DieselNet: What's New

Conference report: ASME 2011 ICE Fall Technical Conference

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This year's ASME Internal Combustion Engine Division Fall Technical Conference was held on October 2-5, 2011 at the Waterfront Place Hotel in Morgantown, West Virginia. It was hosted by West Virginia University (WVU). There were 183 registered attendees and about 100 technical presentations.

The conference included a lunch time talk by Dr. Eric Kurtz, Diesel Combustion Technical Expert, Ford Motor Company. He discussed Ford's perspective on the challenges and opportunities for internal combustion engines for light-duty vehicles.

For SI gasoline engines, downsizing and direct injection appear to be the technology path for the future. Challenges for these engines are PM emissions, avoiding knock and improving part load efficiency. Unlike diesel where PM emissions are a result of poor air/fuel mixing, PM emissions from DISI engines are predominantly a result of wall wetting. Minimizing wall wetting is thus a critical feature to keeping PM emissions from these engines low. Avoiding knock may require use of higher octane number fuels such as E85 or higher octane gasoline. The refinery impact of increasing high octane number gasoline production is currently unclear. Part load efficiency can be improved by reducing throttling losses with lean combustion or stoichiometric combustion with higher EGR ratios.

For diesel engines, advanced combustion strategies will be an important technology to meeting future design targets. Associated with many of these strategies is a noise vs. efficiency trade-off. Noise is an important factor that could impact consumer acceptance of light-duty diesel technology. Interestingly, higher and more consistent cetane number was discussed as an enabler for new combustion modes, improved performance and improved efficiency. Higher cetane number is also beneficial for emissions reductions from engines utilizing conventional diesel combustion.

Improved cold starting performance of diesel engines was also identified as an important area of research. Reduced hydrocarbon emissions and improved stability are critical cold start performance parameters that need attention. A higher cetane number fuel would help here as well.

A third area important for diesels is technologies that enable improved aftertreatment performance. As an example, the difference in light-off performance between diesel and gasoline engines was discussed. Typical diesel catalyst light-off times are about 200s while those for gasoline engines are 20s. Shortening the diesel light-off times would enable further CO_2 reductions.

Locomotive Engines. Work continues on technologies to meet upcoming locomotive emission standards. The University of Michigan and Peaker Services characterized exhaust emissions from a 1973 EMD 16-645E3B line haul locomotive fitted with an early-development Tier 0+ emissions kit. Results showed that NOx emissions comfortably met the Tier 0+ NOx limit but PM just barely met the limit. At notches 3-8, while the largest contributor to PM mass was insolubles (mostly elemental carbon), solubles were also significant. Well over half of the solubles were oil-like hydrocarbons. Advancing combustion timing, at the expense of a small increase in NOx, and reducing engine oil consumption were identified as possible measures to further reduce PM [ICEF2011-60102].

Electro Motive reported on simulation work based on an EMD 710 Tier 2 engine that showed emissions reductions relative to Tier 2 levels are possible with combustion chamber optimization. A wider and shallower piston bowl to allow for further spray penetration and better air entrainment with spray targeted into the corner of the piston bowl seemed to be most promising approach [ICEF2011-60155].

Gas Engines. A number of topics related to gas engines fuelled with various fuels were covered. Woodward, Inc. reported on progress they had made on a high performance passive prechamber spark plug (Woodward Lean Quality Plug, WW-LQP) and ignition system intended to enable faster and more stable combustion under increasingly lean conditions for large stationary natural gas engines. Testing at $\lambda = 1.69$ showed the WW-LQP to have a better COV of IMEP than a J-gap plug and a conventional pre-chamber plug [ICEF2011-60115].

Colorado State University and Cummins presented results on measures that could be taken to compensate for engine operation in wellhead gas compression applications where considerable variability in gas quality can be experienced. Using a low compression ratio (to avoid knock) Cummins GTA8.3SLB engine operating under lean, closed-loop equivalence ratio control, they determined that NOx and CO emissions increased with decreasing methane number while combustion stability remained constant. NOx increases could be avoided by reducing equivalence ratio for low methane number fuels while spark timing could be advanced to maintain engine performance when diluents were present [ICEF2011-60071].

For stationary rich burn spark ignition engines, non selective catalytic reduction (NSCR) is a potential emission control technology. However, consistently controlling the emissions level below the compliance limits can be a significant challenge. One contributing factor identified by Kansas State University is that oxygen sensor output is influenced by the concentration of reducing species such as CO and H_2 [ICEF2011-60188].

Caterpillar reported on engine performance tests with producer gas (syngas) on a single cylinder test engine to explore the engine operating limits and combustion characteristics. A small amount of CH_4 in the fuel appears to be important to lower the rate of the main branching reaction of hydrogen and mitigate the explosive reaction of hydrogen. High exhaust levels of CO emissions, from the unburned fuel CO component, would require an oxidation catalyst. Emissions and lean limit AFR can vary widely depending on fuel composition [ICEF2011-60060].

Alternative Engine Concepts. The increased interest in alternatives to the slider-crank mechanism that dominates current engine designs was also reflected in this year's program. Achates Power and Da Vinci Emissions Services reported on oil consumption measurements on Achates Power's opposed-piston two-stroke diesel engine. A weighted average fuel-specific lubricant oil consumption of 0.18% was achieved [ICEF2011-60140].

Szechenyi Istvan University and West Virginia University reported on a two-cylinder, two-stroke, common rail direct injection, compression ignition linear engine/alternator. The engine was far from optimized but the trends of engine behavior were clearly determinable [ICEF2011-60157].

Applied Thermal Sciences' HiPerTEC engine is an opposed free-piston engine arranged in a toroidal configuration with two counter reciprocating sets of pistons [ICEF2011-60226]. A control system for this engine has been developed that was demonstrated up to an effective speed of 2,200 rpm [ICEF2011-60225].

Emissions and Emission Control. Massachusetts Institute of Technology, Aerodyne Research, Inc. and AeroMegt GmbH demonstrated that real-time measurements of size, mass and composition of submicron lubricant-derived particle emissions can be carried out with a Soot Particle Aerosol Mass Spectrometer (SP-AMS) developed by Aerodyne Research. A good correlation between oil consumption and measured levels of lubricant-derived trace elements in the particle phase was shown [ICEF2011-60100].

MIT also presented work where they used conventional lubricant additives (Ca, Mg and Zn) as elemental tracers to elucidate details of ash buildup and transport within individual diesel particulate filter (DPF) channels. Beginning with a clean DPF, ash initially accumulates along the channel walls and then slowly migrates toward the back of the channels to form end-plugs. More ash is transported to the back of the channels in a highly ash-loaded filter relative to a filter with only low or moderate ash levels. It was also observed that ash may be removed from the walls and transported to the back of the channel in either a continuous or periodic fashion. The continuous process is characterized by the removal of small ash particles from the ash layer on the wall surface. The periodic process is the result of bulk removal and transport of larger ash agglomerates or entire pieces from the wall surface layer. Significant non-uniformities in the ash end-plug packing density can result from these transport mechanisms [ICEF2011-60072].

In another study, Andreas Mayer, TTM, Jan Czerwinski, University of Applied Sciences Biel and Markus Kasper, Matter Aerosol AG investigated nanosize metal oxide particulate emissions from vehicles with SI engines. They found that metal oxide particulate emissions from SI engines, primarily Zn and Ca from lube oil, can be comparable to those typical of diesel engines. Size dependent measurements were not carried out [ICEF2011-60045].

West Virginia University and Pegasor Oy assessed the capabilities, limitations and sensitivity of the Pegassor in-line PM sensor. Test results demonstrated a stable and repeatable response over consecutive ETC and FTP cycles, as well as over idle and constant load operation with coefficients of variation below 2% [ICEF2011-60142].

The University of Michigan investigated several issues relevant to combination Lean NOx Trap and Selective Catalytic Reduction (LNT-SCR) catalyst systems, such as the Eaton Aftertreatment System (EAS). They used an iron zeolite SCR catalyst. It was discovered that the required increase in NO_2 concentration at the inlet of the SCR can result in the formation of large quantities of N_2O in the 200°C to 400°C range with subsequent N_2O decomposition by NH_3 occurring above 350°C. It was recommended that the global chemical reactions for SCR of NOx in lean exhaust be modified to reflect this observation [ICEF2011-60114]. Also, H_2O and CO_2 levels resulting from the lean-rich cycling inhibits the NH_3 storage capacity of the SCR catalyst with H_2O being the stronger inhibitor of the two [ICEF2011-60233].

West Virginia University and M.J. Bradley & Associates verified the operating principle and the NOx reduction potential of a NOx scrubber for potential marine applications. The system works on the principle of absorption of NOx species into water. Since NO is relatively insoluble in water, an oxidation catalyst is required upstream of the scrubber to maximize the conversion of NO to NO_2. A catalyzed DPF minimized the contamination of the scrubber with diesel PM. A packing material placed in the scrubber increases the surface area for NOx absorption. The scrubber liquor circulates in a closed loop and its final composition is a weak nitric acid solution. Engine testing showed NOx conversions from 17%-60% depending on exhaust flow rate and scrubber length. A scrubber of about 3 m in length was required to achieve the highest NOx conversions measured. Adding hydrogen peroxide to the scrubber liquor can improve the NOx reduction efficiency [ICEF2011-60182].

The effect of HC fouling under conventional and PCCI combustion modes on the NOx reduction performance of commercial Fe-and Cu-zeolite SCR catalysts was presented by Oak Ridge National Laboratory. The Fe-zeolite NOx conversion efficiency was significantly degraded by similar amounts for both combustion modes, especially at low temperatures (<250°C). The Cu-zeolite catalyst was much more resistant to HC fouling but relative to conventional combustion, PCCI exhaust had a more significant impact. Catalyst performance was recovered after heating to 600°C for both cases [ICEF2011-60129].

West Virginia University and South Coast Air Quality Management District discussed a technique that could be used to develop multiple engine calibrations to optimize operation of engines equipped with DPF-SCR systems for different driving conditions. In cases where there may be insufficient heat in the exhaust to allow an SCR catalyst to achieve a high NOx reduction efficiency, the ECU would shift the engine maps to a calibration emitting lower engine-out NOx in order to ensure compliance with emissions regulations. On the other hand, during operating conditions with sufficient exhaust temperature to realize a high SCR conversion efficiency, higher engine-out NOx levels can be tolerated and the engine maps can be shifted to a more fuel consumption oriented calibration [ICEF2011-60134].

Biodiesel. Several papers discussed issues pertinent to current biodiesel trends including algae derived biodiesel, emissions from post 2007 heavy-duty engines, engine oil dilution and soot generation.

Colorado State University presented an overview of selected issues important to algae derived biodiesel. Several microalgae species under consideration as biodiesel feedstocks produce lipids with relatively high quantities of long chain-polyunsaturated fatty acids (LC-PUFA). These can create challenges in meeting oxidative stability and cetane number requirements of current biodiesel standards. Removal of a portion of these LC-PUFA fatty acids, which may be economical because of the current high value of these products as nutritional supplements, can improve oxidative stability sufficiently to meet a 3 h Rancimat requirement. However, their removal would result in biodiesel high in saturates and thus with poor low temperature properties. It may also flood the market with LC-PUFA, depressing their price and making removal less economical. Alternatively, anti-oxidants such as TBHQ could be used to improve oxidative stability. Minimum TBHQ concentrations of 300 ppm and 600 ppm would be required to meet the 3 h ASTM and 6 h EN limits respectively. Algae derived biodiesel can also have cetane numbers as low as 38 making it necessary to use cetane enhancers to meet cetane number limits for B100 [ICEF2011-60047].

The National Renewable Energy Laboratory tested two 2008 model-year heavy-duty diesel engines (a Cummins ISB and a Navistar Maxxforce 10) using four petroleum diesel fuels and five blends of B20 derived from various sources. Both engines were equipped with actively regenerated DPFs. Fuel consumption was roughly 1.5% to 2% greater for the B20 blends versus ULSD in both engines. NOx emissions for the Cummins ISB engine were about 2.5% higher with most of the B20 blends. No statistically significant difference in NOx could be detected with the Maxxforce 10 engine because of the high degree of variability demonstrated by this engine. CO, THC and PM emissions for all fuels was reduced to nearly undetectable levels by the aftertreatment system. The paper also reported some observations of the effect of active DPF regeneration on emissions and fuel consumption [ICEF2011-60106].

Other biodiesel papers included one by Tokyo City University and Riken Corp. that found that post injection of B100 could produce local fuel dilution rates as high as 90% near the top ring reversal point of the cylinder liner [ICEF2011-60210] and one by Wayne State University that explored in-cylinder soot evolution differences between ULSD and B20 [ICEF2011-60146].

Combustion. The University of Michigan evaluated the potential fuel economy benefits of integrating a dual-mode SI-HCCI engine into a conventional vehicle, a mild parallel hybrid and a power-split hybrid. The dual-mode engine in the conventional vehicle offers only a modest gain in vehicle fuel economy of approximately 5-7% because the transmission and shift schedule limit the amount of time spent in the HCCI operating window. By using a control strategy that minimized the number of engine mode transitions and maximized the time spent in HCCI mode, the parallel hybrid with the dual-mode engine provided up to 48% improvement in city driving. When the mild parallel hybrid was fitted with a conventional SI engine, the improvement was 32% over the baseline vehicle. The dual mode engine provided little benefit in the power-split hybrid because the relatively high engine loads largely avoiding the HCCI window [ICEF2011-60160].

Several papers examined using aspects of reactivity controlled compression ignition (RCCI). This approach uses direct injection of diesel fuel and port injection of an SI engine fuel such as gasoline. Oak Ridge National Laboratory compared RCCI against both conventional diesel combustion (CDC) and premixed charge compression ignition (PCCI) strategies applied to a light-duty diesel engine. For RCCI, engine-out emissions of NOx and PM were found to be considerably lower, HC and CO emissions higher and brake thermal efficiency was similar or higher. Despite the reductions in NOx and PM emissions with RCCI, an oxidation catalyst will be required for CO and HC control and some level of NOx and PM aftertreatment will still be needed [ICEF2011-60227].

The University of Wisconsin-Madison used numerical simulations to explore the use of hydrated (wet) ethanol in a heavy duty RCCI engine. Using hydrated ethanol minimizes the amount of water that must be removed in ethanol production and improves the net energy balance. The results showed that hydrated ethanol can be lead to gross indicated thermal efficiencies up to 55% and very low emissions. A 70/30 ethanol/water mixture (by mass) was found to yield the best results across the entire load range without the need for EGR [ICEF2011-60235].

Westport Innovations explored of a novel natural gas fueling strategy combining auto-ignition, premixed and non-premixed combustion to achieve high load and high efficiency with low emissions. Their commercial 15L direct injection natural gas heavy duty engine was modified to enable both premixed and non-premixed combustion modes. Direct injection of natural gas during the intake was used to generate a lean premixed charge and diesel injection during compression generated a premixed mixture that auto-ignited near TDC. For high load, a second pulse of natural gas around TDC generated a late non-premixed combustion event. Up to 19 bar BMEP was achieved at NOx below 0.2 g/bhp-hr and brake thermal efficiency above 40% [ICEF2011-60181].

Oak Ridge National Laboratory characterized stoichiometric spark assisted (SA) HCCI using three gasoline-like fuels in a direct injection SI engine: gasoline, a 50 vol% blend of iso-butanol and gasoline (IB50) and E85. The stoichiometric SA-HCCI regime was demonstrated improved load range (up to 700kPa IMEP) and tolerance to a wide range of fuel properties including octane number. Varying spark timing, injection timing and intake valve closing angle was required to accommodate variations in fuel properties. A three way catalyst would be required to lower emissions of NOx, CO and HC. Reduced throttling losses and decreased combustion duration provided a higher efficiency than conventional SI combustion [ICEF2011-60122].

General Motors carried out a study to understand the improvement in combustion performance of a 4-valve SIDI wall-guided engine operating at lean, stratified idle with enhanced in-cylinder charge motion by deactivating one of the two intake valves. Valve deactivation primarily increased the in-cylinder swirl intensity as compared to opening both intake valves. Engine dynamometer measurements showed improved combustion stability, increased combustion efficiency, lower fuel consumption, and higher dilution tolerance [ICEF2011-60171].

The University of Michigan and Robert Bosch LLC used modeling to compare two-stage boosting systems for a 4-cylinder, 2.0 liter engine. Two turbochargers connected in series (TCTC) was compared to a turbocharger followed by a small supercharger (TCSC). When intake pressures for the two charging systems are matched, the BSFC for the TCSC system was worse. However, when the amount of fresh air supplied by the two systems was matched, the BSFC of the TCSC system was comparable or even better than the TCTC system. The supercharger resulted in lower exhaust manifold backpressure that minimized pumping losses. The parasitic losses of the supercharger were kept low because a lower intake pressure was required. Pumping losses for the TCTC system are high because of the high exhaust back pressures required to generate the high boost pressures required for HCCI combustion from relatively low enthalpy exhaust gas. The system with the supercharger also had higher pre-catalyst exhaust temperatures than the TCTC system, making it more favorable in terms of catalyst warm up [ICEF2011-60220].

Other Topics. MAHLE GmbH discussed a new ductile iron (DI), also known as nodular iron or spheroidal-graphite (SG) cast iron, to meet demand for stronger wet cylinder liners required for increased peak firing pressures in diesel engines. The new material has about 60 and 70% higher limits respectively for tensile stress and fatigue resistance as compared to conventional gray cast irons, while providing good tribological properties. The material also offers the potential to avoid cavitation on the outside liner surface due to its higher Young’s modulus (i.e., stiffer). Testing in a heavy-duty diesel engine showed the material, combined with induction hardening and a slide honing structure on the running surface, is suitable for peak cylinder pressures up to 250 bar [ICEF2011-60163].

Mahle Industries has developed a testing method to accurately measure small changes in engine BSFC resulting from design changes meant to decrease piston friction. Since these changes in BSFC will be small, it is a considerable challenge to precisely quantify them using an engine dynamometer. The repeatability (quantified as 2σ COV) of BSFC measurements from build-to-build was determined to be 0.17% [ICEF2011-60219].

Oak Ridge National Laboratory modeled the implications of motor/generator and battery size on fuel economy and GHG emissions in a medium-duty (33,000 lb) PHEV. The optimal solution was found to be a 120 kW motor/generator connected in a parallel configuration to the driveline after the transmission combined with a 10-module battery. A 40% improvement in fuel economy and a 30% reduction in GHG emissions relative to a non-hybrid diesel vehicle was calculated [ICEF2011-60028].

Hitachi, Ltd. discussed a new injector for direct injection gasoline engines to reduce exhaust emissions and fuel consumption. The injector has a bounce-less valve closing mechanism to control THC emissions by preventing the injection of large droplets and quick-response moving parts to enable a 25% reduction in minimum injection quantity for reducing fuel consumption under low load engine conditions [ICEF2011-60032].

Conference website: www.asmeconferences.org/ICEF2011