

## Exhibit F - UTCRS

UTC Project Information	
Project Title	Modeling the Residual Useful Life of Bearing Grease
University	The University of Texas-Pan American (UTPA)
Principal Investigator	Doug Timmer, Ph.D., Manufacturing Engineering (PI) Robert Jones, Ph.D., Mechanical Engineering (Co-PI) Constantine Tarawneh, Ph.D., Mechanical Engineering (Co-PI)
PI Contact Information	Manufacturing Engineering ENGR 3.258 Dept. (956) 665-2606 Office (956) 665-2608 <a href="mailto:timmer@utpa.edu">timmer@utpa.edu</a>
Funding Source(s) and Amounts Provided (by each agency or organization)	Federal Funds (USDOT UTC Program): \$54,351 Cost Share Funds (UTPA): \$10,977
Total Project Cost	\$65,328
Agency ID or Contract Number	DTRT13-G-UTC59
Start and End Dates	November 2013 – December 2014
Brief Description of Research Project	This research developed an analytical model to predict the residual useful life of bearing grease. Modeling techniques that were employed include mechanistic or first principle models based upon process kinetics and empirical models including physics-based reliability models, non-linear regression, and neural networks. The analytical model provides users the ability to predict residual life based upon operational characteristics.
Describe Implementation of Research Outcomes (or why not implemented)	A linear regression model was developed based on a split, split-plot design to predict residual life of grease based upon operational characteristics. Some of the outcomes are listed hereafter: <ol style="list-style-type: none"> <li>1. Characterized residual life of bearing grease as the Oxidation Induction Time (OIT).</li> <li>2. Novel utilization of statistical design of experiments and linear regression to model residual life of bearing grease. The data was</li> </ol>
Place Any Photos Here	

	<p>collected as a split, split-plot design and analyzed using restricted maximum likelihood technique implemented in Matlab™.</p> <p>3. Mathematical model that predicts residual life of bearing grease. The following findings were established: (a) the mileage had the most significant impact upon the life of the bearing grease and the relationship was negative, (b) the bearing temperature had the second largest impact upon bearing grease and the correlation between temperature and OIT was negative, and (c) OIT values were higher, indicating larger remaining life, for the grease samples at the spacer ring location than grease sampled at the inner and outer bearing raceway.</p>
Impacts/Benefits of Implementation (actual, not anticipated)	<p>The research performed for this project has resulted in two national conference papers and presentations, and a Master's Thesis. The following are benefits resulting from this research:</p> <ol style="list-style-type: none"> <li>1. Timmer, D., Martinez, T., Jones, R., and Tarawneh, C., "Modeling the Residual Useful Life of Railroad Bearing Grease," INFORMS Annual Meeting, San Francisco, 2014.</li> <li>2. Martinez, T., Timmer, D., Jones, R., and Tarawneh, C., "Developing Empirical Models of Railroad Bearing Grease," Proceedings of the 2015 ASME Joint Rail Conference, San Jose, CA.</li> <li>3. Martinez, T., "Modeling the Residual Useful Life of Bearing Grease," Master's Thesis, Mechanical Engineering, University of Texas-Pan American, Expected completion: December 2015.</li> </ol>
Web Links <ul style="list-style-type: none"> <li>• Reports</li> <li>• Project website</li> </ul>	<a href="http://portal.utpa.edu/railwaysafety/research/mechanical/projects/2014/lubrication-study">http://portal.utpa.edu/railwaysafety/research/mechanical/projects/2014/lubrication-study</a>