September 2014 Highlights

ORNL Fuels, Engines, and Emissions Research Center

TECHNICAL HIGHLIGHTS

Fuels, Engines, and Emissions Research Center (FEERC) Study Investigates the Best use of Natural Gas for Passenger Vehicles

A recent Oak Ridge National Laboratory (ORNL) study led by FEERC researcher, Scott Curran, was published in the journal *Energy* investigating the well-to-wheels energy use and greenhouse gas emissions for natural gas to transportation fuel pathways and compares the results to conventional gasoline vehicles and electric vehicles using the United States (U.S.) electrical generation mix. Specifically, natural gas vehicles running on compressed natural gas are compared against electric vehicles charged with electricity produced solely from natural gas combustion in stationary power plants. The results of the study show that the dependency on the combustion efficiency of natural gas in stationary power can outweigh the inherent efficiency of electric vehicles, thus highlighting the importance of examining energy use on a well-to-wheels basis. The article was also featured in a story by *Green Car Congress*. The study titled "Well-to-Wheel Analysis of Direct and Indirect use of Natural Gas in Passenger Vehicles" was authored by Scott Curran, FEERC center director Robert Wagner, ORNL Sustainable Transportation Director Ron Graves, Energy and Environmental Sciences Directorate (EESD) Director Martin Keller, and Energy and Transportation Sciences Division (ETSD) Director Johney Green. The article is pen source and free to download at:
http://www.sciencedirect.com/science/article/pii/S0360544214008573.

Collaboration with the University of Minnesota (UMN) Investigates the Nature of Particulate Matter (PM) from Reactivity-Controlled Compression Ignition (RCCI)

A recent collaboration with UMN researchers Prof. Will Northrop and doctoral student Glen Lucachick examined the make-up of RCCI PM using a prototype instrument at FEERC engine laboratories. FEERC researchers Vitaly Prikhodko, Scott Curran, John Storey, Sam Lewis, Maggie Connatser, and Melanie DeBusk hosted the student for multi-cylinder engine experiments. The advanced combustion engine capabilities, analytical chemistry, and PM expertise at ORNL provided an opportunity for the UMN researchers to collect PM from a proto-type engine using specialized equipment to help identify and characterize the nature of RCCI PM. RCCI PM is unique in having almost 0% elemental carbon (soot) yet still having other characteristics that are typical of exhaust PM. After analysis of the extensive data set, the findings will be reported in a series of upcoming publications.

FEERC Researchers Use New Dithering Flow Reactor to Investigate Effectiveness of Three-Way Catalyst (TWC) Materials for Natural Gas Engine Applications with an Industrial Sponsor

Using internal ORNL funds provided by EESD and ETSD, researchers at ORNL/FEERC have designed, constructed, and commissioned a new automated flow reactor system with fast transient flow control and instrumentation capabilities that enable rapid oscillations in gas composition similar to those seen in stoichiometric gasoline and natural gas engine exhaust. Capturing these oscillations, known as dithering, is a key capability for evaluating TWC materials that will play a critical role in achieving emissions compliance with future high efficiency engine technologies, such as highly dilute stoichiometric or lean gasoline engines. After commissioning the reactor, FEERC researchers completed the first phase of a work-for-others (WFO) project aimed at understanding the impacts of composition

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dithering on the effectiveness of a TWC for natural gas engine applications. The WFO sponsor intends to support follow-on research in FY2015. The new flow reactor will also be used for detailed investigations of TWC materials for passive selective catalytic reduction (SCR) applications, a promising strategy for controlling NOx from high efficiency lean gasoline engines.

ORNL Demonstrates 98% Removal of NOx Pollutants in Lean Exhaust to Enable Pathway to more Renewable Fuel Use
Research at ORNL demonstrated 98% NOx reduction on a lean gasoline engine equipped with a silver/alumina catalyst using ethanol/gasoline blends. Ethanol is a very effective reductant of nitrogen oxides over silver/alumina catalysts in the lean exhaust environment. Lean gasoline engines equipped with an Ag/Al_2O_3 catalyst have the potential to deliver higher fuel economy than stoichiometric gasoline engines and to increase biofuel utilization while meeting exhaust emissions regulations. FEERC researchers demonstrated 98% NO_x conversion on a lean burn gasoline engine with ethanol/gasoline blends containing at least 50% ethanol.

Publication in *Wear* related to Lubricating Ceramic-Steel Contact using Zinc Dithiophosphate (ZDDP) and Ionic Liquid (IL) – IL Protects the Steel better but ZDDP Protects the Ceramic better
Z.-B. Cai, H. M. Meyer III, C. Ma, M. Chi, H. Luo, and J. Qu, "Comparison of the Tribological Behavior of Steel-Steel and Si_3N_4-Steel Contacts in Lubricants with ZDDP or Ionic Liquid," pp. 172–183 in *Wear*, **319**, 2014. This publication discusses two base oils of different viscosity grades (SAE 0W30 and 15W40) and two anti-wear (AW) additives (ZDDP and ionic liquid) which were used to explore the effects of viscosity and AW additives on the tribological behavior of steel–steel (AISI 52100– A2 steel) and ceramic–steel (Si3N4–A2 steel) contacts. For steel–steel contact, plate wear was minimal in all lubricants and a low oil viscosity led to a high ball wear rate. Both AWs were effective in wear protection, with IL outperforming ZDDP partially due to reducing adhesive wear. For ceramic–steel contact, oil viscosity had a more important role in the wear performance of the steel plate. Although IL reduced wear to a greater degree for the steel flat than ZDDP, IL generated a higher wear rate for the ceramic ball because of the elimination of a transfer film. Results suggest that the IL's unique function in adhesion reduction is a material-dependent double-sided sward.

INVITED TALKS AND PRESENTATIONS

FEERC Hosts University of Tennessee (UT) Bredesen Center Doctorial Students Showcasing Sustainable Transportation Research
FEERC Researcher Scott Curran gave a graduate seminar for the joint UT/ORNL Bredesen Center for Interdisciplinary Research and Graduate Education. The seminar was followed by tours of the FEERC and Power Electronics Laboratories at the National Transportation Research Center (NTRC) hosted by Scott Curran and Power Electronics researcher Omer Onar. In May of 2014, Scott Curran became one of the first two graduates from the specialized interdisciplinary doctoral program and the first student in the transportation sciences thrust. The tour highlighted the wide range of interdisciplinary sustainable transportation research at ORNL.

FEERC Advanced Combustion Research Featured at Car Training Institute (CTI) Emissions Challenges Conference
FEERC Researcher Scott Curran was an invited speaker at the 2014 International CTI Conference on Emissions Challenges held in Troy, Michigan. The focus of the conference was greenhouse gas emissions, on-board diagnostics and criteria pollutants for current and future vehicles. The conference was well attended by industry and featured many of leading experts in emissions control. ORNL advanced combustion research into multi-cylinder RCCI including emissions control opportunities and challenges and potential fuel economy improvements was presented as an invited talk.

ORNL Staff Meet with Cummins Research Team to Discuss Natural Gas Ignition
ORNL/FEERC researchers Mike Kass and Brian Kaul met with a Cummins team of ignition researchers in Columbus, Indiana. The two ORNL researchers presented the latest results from their investigation to chemically-enhance and stabilize early flame kernel growth and propagation in spark-ignition combustion. Further studies considering the impact of charge motion will be performed and presented to the Cummins team at a later date.

Wagner Attends the Invitation-only SAE North American International Powertrain Conference (NAIPC)
FEERC Director Robert Wagner attended the NAIPC which "is an exclusive, executive-level event where the most profound issues in the automotive industry are presented, discussed, and debated; focusing on current and future challenges and

opportunities in the North American powertrain market." The theme of the 2014 meeting was "Roadmaps for the Future: Challenging Conventional Wisdom". The meeting was also attended by the Dr. Ron Graves, Director of the ORNL Sustainable Transportation Program.

AWARDS

FEERC's Scott Sluder Elected Fellow of the Society of Automotive Engineers (SAE) International

Scott Sluder was elected a Fellow of SAE International in September. Scott was recognized for his sustained technical contributions to mobility engineering including groundbreaking studies elucidating fouling mechanisms of exhaust gas recirculation (EGR) coolers for diesel engines and research critical to guiding national fuel and emissions policies. Scott has been active in SAE for many years, including his most recent role as the Chair of SAE's Land & Sea Operating Group. He contributed critical technical work in support of the 2000 Environmental protection Agency (EPA) ultra-low sulfur diesel rulemaking, the 2010 and 2011 EPA E15 decisions, and the 2014 EPA Tier 3 light-duty emissions regulations.