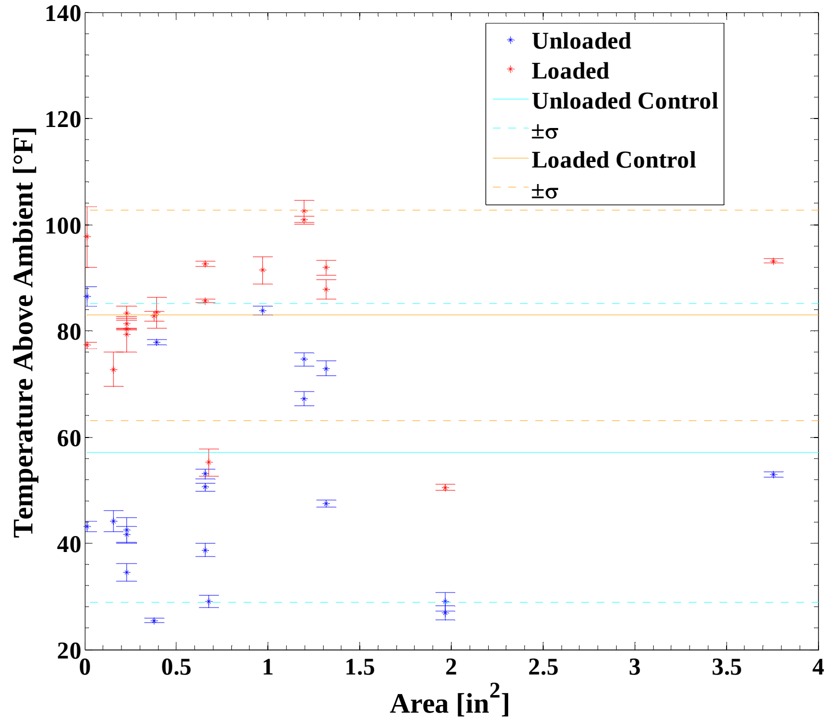
Experimental Results

Temperature data of bearings with outer ring (cup) defects of various sizes (defect area) compared against the range of operating temperatures for healthy (control bearings) under fully-loaded (100% load) and unloaded (17% load) conditions.



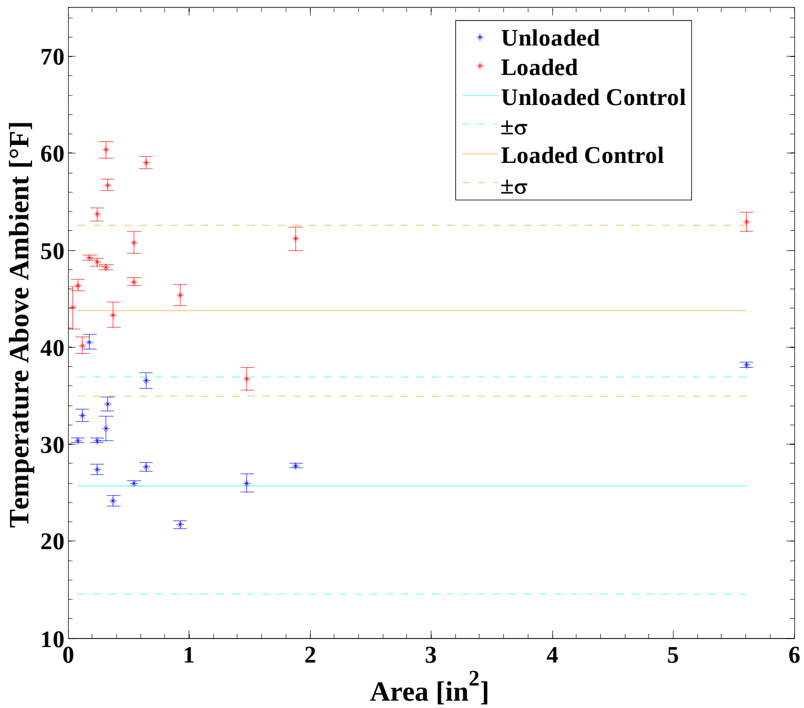
30 mph



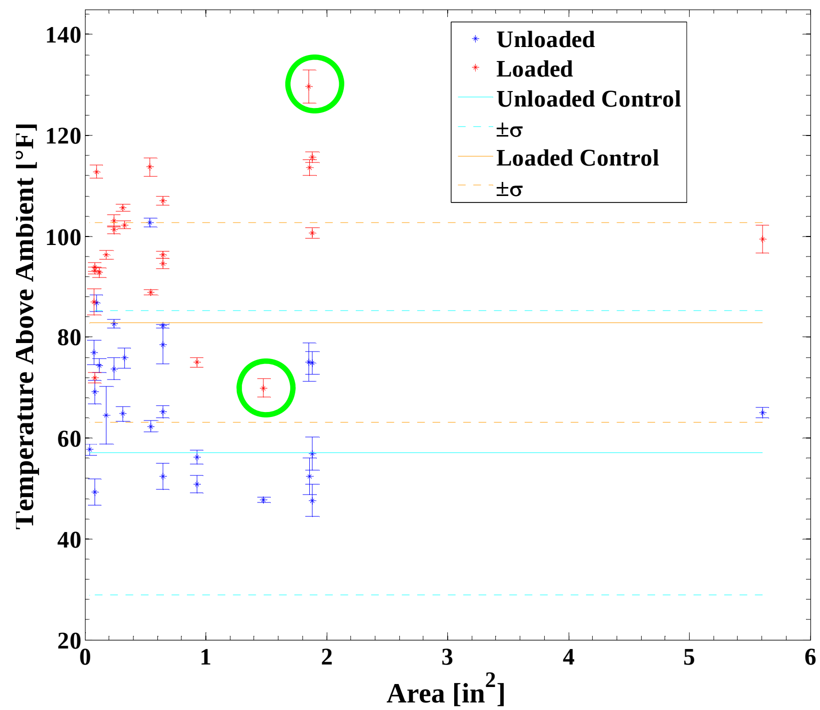
60 mph

Experimental Results

Temperature data of bearings with inner ring (cone) defects of various sizes (defect area) compared against the range of operating temperatures for healthy (control bearings) under fully loaded (100% load) and unloaded (17% load) conditions.



30 mph

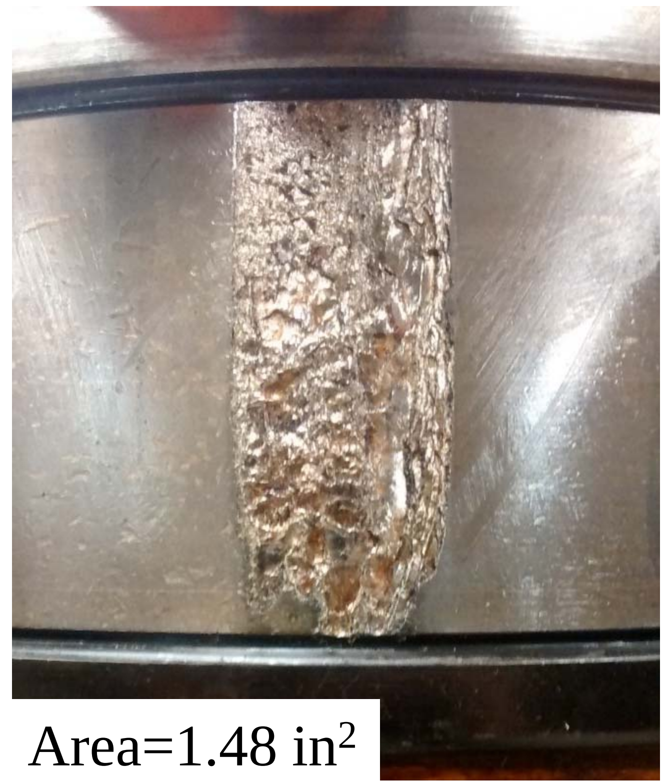


60 mph

Experimental Results

Examples of two large defects of similar size resulting in different operating temperatures.

Area=1.88 in^2



Area=1.48 in^2

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Experimental Results

Examples of small and medium sized defects.

Small Spall

Area = 0.16 in^2

Medium Spall

Area = 0.68 in^2

Experimental Results

- Summary of average operating temperatures above ambient (26°C / 78°F) for bearings with outer ring (cup) defects.

17% Load (empty/unloaded railcar)				100% Load (fully-loaded railcar)			
Speed [mph]	Spall Size [in^2]	ΔT [°C / °F]	Control ΔT [°C / °F]	**Speed [mph]**	Spall Size [in^2]	ΔT [°C / °F]	Control ΔT [°C / °F]
15 - 30	0 - 0.25	11.2 / 20.1	11.1 / 20.0	**15 - 30**	0 - 0.25	21.8 / 39.2	19.2 / 34.6
	0.25 - 1	12.5 / 22.5			0.25 - 1	22.5 / 40.5	
	> 1	15.9 / 28.7			> 1	23.0 / 41.4	
30 - 55	0 - 0.25	20.7 / 37.3	20.6 / 37.1	**30 - 55**	0 - 0.25	30.4 / 54.8	32.8 / 59.0
	0.25 - 1	23.8 / 42.9			0.25 - 1	30.6 / 55.2	
	> 1	23.2 / 41.8			> 1	34.4 / 61.9	
> 55	0 - 0.25	27.4 / 49.3	38.5 / 69.3	**> 55**	0 - 0.25	40.1 / 72.2	55.2 / 99.4
	0.25 - 1	36.2 / 65.2			0.25 - 1	51.8 / 93.3	
	> 1	37.4 / 67.3			> 1	53.1 / 95.6	

Experimental Results

- Summary of average operating temperatures above ambient (26°C / 78°F) for bearings with inner ring (cone) defects.

17% Load (empty/unloaded railcar)				100% Load (fully-loaded railcar)			
Speed [mph]	Spall Size [in^2]	ΔT [°C / °F]	Control ΔT [°C / °F]	**Speed [mph]**	Spall Size [in^2]	ΔT [°C / °F]	Control ΔT [°C / °F]
15 - 30	0 - 0.25	17.2 / 30.9	11.1 / 20.0	**15 - 30**	0 - 0.25	25.1 / 45.2	19.2 / 34.6
	0.25 - 1	14.3 / 25.8			0.25 - 1	19.7 / 35.5	
	> 1	15.9 / 28.6			> 1	25.0 / 44.9	
30 - 55	0 - 0.25	26.5 / 47.7	20.6 / 37.1	**30 - 55**	0 - 0.25	37.4 / 67.2	32.8 / 59.0
	0.25 - 1	24.2 / 43.5			0.25 - 1	39.1 / 70.4	
	> 1	22.4 / 40.4			> 1	38.8 / 69.9	
> 55	0 - 0.25	33.3 / 60.0	38.5 / 69.3	**> 55**	0 - 0.25	43.2 / 77.8	55.2 / 99.4
	0.25 - 1	52.0 / 93.6			0.25 - 1	65.3 / 117.6	
	> 1	44.6 / 80.3			> 1	64.8 / 116.7	

Conclusions and Future Work

- No distinct correlation is found between defect severity (as measured by defect area) and bearing operating temperature.
- A significant number of bearings with outer (cup) and inner (cone) ring defects of considerable size where operating at or below the temperature range of healthy bearings.
- None of the defective bearings in this study reached the HBD temperature trigger of 170°F above ambient conditions.
- Continue building and expanding the library of temperature data collected for defective and healthy bearings.
- Investigate the effects of defect geometry and location on the bearing operating temperature.

Acknowledgements

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