Hydrogen assisted combustion of ethanol in Diesel engines

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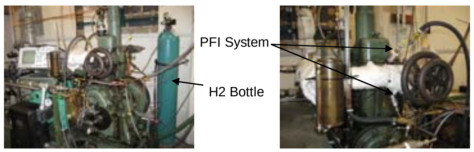
Objective

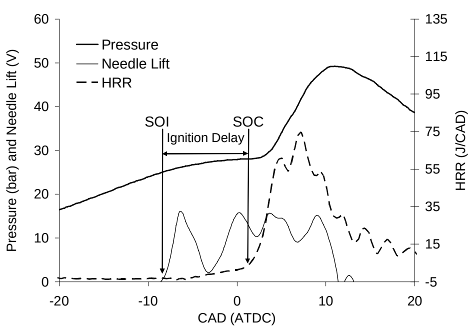
- The objective of this project is to develop a means of using nearly pure ethanol as a diesel engine fuel by using hydrogen rich gases to facilitate the combustion.

Engine Test Stand



- Variable compression ratio from 8:1 to over 24:1
- Fully variable intake heating and injection timing
- Engine outfitted with port fuel injection system with gaseous and liquid fuel injectors
- Currently gaseous H2 injection is from bottled gas, but end goal is to use on-board ethanol reformer to produce the H2 rich gases used to facilitate ethanol combustion

In- Cylinder Combustion Fundamentals



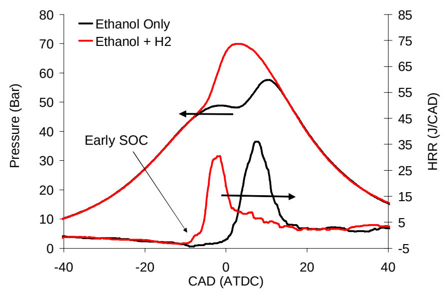
- In-cylinder pressure is measured on engine and used to derive combustion parameters
- Injector needle lift is used to determine start of injection (SOI)
- Heat Release Rate (HRR) indicates how and when fuel energy is released and gives the start of combustion (SOC)
- A good diesel fuel has a low ignition delay period and hence a high CN
- Ethanol has a long ignition delay period, which must be minimized to be used as a diesel fuel

Engine Testing Approach

- In all tests 2% lauric acid (coconut oil) must be added for lubricity and the main fuel, ethanol, is injected via the diesel injection pump
- Hydrogen Port Fuel Injection (H2 PFI)
  - Ethanol is injected through diesel pump and gaseous H2 is injected with intake air to possibly achieve combustion at lower intake temperatures and compression ratios
- Ethanol Port Fuel Injection (EtOH PFI)
  - Ethanol is injected through diesel pump and liquid ethanol is injected with intake air to possibly achieve combustion at lower intake temperatures and compression ratios

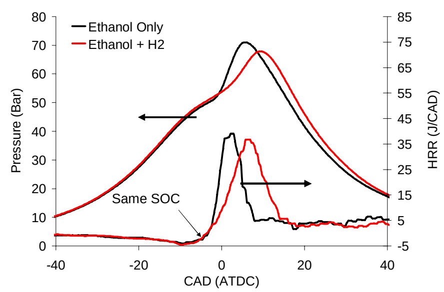
Results

H2 PFI: H2 significantly advances ethanol combustion in a diesel engine



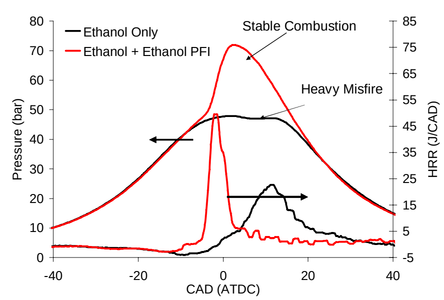
- Intake temperature and compression ratios were kept constant at 120 C and 24.5:1
- H2 addition was 5lpm, corresponding to roughly 15% energy input
- Significant SOC advance is seen
- With diesel fuel H2 retards SOC timing, opposite from ethanol

H2 PFI: ethanol combustion achieved at much lower intake temperatures with H2



- Compression ratio constant at 24.5:1
- Intake temperature of 120 C for ethanol only and 68 C for H2 addition condition
- Overall energy input kept constant
- H2 energy input corresponding to roughly 10%
- SOC remained constant even at low intake temperature

EtOH PFI: ethanol PFI stabilizes ethanol direct injection combustion in diesel engine



- The ethanol PFI results are preliminary
- Intake temperature of 120 C and compression ratio of 24.5:1
- Without ethanol PFI, engine was heavily misfiring , but with ethanol PFI, stable engine operation is achieved

Discussion

- SOC advance in both the H2 PFI condition and the ethanol PFI condition is possibly caused by a free radical pool build up
- Radicals may build up because of the H2/ethanol addition, high intake temperatures, high compression ratios, or a combination.
- H2 PFI with ethanol shows opposite behavior than H2 PFI with diesel fuel, which means fuel chemistry may be important
- Data shows that the H2 addition enables the ethanol to burn at lower intake temperatures.

Summary

- Ethanol has been successfully run in a diesel engine with increases in compression ratio and intake manifold temperatures to 24:1 and 125 C, respectively. The only additive required was 2% by volume of lauric acid for proper lubricity.
- The combustion characteristics of ethanol have been modified to operate at lower intake temperatures using small amounts of H2 injected with the intake air. This means that H2 injection may provide a means to operate diesel engines with ethanol with minimal engine modification, as was stated in the initial proposal.
- Preliminary investigations using PFI of ethanol instead of hydrogen shortened the ignition delay and gave behavior qualitatively similar to that of hydrogen.

Future Work

- Investigate limits on intake temperature and compression to determine a viable real world operating condition
- Conduct kinetic modeling simulations to determine the cause of SOC advance

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