August 2014 Highlights

ORNL Fuels, Engines, and Emissions Research Center

TECHNICAL HIGHLIGHTS

ORNL Team Commissions New Spray Chamber During Recent Neutron Imaging Fuel Injection Campaign

Eric Nafziger, Derek Splitter, and Todd Toops led an intensive effort to complete and commission a closed loop fuel injection system for use in a neutron imaging beamline at ORNL's High Flux Isotope Reactor (HFIR). The effort is focused on the intra-nozzle fluid dynamics that occurs in gasoline-direct injection (GDI) systems, with a specific focus on identifying the time and location of cavitation events. These events result in gas bubble formation in the injectors, disrupt the spray pattern, and deteriorate the injector material properties. Neutrons are ideally suited for this study due to their high interactions with hydrogen-containing fuel and low interactions with the metal-based fuel injectors. The sophisticated system is designed to operate with commercial and prototype injectors and deliver fuel to the injectors at pressures up to 125 bar. The spray chamber can be operated at absolute pressures as low as 0.2 bar, i.e. sub-ambient, and currently has a maximum pressure just slightly over 1 bar. The vacuum pumps pull the injected fuel, which is primarily in the vapor phase at these pressures, out of the spray chamber and exhausts it into a large vessel that is chilled to ~0°C. This condenses the majority of the fuel and any residual fuel in the argon sweep gas is filtered through a charcoal trap or commercial filtration system. With the help of neutron scientists Hassina Bilheux, Louis Santodonato, and Anton Tremsin, this system was operated continuously at HFIR for 120 hours and relied on an additional team of FEERC researchers—Maggie Connatser, Melanie DeBusk, Charles Finney, and John Thomas—to provide around-the-clock oversight of the operation and ensure the system was working properly. Approximately 1 million injection events are compiled to capture the 7 millisecond (ms) composite injection sequence (1 ms before injection, 1 ms injection, and 5 ms after injection). In the initial analysis of the composite neutron images, it is possible to see both internal injector motion and the spray exiting the nozzle. Just inside the nozzle area, a marked difference in fluid density is also observed during the injection event indicating vaporization of the fluid and possible cavitation. More detailed analysis will be forthcoming.

FEERC and the Coordinating Research Council (CRC) Win a DOE FOA Award to Study Interactions between Future Gasoline Formulations and Engines

A proposal led by Scott Sluder of FEERC in close partnership with the CRC was selected for a $1M award from DOE under a competitive FOA. The project will make use of next generation engine technologies and ethanol blends to develop an engine strategy for improved engine efficiency and emissions, which is expected to result in at least a 25% reduction in petroleum consumption. Future mainstream technologies to be considered include high exhaust gas recirculation levels approaching 25%, dual-stage turbocharging, and a high-energy ignition system as well as high compression ratio pistons to enhance engine efficiency and power density. The base engine in the proposal is a state-of-the-art General Motors (GM) 2.0 L gasoline, turbocharged, direct-injection (GTDI) engine with appropriate control access provided by the CRC through its member companies.

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Winning FOA-988 Proposal: Metal Oxide Nano-Array Catalysts for Low Temperature Diesel Oxidation
The University of Connecticut and the Oak Ridge National Laboratory (ORNL) were awarded a two year, DOE-funded research and development (R&D) project to develop cost-competitive, stable, and efficient nano-catalysts for HC, CO, and NO oxidation at low temperature. Specifically, the project is aimed at identifying a series of low-cost and low temperature diesel oxidation catalysts (DOC) based on metal oxide nano-array configurations which merit various advantages including high materials usage efficiency, multifunctional catalytic oxidation efficiency, excellent robustness, and cost-effectiveness in both materials and manufacturing protocols. Eventually, the nano-array catalysts are expected to be able to be directly implemented for on-board vehicle demonstration at low temperature. Todd Toops is the ORNL lead for this activity.

Winning FOA-991 Proposal: Next Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines
Ford Motor Company, ORNL, and the University of Michigan will jointly carry out a three year, DOE-funded R&D project to identify potential low temperature automotive catalysts that meet future LEVIII emissions requirements while satisfying regulatory mandates of fuel economy (54.5 mpg) and the concomitant efficiency improvements that will by necessity reduce exhaust sensible heat. This project will build on promising research in the areas of nano-structured, highly engineered, support materials and chemical treatments shown to reduce precious metal sintering, base metal oxides that can replace precious metals, and novel core-shell materials that have shown promise to reduce precious metal particle migration and interactions, and inhibition or poisoning. Todd Toops is the ORNL lead for this activity.

ORNL Team Wins DOE FOA on Ionic Liquid-Additized Engine Oil
The ORNL-GM team won an award of the VTO FOA 991 to further develop the ionic liquid-additized low-viscosity engine oil meeting the GF-5/6 specifications and possessing superior lubricating characteristics, and expand the ionic liquid additive technology to rear axle lubricant to gain a combined 4% improvement in vehicle fuel economy. The PIs include Jun Qu, Huimin Luo, and Todd Toops from ORNL and Michael Viola from GM R&D Center.

ORNL Member of Winning Delphi Team on $25M DOE FOA Project
ORNL-FEERC researchers are partners for the Delphi-led FOA award on "Ultra Efficient Light Duty Powertrain with Gasoline Low Temperature Combustion." Additional project members include Hyundai and Umicore. DOE support for this project will be $10M with Delphi and the other industrial partners providing the additional cost share. Delphi is a leading developer of gasoline compression ignition engine technology and will continue this development to demonstrate the fuel efficiency and low emissions potential in a vehicle. Due to the low temperature of the combustion, these engines have very high thermal efficiency with very low NOx and particulate matter emissions. ORNL will be working with Delphi at their Auburn Hills facility to characterize the PM and HC emissions from these advanced engines and corresponding vehicles.

INVITED TALKS AND PRESENTATIONS

ORNL-led Team Successfully Organizes 8th International Conference on Environmental Catalysis (ICEC)
FEERC staff members organized the highly successful 8th ICEC held August 24–27 in Asheville, North Carolina. Todd Toops served as the conference Chair, Bill Partridge as Co-Chair, Jae-Soon Choi as Treasurer, and Charles Finney as Web Chair. The conference showcased leading international science contributions in the fields of Sustainable and Clean Energy Production, Emission Control, Water Treatment, Indoor Air Cleaning, and Green Chemistry. Approximately 400 attendees representing 44 countries attended and there were 149 oral presentations and close to 200 poster presentations. The meeting was hosted by the Southeastern Catalysis Society, in which ORNL staff have participated actively since its founding. The ORNL conference team collaborated closely with Scientific Program Chairs, Prof. James Spivey (LSU) and Dr. Nitin Kumar (LSU), as well as many other internationally known catalysis experts from universities and industry that made up the full scientific and advisory committees.

FEERC Researchers Present Advanced Combustion Research at DOE/Industry/University Working Group Meeting
FEERC researchers Dean Edwards, Brian Kaul, Adam Dempsey, and Scott Curran presented advanced combustion research at the Advanced Engine Combustion (AEC) Working Group meeting at the United States Council for Automotive Research (USCAR) facility in Southfield, Michigan, on August 19–21, 2014. Dean Edwards presented recent modeling findings from ORNL high-performance computing (HPC) collaborations with industry partners and an overview of ORNL's efforts in accelerating advanced engine development with HPC and predictive simulation. Brian Kaul presented research on control of

cycle-to-cycle dynamics for dilution limit extension in high-exhaust gas recirculation (EGR) stoichiometric GDI engines. Adam Dempsey presented an in-depth study of the effect of first injection timing on low temperature combustion gasoline compression ignition using a low octane fuel supplied by Chevron. Scott Curran reported recent findings from multi-cylinder reactivity controlled compression ignition (RCCI) experiments including fuel effects, engine mapping, and vehicle system simulation estimates of diesel/RCCI multi-mode fuel economy. Other presenters included universities that were recipients of the new DOE/NSF Partnership on Advanced Combustion Engines, and industry members of the AEC working group. ORNL has been participating in the AEC working group for over seven years.

ORNL Co-Chairs and Presents at Symposium on Dimethyl Ether (DME) as a Transportation Fuel
John Storey and Robert Wagner of ORNL-FEERC, along with André Boehman of the University of Michigan and William Northrop of the University of Minnesota, recently co-organized a symposium at the 248th American Chemical Society National Exposition, held in San Francisco, California. The symposium, "Production, Distribution, and Utilization of Dimethyl Ether as a Transportation Fuel," featured international experts speaking on the potential benefits of using DME as a substitute for diesel fuel. DME can be made from natural gas and due to the recent finds of domestic gas, the price per gallon equivalent is about 75% that of diesel fuel. In addition to co-chairing the symposium, John Storey presented a paper co-authored with Jim Szybist of ORNL-FEERC titled, "Emissions and Performance Benchmarking of a Prototype Dimethyl Ether-Fueled Heavy-Duty Truck."

FEERC Attends U.S.-China Clean Energy Research Center (CERC) Meeting on Clean Vehicles
Robert Wagner of FEERC and several other ORNL staff members attended the U.S.-China CERC meeting on Clean Vehicles at the University of Michigan. Robert is the ORNL-lead for the CERC. ORNL has a significant role in the areas of bio-renewable fuels, combustion, and energy storage. This annual meeting brings together more than 100 researchers from the U.S. and China to discuss on-going collaborative research.

FEERC Co-organizes Engine Simulation Workshop with the DOE and Sandia National Laboratories
Robert Wagner co-organized a DOE Vehicle Technologies Office (VTO) workshop to help define the role of DOE in supporting the development of advanced engineering computational fluid dynamics (CFD) codes for advanced engine and combustion technologies. Other organizers included Sreekanth Pannala from ORNL, Paul Miles from Sandia National Laboratories, and Leo Breton and Gurpreet Singh of the DOE Advanced Combustion Engines R&D program. This workshop brought together stakeholders from industry, universities, national laboratories, and software vendors. Dean Edwards also of FEERC presented an ORNL perspective on engine combustion simulation. A roadmap is currently under development and expected to be complete later this year.

AWARDS

FEERC Interns Recognized for Research at ORNL
A number of recent FEERC summer student researchers have been recognized for the research they completed while being mentored by FEERC researchers. Ashley Thompson, an undergraduate mechanical engineering student from the University Chattanooga, was selected as a winner for the 2014 American Society of Mechanical Engineers (ASME) Internal Combustion Engine Fall (ICEF) Undergraduate Student Presentation Competition based on her work modeling lean-gasoline aftertreatment with Vitaly Prikhodko and Jim Parks. Karson Stone, an undergraduate mechanical engineering student from the University of Tennessee and a participant in the NSF Research and Instructional Strategies for Engineering Retention (RISER) program, won honorable mention for a poster at the University of Tennessee's College of Engineering poster session for the Center for Materials Processing (CMP). Her poster covered research on a well-to-wheel analysis of alternative diesel fuels with Scott Curran and Robert Wagner of FEERC. Michelle Edwards, an undergraduate in civil engineering from Tennessee Tech, along with Karson Stone both presented posters on well-to-wheels analysis at a the University of Alabama's Sustainable Fuels: Production and Combustion workshop.