Coal-Derived Liquids to Enable HCCI Technology

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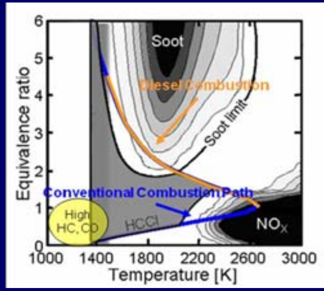
Objectives

The primary objectives of this study are twofold. The f rst objective is to conduct a thorough literature rev ew n the research areas of fuel development in HCCI engines, the use of coal-derived or Fischer-Tropsch fue s n HCCI engines, organizationa activities related to the development of HCCI specific fuels and fuel specifications, and we to wheels analyses of coal-derived fuels. The second objective is to conduct a gap ana ysis based upon that literature review.

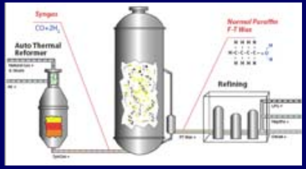
Current Research Status Related to HCCI Engines

1. Fuel Development for HCCI :
   - Fuel effects
   - Autoignit on
   - Fuel properties requ red for HCCI combust on: fuel reactiv ty, volatility.
   - Ideal fuel for HCCI combustion.
2. Infrastructure
   - The existing infrastructure is compatib e w th Fischer-Tropsch liqu ds, as its properties are able to closely resemble those of gasoline and diese fuel. Other alternative fuels, such as those derived from vegetables and animal fats that may be high n alcohol content, will require a large investment in upgrading the existing infrastructure to ensure purity and acceptab e performance.



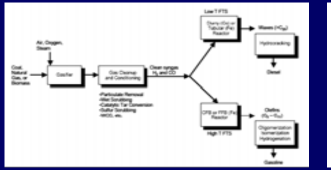
HCCI Combustion Regime [1]

Use of Coal-Derived or Fischer-Tropsch Fuels in HCCI Engines

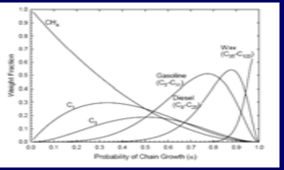


Syntroleum s Fischer Tropsch Reactor (from natural gas feedstock) [2]

1. Coa -Derived Liquid Stud es
   - Choice of the Fischer-Tropsch fuel
   - Fischer-Tropsch process
2. Chemical species used as fue
3. Potential for an ideal HCCI fuel derived from coal: DME and F-T naphtha.



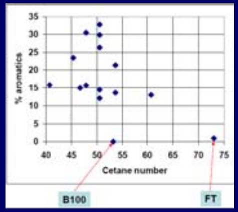
Fischer Tropsch General Flow Diagram [3]



Anderson-Shulz Flory Distribution [3]

Organizational Activities Related to HCCI Development

1. Coordinating Research Council (CRC) Fuels for Advanced Combust on Engines (FACE) Group
2. Diesel Engine-Eff ciency and Emissions Research (DEER) Conferences:
   - Advanced Combustion Technologies
   - Low-Temperature Combustion
   - Homogeneous Charge Compression Ignition
   - Pre-m xed Charge Compression Ignition
   - M xed Mode Combustion
   - High Efficiency Clean Combustion
   - Fue Chem stry
3. SAE Homogeneous Charge Compression Ign t on Symposiums



Cetane Number and Aromatic Ranges of Fuels Used in a 2005 Study conducted by Oak Ridge National Laboratory [4]

Well to Wheel Analysis

Benefits and Detriments of Coal-Derived Fuels: Abundance of Coal in U.S.A

Carbon Sequestration:

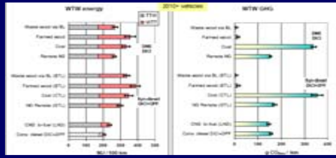
Carbon Formation and Sequestration of Fischer-Tropsch Fuels

- CO_2 Sequestration Evaluated from an Emissions and Economic V ew: poly-generat on plant

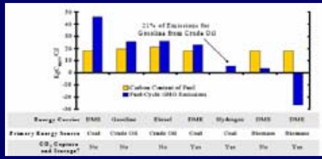
Lifecycle Cost of CO_2 Sequestration: When DME is produced, the energy conversion eff ciency s 55%. A reduction of two percentage points shou d be considered for CO_2 sequestration. A DME production based on US condition was estimated at $250/t. If DME were to be used in vehicles, it cou d be a competitive subst tute for gasoline w th a world oil price of $23/bbl, even w th CO_2 capture. Capital cost cou d be 60-75% of the US cost if it were manufactured in China [5].

	DME (coal)	DME (natural gas)	DME (biomass)
Energy consumption [MJ/MJ]	0.759	0.468	0.858
GHG emissions [g eq-CO2/MJ]	63.31	17.14	7.35
LHV	0.565	0.671	0.536

WTT Analysis of DME for Three Different Feedstocks [6]



Well to Wheel Analysis for DME and Syn Diesel [7]



Fuel Carbon Content and GHG Emissions for DME, Diesel, Gasoline and H_2 Fuels and Their Primary Energy Sources [8]

Conclusions

The use of HCCI combustion shows potential to reduce emissions inventories of NOx and PM from internal combustion engines due to its ability to operate at a low equiva ence rat o and low temperature.

The composition of readily available commercial fuels, such as gasoline and diesel fuel, may widely vary, mak ng precise engine control, part cular y in the case of HCCI engine operation, extremely difficult.

Various engine technologies, includ ng EGR and VVA, can be used to increase exhaust gas temperature to ensure proper operation of a catalyst.

Autoignition descriptors that are s gnificant for an HCCI fuel are octane number, cetane number, ignit on delay, combustion duration, and pressure rising rate. A fuel with a high octane number shows resistance to knock. Due to the low vo atility of diesel like fuels, the octane number is nsignificant, and thus the cetane number describes the autoign tion quality of the fuel. An HCCI fuel should have a low ignition delay, lending to a more reactive mixture. A fuel high in aromatic content has shown to be beneficial to HCCI combustion, as increased aromatics increase the sensitivity of the fuel. However, current regu atory trends tend to cause a reduct on in aromatics, limiting their use in an HCCI fuel.

The ideal HCCI fuel should be comprised of long branched paraffin chains with a low octane and cetane rating. A fuel with a cetane number close to that of diesel fuel will exhib t a desirable low ignit on temperature. To increase combustion efficiency, the fuel should have the second ignition peak of the two stage combustion process close to TDC. A high value of volatility, c ose to the volatility of gasoline, w ll allow the m xture sufficient time to form. A high volatility also ensures a low boiling point of the fuel. Such a fuel may be made from coa through Fischer-Tropsch synthesis.

Fischer-Tropsch fuels have been used n a limited amount in HCCI combustion. F-T diesel has been used due to its high paraffin content, h gh cetane number, and low sulfur and aromatic content.

Many well to tank, tank to wheels, and well to wheels studies have been conducted with DME and Fischer-Tropsch naphtha derived from synfuels obtained from coal. These studies show that crude oil-based fuels are more attractive than F-T liquids from coal due to a higher efficiency and lower greenhouse gas emissions. But by the utilization of proper carbon sequestration during the F-T synthesis, and w th the proper amount of biomass feedstock, a blend of F-T coal-derived liquid, or a synfuel derived from coal, and biomass-derived liquid shows promise for a fuel suitable for HCCI combust on, thus advancing a ternative combustion technology and lower engine out emissions.

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