Fuel Engine Technologies

Oral

The path towards a high efficiency IC engine

Bengt Johansson - KAUST, KSA

The internal combustion engine has great potential for high fuel efficiency. The ideal otto and diesel cycles can easily achieve more than 70% thermodynamic efficiency. The problems come when those cycles should be implemented in a real engine. Extreme peak pressure during the cycle will call for a very robust engine structure that in turn will increase friction and hence reduce mechanical efficiency. A very high compression ratio also increase the surface to volume ratio and promote heat losses, taking away much of the benefits from the theoretical cycle.

The presentation will start with a standard SI engine and it's efficiency as a function of load. Then a high compression ratio SI with be introduced and compared with the same engine operated in HCCI mode. The four efficiencies of SI as well as HCCI will be discussed and variations like HCCI with negative valve overlap and higher mean piston speed will be shown. A next step is the results with Partially Premixed Combustion. With PPC the indicated efficiency was shown to be up to 57%, thus 10% up from the best HCCI engine of 47%. However, to get the very high efficiency a high dilution level is needed. This is a challenge for the gas management system and hence gas exchange and mechanical efficiencies can suffer. The final part of the presentation is giving an engine concept that can enable the conditions for PPC combustion but with much improved gas exchange and mechanical efficiency. It enables an effective compression ratio in excess of 60:1 but with much less cylinder surface area. The concept also enables low friction and hence high mechanical efficiency. The basic concept will be explained and initial simulation results will be presented.

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Fuel Additives for Ultra Low Sulphur Diesel Fuel

Laura MacIver - innospec inc, USA

Hydro-desulphurisation process removes sulphur, nitrogen and oxygen from the fuel, which affects the fuels natural lubricity, conductivity, thermal stability, vulnerability to form peroxides, cetane number and low temperature properties. The process removes trace materials that provide natural lubricity to fuels which can then lead to fuel-pump wear and subsequent engine failure. The simple addition of a suitable fuel lubricity improver will provide effective boundary lubrication for a broad range of diesel fuels and other middle distillates.

Safety is critical when refining or handling fuels. However, as fuels have become 'cleaner', the risk of electro-static ignition has increased dramatically. Addition of a static dissipater can increase the conductivity of the fuel to a safe state and hence significantly mitigate any risks associated with static-discharge. Hydro-desulphurisation also removes the naturally occurring antioxidant characteristics of middle distillate fuels thus allowing formation of peroxides in storage. Peroxides promote oxidation and the use of appropriate polymerisation antioxidants can be added to prevent such degradation taking place. When sulphur is removed during the Hydro-desulphurisation process the fuels become more paraffinic this can lead to a beneficial increase in the natural Cetane number but the increase is limited. The use of cetane number improver can be added to ensure the fuel meets the required specification. Such highly paraffinic fuels also have an effect on the wax content of the fuel resulting in worsening low temperature properties. Large wax crystals can block fuel filters, pipes and hoses cutting off supply to the engine. Conventional cold flow Improvers are often in-effective with such fuels and the use of more modern cold flow improver technology is often required to alleviate this issue and meet the required low temperature fuel specifications.

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Understanding the spectrum of diesel injector deposits and exploring the impact on fuel efficiency

David Spivey - Lubrizol, UK

Diesel fuel injector fouling used to be predominantly associated with organic coking of nozzle orifices, due to decomposition of fuel during the combustion process. However, in modern more sophisticated fuel injectors, designed to help deliver enhanced emissions and efficiency, increased susceptibility to a wider range of deposit types has been observed. As a result, the full spectrum of deposit types now observed ranges from organic to partially or fully inorganic, and from nozzle coking to those that can impact the operation of internal components in the injector, so called Internal Diesel Injector Deposits. These various types of deposit, and their causes, are reviewed.

Impacts from such deposits can range from power loss, emissions and driveability through to deterioration in fuel efficiency, and even failure of the engine to operate. These impacts are explored, along with potential solutions to prevent or indeed remove such deposit formation. The impact of injector nozzle fouling on fuel efficiency is discussed in detail, with a careful analysis of available data used to show a clear relationship.

Oral

Physical and Chemical Effects of Low Octane Gasoline Fuels on Compression Ignition Combustion

Jihad Badra - Aramco, KSA

Gasoline compression ignition (GCI) engines running on low octane gasoline fuels are considered an attractive alternative to traditional spark ignition engines. In this study, three fuels with different chemical and physical characteristics have been investigated in single cylinder engine running in GCI combustion mode at part-load conditions both experimentally and numerically. The studied fuels are: Saudi Aramco light naphtha (SALN) (Research octane number (RON) = 62 and final boiling point (FBP) = 91°C), Haltermann straight run naphtha (HSRN) (RON = 60 and FBP = 140°C) and a primary reference fuel (PRF65) (RON = 65 and FBP = 99°C). Injection sweeps, where the start of injection (SOI) is changed between -60 and -11 CAD aTDC, have been performed for the three fuels. Full cycle computational fluid dynamics (CFD) simulations were executed using PRFs as chemical surrogates for the naphtha fuels. Physical surrogates based on the evaporation characteristics of the naphtha streams have been developed and their properties have been implemented in the engine simulations. It was found that the three fuels have similar combustion phasings and emissions at the conditions tested in this work with minor differences at SOI earlier than -30 CAD aTDC. These trends were successfully reproduced by the CFD calculations. The chemical and physical effects were further investigated numerically. It was found that the physical characteristics of the fuel significantly affect the combustion for injections earlier than -30 CAD aTDC because of the low evaporation rates of the fuel because of the higher boiling temperature of the fuel and the colder in-cylinder air during injection.

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Refinery Additives

Thomas Paschkowski - BASF, UAE

With increasing worldwide demand for diesel fuel, more stringent environmental legislation for transportation fuels, and changing fossil energy resources, refiners are facing many significant challenges. Refinery additives offer a wide range of solutions to many of these challenges and play an important role in the manufacture of modern, high quality transportation fuels. From cold flow improvers assuring the operability of diesel fuels even at cold temperatures and lubricity additives preventing wear in diesel distribution pumps, to antistatic additives providing a minimum conductivity in low sulfur fuels, refinery additives are an answer to many problems encountered in the production of fuels today. Examples of the important role refinery additives play in the production of transportation fuels will be discussed during this presentation.

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Deposit Control Additives and their Application to Direct Injection Gasoline Engines

John Bennett - Afton Chemical Ltd, UK

As vehicle manufacturers strive to deliver increased fuel efficiency from their vehicles, Direct Injection Gasoline (DIG) engines have becoming globally widespread, and in 2017 will be a half of global gasoline engine production. However, whilst the technology might be more modern than tradition port fuelled engines, the need to control deposits remains as strong as ever, and potentially even more critical. This presentation will discuss the growth of the DIG engine, what challenges arise from the deposits in these engines and what solutions can be offered by the use of deposit control additives. Conversely, whilst half of new engines may be DIG, the other half will still be port fuelled and will also need protection against deposit formation, so the need to encompass both engine types will also be discussed. Examples of the effects of deposits in DIG engines will be shown, alongside demonstration of the performance, efficiency and emissions benefits delivered by control of those deposits.

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Octane On Demand or an Effective Way to Improve SI Engines and Fuel Adequacy

Loic de Francqueville - IFP Energies Nouvelles, France

Reduction of Green House Gas (GHG) and then CO_2 emissions is paramount for industry and transportation worldwide. In addition to being compliant with regulations on harmful pollutant emissions, car manufacturers have a big pressure to decrease fossil fuel consumption. There is a synergetic way to be found in the fuel and engine adequacy. Indeed, not only engine efficiency must be improved, but Well-to-Wheel (WtW) CO_2 emissions must be reduced. In addition, in some parts of the world, legislation imposes some bio-content in the fuel (currently 10% energy-based in Europe). In this context, Saudi Aramco and IFP Energies Nouvelles are working together to pave the way for promising fuel formulations altogether with highly efficient engine solutions. The present work is focused on Spark Ignition (SI) engines. Knocking (abnormal combustion which decreases the engine efficiency at high load) is the biggest limitation for the improvement of SI engines. It is especially limiting the downsizing (engine displacement reduction), which is one of the most promising strategies to increase SI engine efficiency. Therefore knock-limiting technologies are key improvers for modern SI engines and could also lower the constraints on refining industry. The aim of the current research program is to adapt on demand the fuel Research-Octane-Number (RON) injected in the combustion chamber to prevent knock occurrence and keep combustion phasing at its optimum. This is achieved by a dual fuel injection strategy, involving a low-processed, low-RON naphtha-based fuel (naphtha, RON 71) and a bio-sourced, high-RON octane booster (ethanol, RON107). The ratio of fuel quantity on each injector is adapted to fit the RON requirement as a function of engine operating conditions. The Octane On Demand (OOD) concept is still under development. Preliminary encouraging results were obtained on a 1.6L turbocharged GDI+PFI engine. Among various octane boosters that were evaluated (ethanol, refinery reformate, a mixture of di-isobutylenes (DIB), 2-butanol, and a mixture of butanols (patented Saudi Aramco stream, SuperButolâ„¢), ethanol has shown to be the most promising one. Driving cycle simulations performed on an M-segment vehicle showed that 4% Tank-to-Wheel CO_2 benefit are expected on the WLTP cycle. Combined with 5% Well-to-Tank CO_2 reduction, estimated from Life Cycle Analysis (LCA), the OOD concept enables an overall potential of 9% WtW CO_2 benefit compared to regular E5 RON95 gasoline. The next step of this work is to build by the end of 2016 a vehicle demonstrator equipped the OOD engine technology.

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Developing combustion systems for high efficiency SI and CI engines

Ernst Winklhofer - AVL List GmbH, Austria

The market for automotive vehicle propulsion systems is driven by the respective legislative frameworks, the fuels' availability and infrastructure and the technologies to provide cost effective combustion engines. Diesel and gasoline engines continue to be the central power sources, supported by electrical systems to enhance these engines' emissions and driveability qualities. The combustion systems, however, will continue to being developed to exploit their thermodynamic limits with "clean combustion" to meet both emissions and fuel efficiency requirements. In passenger car (PC) gasoline engines, combustion systems benefit from direct injection turbocharged (DI TC) operation, combustion of stoichiometric mixtures provides highly attractive torque characteristics and engine control strategies support clean combustion even at the level of individual combustion cycles. In Diesel engines, the fuel injection process is at the center of combustion strategies, aided with actuators to handle air and exhaust gas (EGR) for exploiting thermodynamic efficiency and conditioning the exhaust gas for best aftertreatment functionality. The paper, first of all, defines the concept of "clean and efficient" combustion and how fuels and mixture formation processes take influence on combustion quality. Such basic insight is extended to focus on the requirements and on some engineering details to providing the fuel – air mixtures suited to enable clean combustion. Implementing these combustion concepts into the target operating regimes of an actual vehicle then is the engineering challenge to enable exploitation of desired fuel efficient engine operation. We describe key features of today's spark ignition (SI) and compression ignition (CI) systems and give focus on the fuels' influence in achieving emissions and efficiency targets. In developing modern combustion systems, their complexities are addressed with a well selected mix of simulation and testing. The paper, in particular, describes fuel – air mixture formation processes and the selection and calibration of fuel injection systems to achieve target performance and emissions qualities. This includes examples of test facilities and instrumentation applied to the analysis of combustion processes under conditions relevant for practical engine development

Fuel Engine Technologies

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Comparison of on-board fuel reforming for hydrogen production using air, normal combustion exhaust gas and lean burn exhaust gas in vehicle

Seunghyeon Choi - KAIST, South Korea

In current days, fuel economy of automobile become major concerns for not only consumers but also automobile products. Hydrogen application in vehicle system emerges a new solution for those drawbacks. The addition of hydrogen in lean burn combustion is one of the way to increase fuel economy and reduce toxic exhaust gas components such as unburned hydrocarbon, carbon monoxide and nitrogen oxides (NOx). Hydrogen also use as reduction agent for selective catalytic reduction (SCR) equipment. Finally, hydrogen can be fuel for solid oxide fuel cell based auxiliary power unit (APU). By the way, for supply hydrogen in vehicle, we need to hydrogen source. Among the many methods, on-board fuel reforming can be a solution for hydrogen supply in automobile system with minimum amount of volumetric, gravimetric and system complexity increase. To produce hydrogen with fuel reformer, we need oxidizer. Current fuel reformer need to additional water tank. Therefore, we can use air with simple air blower or compressor or exhaust gas, due to there are enough steam and oxygen in engine exhaust gas. In case of normal combustion exhaust gas, only steam affect in reforming reaction. Whereas lean burn combustion exhaust gas contain some amount oxygen, therefore both steam and oxygen affect in reforming reaction. In this work, we found the possibility of fuel reforming with using exhaust gas by catalytic reforming experiments. First, calculate thermodynamic equilibrium composition of fuel reforming system. Use air, normal combustion exhaust gas and lean burn combustion exhaust gas as oxidant of this fuel reforming system. Result of calculation, lean burn combustion exhaust is suitable oxidant for on-board fuel reforming system. After calculation, we operate micro reactor size fuel reforming experiments and confirm the hydrogen production amount of exhaust gas fuel reforming in vehicle system.

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Simulation Drive Fuel Design

S. Mani Sarathy - KAUST, KSA

A difficult question to answer is “what is the ideal fuel for future engines?”. The combustion performance and pollutant emissions of a particular fuel are dictated by the physical and chemical properties of its constituent molecules. In addition, life cycle issues related to fuel production, distribution, and end-use need to be carefully considered. Our goal is to enable simulation driven fuel design by developing a fuel formulation strategy based on first-principles of engineering and science. We have developed a broad scientific methodology that can be applied to better understand the combustion of real world fuels in their respective technologies, as well as a systems-based approach to evaluating the environmental and economic impacts of novel fuel formulations. We demonstrate a concerted effort towards optimal blending strategies for alternative fuels (e.g., oxygenates) with petroleum hydrocarbon fuels. This talk presents recent results on formulating high anti-knock quality fuels for use in next-generation downsized turbocharged direct injection spark ignition engines. Fundamental chemical kinetic models are used to predict the ignition chemistry of alternative fuels blended with petroleum hydrocarbons. The suitability of these mixtures for improving engine performance is then demonstrated in single cylinder engine experiments. Finally, petroleum refinery process models are coupled with fuel life cycle models and turbocharged engine simulations to find optimal blends that can achieve sustainability targets

Oral

On-Board Volatility-Based Fuel Separation

Husain Baaqel, Ahmad A. Khan and Esam Z. Hamad - Saudi Aramco, KSA

This presentation highlights the development in fuel separation methods used for Octane-on-Demand (OOD) technology for internal combustion engines. OOD technology utilizes two levels of Research Octane Number (RON) to optimize overall engine efficiency and fuel consumption. In this research, the two RON levels are obtained from a single market fuel using an on-board separation system. This research focuses on volatility-based separation. A simple flash tank can partially vaporize a fuel into two streams of different RON. Related volatility-based methods were also examined, including distillation, extractive distillation, and membrane distillation

Saudi Aramco: Public

Fuel Engine Technologies

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Fuel/Engine Systems for the Future

Gautam Kalghatgi, Principal Professional - Saudi Aramco, KSA

Transport is of central importance to modern society and is almost entirely powered by combustion engines running mostly on petroleum-based liquid fuels. The global demand for transport energy, driven by growth in non-OECD countries, is increasing. Even by 2040, around 90% (compared to 95% now) of transport energy is expected to come from petroleum. This is primarily because the global demand for transport fuels is very large and alternatives such as biofuels and electric vehicles (EVs) start from a very low base and have constraints on growth. Hence global and local problems associated with mobility can only really be addressed by improving the efficiency, environmental impact and affordability of such engine/fuel combinations.

Moreover the demand growth in transport energy is expected to be heavily skewed towards commercial transport under the current technology trajectory so that in the future much more diesel and jet fuel will be needed compared to gasoline. Such trends will demand huge investments from the refining industry and will lead to a surplus of low-octane, light components. New solutions which can use such components in efficient, clean and affordable engines need to be developed to ensure the sustainability of the transport sector. For instance, if spark ignition (SI) engines are to become more efficient, they will need higher-octane fuels when they are limited by knock at high loads. However, they could run on low-octane gasoline at all other operating conditions. It would also be much easier to meet increasingly stringent restrictions on particulates and NOx from diesel engines if they were to run on low octane gasoline – Gasoline Compression Ignition (GCI) engines.

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Measurement and Simulation of Chemiluminescence and Chemi-ion production in Engines

Prof. Robert Dibble, KAUST, KSA

One can easily see light emitted by a flame. This flame radiation is often blue, green, or red. These various colors result from "unimportant" reactions that generate intermediate molecules in excited states, such as CH*, OH*, C2*, CO2*, H2O* (where "*" implies not in ground state.) In nearly all cases, the radiation is a small fraction (< 1%) of the total energy liberated in the flame. Thus, in the modeling of combustion, one can do well by ignoring all the chemiluminescence reactions that generate these excited species of negligible concentrations. Yet, the visible radiation is "easy to measure". This talk will discuss how we use simulations, that include the minor reactions of chemiluminescence and chemi-ionization, to advise use what are the main energy releasing reactions doing.

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Oil Refining in a CO_2 Constrained World with Implications for Gasoline and Diesel Fuels

Amir Abdul Manan - Saudi Aramco, KSA

Diesel compression ignition engines are known to be more efficient, and therefore less CO_2 intensive, than their gasoline spark-ignition counterpart. This has been reflected in many Well-to-Wheels (WtW) studies to date, some of which underpin regulatory measures that favor dieselization. In this study we explore the CO_2 emissions benefits of diesel vs gasoline from a refining standpoint. We utilized refinery Linear Programming (LP) models to represent the global refining industry, and imposed a price on refinery CO_2 in order to optimize refinery productions under a CO_2 constrained world. Contrary to popular belief, we show that in a world that internalizes the cost of CO_2 emissions, refineries would favor gasoline over diesel production. This highlights that the global shift towards transport dieselization can lead to greater refinery CO_2 emissions. We propose that an optimum fuel and engine combination is the use of a gasoline-like fuel in an efficient compression-ignition engine.