UNIVERSITY TRANSPORTATION CENTER FOR RAILWAY SAFETY

Exhibit F - UTCRS

UTC Project Information	
Project Title	The Effect of Heat Generation in the Railroad Bearing Thermoplastic Elastomer Suspension Element on the Thermal Behavior of Railroad Bearing Assembly
University	The University of Texas Rio Grande Valley (UTRGV)
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Total Project Cost	$71,676
Agency ID or Contract Number	DTRT13-G-UTC59
Start and End Dates	January 2015 – May 2018
Brief Description of Research Project	The main purpose of this study is to investigate the effect of heat generation in the railroad thermoplastic elastomer suspension element to develop an experimentally informed and validated finite element thermal model which can be used to attain temperature distribution maps of railroad bearing assemblies under a variety of normal and abnormal service conditions. Among other things, these maps will be useful for sensor data interpretation and identifying ideal locations for sensor placement for continuous temperature tracking of railroad bearings (e.g. IONX motes). Specifically, the main objectives of this project are: (1) to explore and quantify the heat generation in the railroad bearing elastomer suspension element with different material systems and under different loads, frequencies, and temperature scenarios; and (2) to determine the effect of this heat generation on the

	thermal behavior of railroad bearing assembly under different operation conditions. To this end, the contribution of the elastomer pad to the system energy balance was modeled using data from dynamic mechanical analysis (DMA) of common materials in use for that part. DMA provides a full characterization of the elastic deformation (energy storage) and viscous dissipation (energy dissipation) behavior of the material as a function of load, frequency, and temperature. In parallel, CAD models of the railroad bearing assembly were developed using SOLIDWORKS™ commercial software to be used in constructing finite element models utilizing the ALGOR™ commercial software. The finite element (FE) model was used to conduct thermal finite element analyses using some of the expected operational boundary conditions and loads including the heat generation in the elastomer suspension system. The FE models were then validated with physical laboratory experiments. Finally, based on the simulations and experimental results, bearing assembly recommendations are suggested to further ensure the safe operation of railroad bearings.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	One of the major goals of the University Transportation Center for Railway Safety (UTCRS) is to increase the railway reliability by, among other things, developing advanced technology for infrastructure monitoring and developing innovative safety assessments and decision-making tools. Along these lines, the Railroad Research Group at the University of Texas Rio Grande Valley has been working on onboard monitoring systems for the railroad industry. Future technologies are focusing on continuous temperature tracking of railroad bearings (e.g. IONX motes). The work conducted in this study concentrated on the effect of the internal heat generation in the railroad thermoplastic elastomer suspension element on the thermal behavior of the railroad bearing assembly. Understanding the impact of the hysteresis heating of the railroad bearing elastomer suspension element during operation is essential to predict its dynamic response and structural integrity, as well as, to predict the thermal behavior of the railroad bearing assembly. In this project, an experimentally validated AdapterPlus™ FE model was devised to investigate the effect of elastomer pad hysteresis heating on the railroad bearing assembly operating temperature. Different internal heating scenarios were simulated with the purpose of obtaining the bearing suspension element and bearing assembly temperature distribution maps during normal and abnormal operation conditions along with no heat generation and applied heat generation in the thermoplastic elastomer suspension element. The combination of temperature and frequency dependent material properties with FEA modeling permits the transient modeling and determination of equilibrium temperature of an elastomeric steering pad.

Results indicate that the combination of ambient temperatures, bearing temperature, and frequency of loading can produce pad temperature increases above ambient of up to 125°C. The finite element analysis and experiment results (samples shown in Figure 1 and 2, respectively) also show that in normal and abnormal operation conditions, the internal heat generation in the thermoplastic elastomer suspension element has limited impact on the thermal behavior of the railroad bearing assembly provided that the pad is able to dissipate heat through the side frame of the truck. The AdapterPlus™ FE model also shows that with normal operation conditions, the temperature distribution of the suspension pad remains relatively the same when heat generation is applied. However, the constant heat generation due to a frequency loading of 50 Hz does cause the maximum temperature of the pad to increase by about 4°C. Although this minor increase in temperature is not significant to the temperature distribution of the suspension pad nor does it significantly impact the thermal management or temperature distribution of the bearing assembly, the results indicate that if a significant amount of energy is generated by the suspension pad with no thermal runway, it can highly impact the structural integrity of the suspension pad.

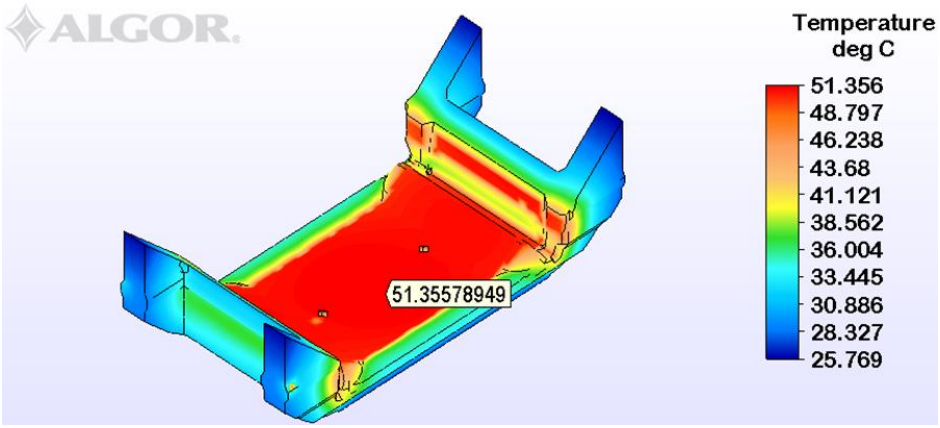
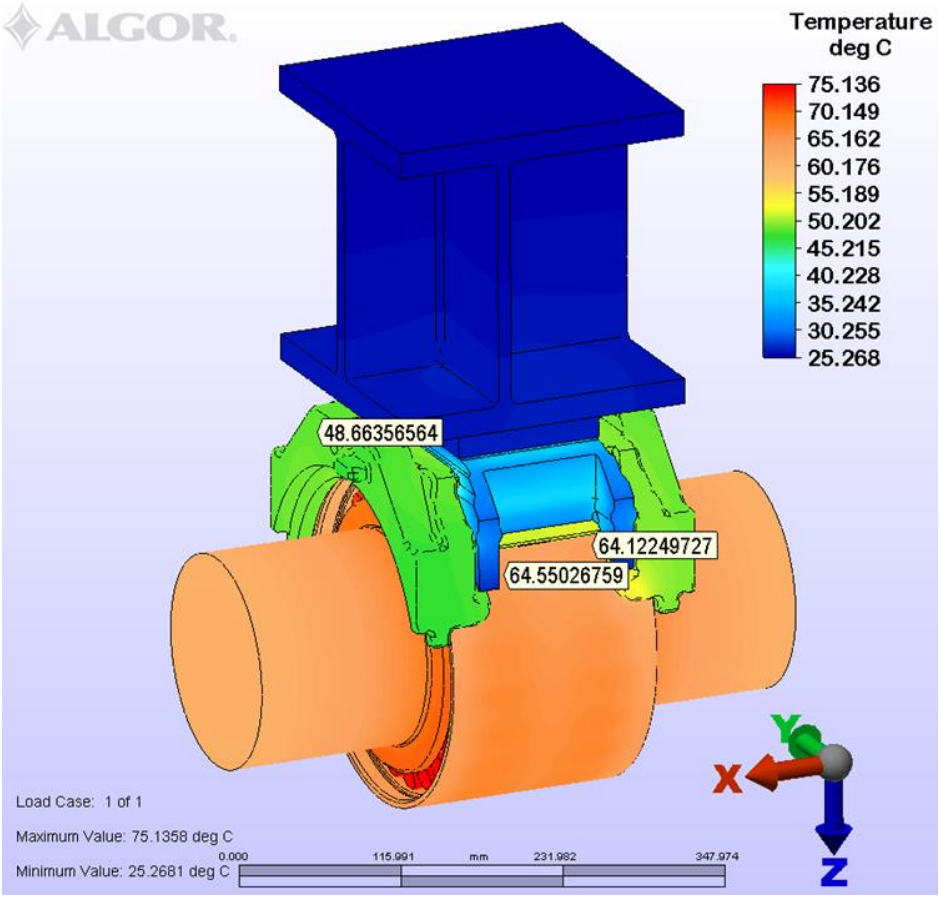


Figure 1: Sample FEA Result for Suspension Pad with Normal Operation Conditions

In conclusion, hysteresis heating is a phenomenon that occurs in service, and may have a significant impact on the structural integrity of the thermoplastic elastomer suspension pad, which can negatively affect the thermal management of the railroad bearing. With proper convection and normal bearing operation conditions, the heat generation will not have a significant effect. However, in extreme hot weather conditions where the ambient temperature is high, when a bearing is defective, rail conditions may produce high frequency loading which can cause the thermoplastic elastomer suspension pad to reach

	temperatures higher than the softening temperature of the pad material (i.e., 120°C).  **Figure 2: Sample FEA Result for Railroad Bearing Assembly Including Heat Generation in the Steering Pad Due to Frequency Loading of 10 Hz with Normal Operation Conditions**
Impacts/Benefits of Implementation (actual, not anticipated)	The researchers at the University of Texas Rio Grande Valley continue to establish a vital track record in the area of experimentally-validated finite element analysis pertaining to the railroad industry, especially railway safety. The research results from this University Transportation Center for Railway Safety (UTCRS) project have been presented at different local, national, and international conferences with different audiences that include science and engineering students and faculty, railroad industry representatives, and researchers in the private and public sectors. Additionally, the work done for this project has been documented in great detail in a master's thesis completed by a graduate student who was selected as the 2017 UTCRS Student of the Year. The list of publications and/or presentations of this UTC project include the following:

	1. Rodriguez, O., "The Effect of Heat Generation in the Railroad Bearing Thermoplastic Elastomer Suspension Element on the Thermal Behavior of Railroad Bearing Assembly," Master's Thesis, Department of Mechanical Engineering, The University of Texas Rio Grande Valley, May 2018. 2. Rodriguez, O., Fuentes, A., and Tarawneh, C., "Impact of Hysteresis Heating of Railroad Bearing Thermoplastic Elastomer Suspension Pad on Railroad Bearing Thermal Management," *Proceedings of the ASME Joint Rail Conference*, Pittsburg, PA, April 18-20, 2018. 3. Rodriguez, O., Fuentes, A., Tarawneh, C. and Jones, R., "Hysteresis Heating of Railroad Bearing Thermoplastic Elastomer Suspension Element," *Proceedings of the ASME Joint Rail Conference*, Philadelphia, PA, April 4-7, 2017. **[Received Best Paper Award]** 4. Rodriguez, O., Carbone, J., Fuentes, A., Tarawneh, C., and Jones, R., "Heat Generation in the Railroad Bearing Thermoplastic Elastomer Suspension Element," *Proceedings of the ASME Joint Rail Conference*, Columbia, SC, April 12-15, 2016. An additional benefit of this project is the training of a critical mass of students in finite element (FE) modeling methods who are mentoring other students and attracting them to the field of transportation.
Web Links • Report • Project Website	http://www.utrgv.edu/railwaysafety/research/mechanical/2015/heat-generation-in-the-railroad-bearing-suspension-element/index.htm