Modeling Parasitic Energy Losses and the Impact of Advanced Tribological Concepts on Fuel Efficiency

Final CRADA Report

Energy Systems

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Summary of Major Accomplishments:

Under the Argonne/Ricardo cooperative research and development agreement (CRADA), multiple codes (PISDYN, RINGPAK, VALVDYN, and ENGDYN) were used to calculate from first principles the parasitic friction losses (FMEP) under prescribed engine conditions (load and speed) for a range of tribological parameters (asperity friction, lubricant viscosity). The results for a large diesel engine were analyzed to determine the dependence of asperity and hydrodynamic FMEP as a function of load, speed, viscosity, and asperity friction. Linear regression trends of FMEP were developed to predict FMEP difference maps and fuel consumption scaling factors. A regression was developed to calculate changes

Summary of Major Accomplishments:

in FMEP and fuel consumption scaling factors (FCSFs) to predict changes in fuel consumption for different driving cycles.

Our primary task for this project was to perform FMEP calculations for a broad range of parameters including engine type [spark ignition (SI) or compression ignition (CI)], engine size, engine mode (speed and load), lubricant viscosity, asperity friction, surface finish, oil type (mineral or synthetic), and additive (friction modifier), as discussed previously [1–3]. The actual analysis was limited to a large diesel engine and it included both load and speed dependencies as well as lubricant viscosity and speed.

The approach used in this project to predict the impact in fuel consumption for arbitrary drive cycles (engine load and speed) for different lubrication conditions (viscosity and asperity friction) is based on the use of FMEP difference maps to calculate FCSFs, which together with fuel consumption maps and weighted drive factors, can be used to predict fuel consumption. The FMEP simulations were used to calculate FMEP for arbitrary conditions of load, speed, viscosity, and asperity friction. The fuel consumption rate for a given load, speed, viscosity, and asperity friction can be predicted using the FCSFs and known fuel consumption rates (as a function of load and speed) for a baseline case (e.g., 40WT oil, 0% reduction in asperity friction). Changes in the drive cycle are also used to weight the contributions for an arbitrary drive cycle.

- Completed a parametric study of a combustion chamber FMEP as a function of engine load (indicated mean effective pressure) and speed for a small spark-ignited engine.
- Analyzed FMEP simulation data using a linear-regression approach to develop an analytical tool that will predict FMEP and fuel consumption scaling factors as functions of load, speed, and lubrication properties.
- Completed a preliminary parametric study of asperity friction for commercial and advanced friction modifiers.

Summary of Technology Transfer Benefits to Industry:

Friction, wear, and lubrication affect fuel economy, durability, and emissions of engines used in ground transportation vehicles. Total frictional losses alone, in typical engines, may account for more than 10% of the total fuel energy (depending on the engine size, driving conditions, etc.). The amount of emissions produced by these engines is related to the fuel economy of each specific engine. In general, the higher the fuel economy, the lower the emissions. Higher fuel economy and lower emissions in future diesel engines may be achieved by the development and widespread use of novel materials, lubricants, and coatings. For example, with increased use of lower viscosity oils (that also contain lower amounts of sulfur- and phosphorus-bearing additives), the fuel economy and environmental performance of future engine systems can be dramatically improved. Furthermore, with the development and increased use of smart surface engineering and coating technologies, even higher fuel economy and better environmental soundness are feasible.

The main goal of this project is to use advanced models of engine-component friction and contact loading to predict the impacts of advanced surface engineering technologies (e.g., near frictionless carbon and superhard coatings) and energy-conserving lubricant additives on parasitic energy losses from diesel engine components. The project also aims to develop more realistic databases on the boundary or asperity friction that are used in advanced codes to predict total (asperity and

Summary of Technology Transfer Benefits to Industry:

hydrodynamic) friction losses and, in the future, to validate the predictions in tests using fired engines. Such information will help to identify critical engine components that can benefit the most from the use of novel surface technologies, especially when low-viscosity engine oils are used to maximize the fuel economy of these engines by reducing churning and/or hydrodynamic losses. The long-term objective of the project is to develop a database that provides a “look-up” capability to predict the impact of lubricant viscosity, asperity friction, surface finish on FMEP, and contact severity at different engine operating modes

Other Information/Results: (Papers, Inventions, Software, etc.)

- 1.EngineFriction Reduction Technologies, G. Fenske, N. Demas, R. Erck, C. Lorenzo-Martin, A. Erdemir, and O. Eryilmaz, U.S. Department of Energy Vehicle Technologies Office Annual Merit Review and Peer Evaluation Meeting, June 11, 2015, Washington, D.C.
- 2.Modeling the Effect of Parasitic Friction Losses on Fuel Economy, G. Fenske, A. Matthews, and D. Dascalescu, Global Automotive Management Council Emissions 2015, June 23, 2015, Troy, MI.
- 3.Overview of Automotive Lubrication Research at Argonne National Laboratory, G. Fenske, Global Automotive Management Council Emissions 2015, June 23, 2015, Troy, MI.
- 4.DOE/DOD Parasitic Energy Loss Collaboration, G. Fenske, A. Matthews, N. Demas, and R. Erck, U.S. Department of Energy Vehicle Technologies Office Annual Merit Review and Peer Evaluation Meeting, June 16–20, 2014, Washington, D.C.
- 5.Engine Friction Reduction Technologies, G. Fenske, N. Demas, R. Erck, C. Lorenzo-Martin, A. Erdemir, and O. Eryilmaz, U.S. Department of Energy Vehicle Technologies Office Annual Merit Review and Peer Evaluation Meeting, June 16–20, 2014, Washington, D.C.
- 6.Application of FMEP maps to model the impact of friction technologies on fuel economy, G. Fenske, A. Matthews, and D. Dascalescu, presentation at 2014 STLE Tribology Frontiers Conference, October 26–28, 2014.
7. VI.2 DOE/DOD Parasitic Energy Loss Collaboration, G. Fenske, A. Matthews, N. Demas, R. Erck, U.S. Department of Energy - Energy Efficiency and Renewable Energy - Vehicle Systems 2015 Annual Progress Report, <http://energy.gov/eere/vehicles/downloads/vehicle-technologies-office-2015-vehicle-systems-annual-progress-report>

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