Recent Trends in Diesel Combustion Research in the US and Research Activities at the ERC

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Quick Assessment

- **Combustion of fossil fuels is the dominate power producing process in the US**
  - **Or, fossil fuels are the dominate energy carrier used in the US**
- **Transportation is a significant proportion of the total power generation within the US**
- **The US is realizing the importance of reducing fuel consumption in the mobility sector**
  - **Trucking industry has always had this constraint**
  - **Automotive sector is realizing it also**

What about CO_2 Emissions?

Life Cycle Energy Costs

&

Wells to Wheels?

Bio-fuels?

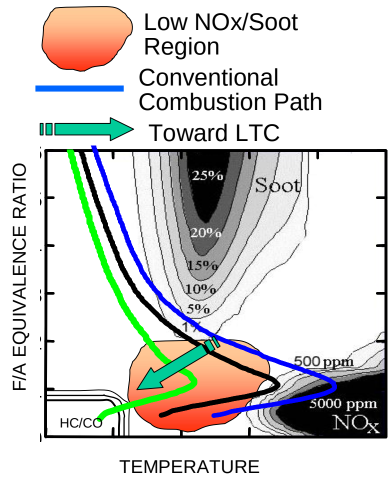
- Bio fuels are oxygenated HC's
  - They will not be as high in specific energy or energy density as gasoline or diesel. But they will be better than H_2 or batteries
- With Bio fuels you are "recycling" the carbon emissions
- Bio fuels are a complicated topic
  - Need to do accurate accounting of all growing, harvesting and processing energy and emissions
  - It appears that Bio fuels can be a contributor to the fuel pool, but are not THE solution

Engine Combustion and System Integration Research

The current emphasis in the US

Low-Temperature Combustion (LTC)

- **Critical Issues:**
  - **Practical "windows" can be identified:**
    - **T<2100 K to keep NOx from forming**
    - **T>1500 K to generate sufficient OH to complete oxidation of CO and HC**
  - **Exhaust temperature are low with LTC**
    - **Catalytic clean up of the exhaust may be difficult**
  - **The soot and NOx islands were determined by static calculations of, T = 1.0 ms, P = 6 MPa and EGR = 0% - In reality they move!**



Concept was originally proposed by Kamimoto, SAE 880423

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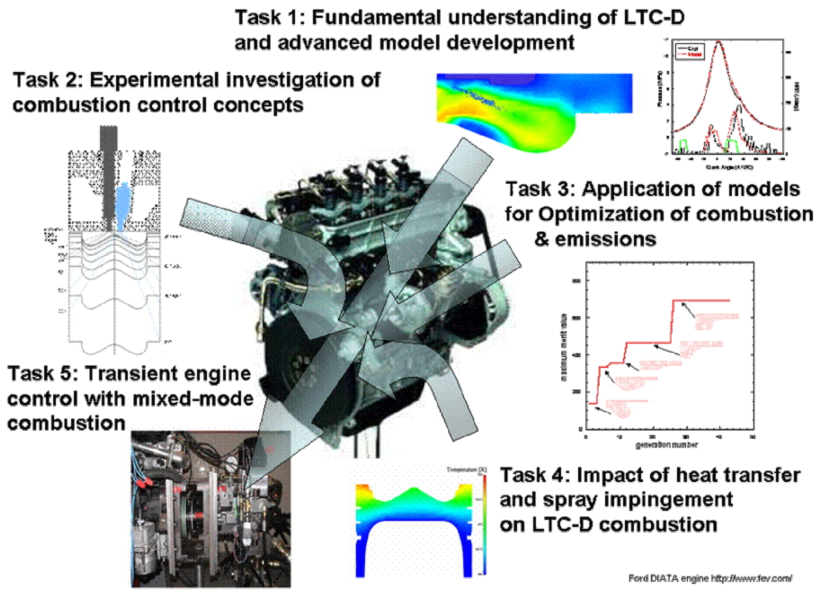
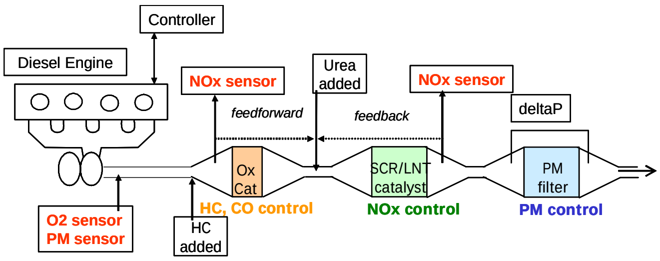
Low Temperature Combustion

- Key to LTC:
  - Achieve appropriate mixing of fuel and oxidizer prior to the ignition chemistry progressing to auto-ignition, which is to occur within some designated time during the cycle
- Many different scenarios have been proposed for achieving this
  - HCCI, PCCI, MK, DCDC, CAI, …
- These different scenarios are really different approaches to mold the engine operation around the fuel's physical and auto-ignition characteristics

Combustion Optimization and New Combustion Regimes



Powertrain Integration and Total System Optimization

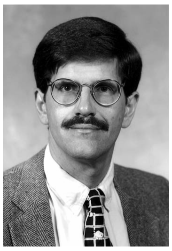


- The aftertreatment system, which is passive, will dictate the engine operating conditions
- Engine needs to supply the exhaust thermodynamic state and composition that is needed for optimum aftertreatment performance at that instant.
- Detailed fundamental understanding of each sub-system will be required

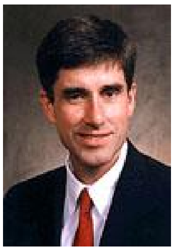
The Engine Research Center

http://www.erc.wisc.edu/

ERC Faculty



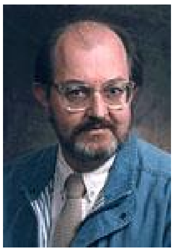
Mike Corradini



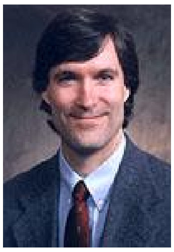
Pat Farrell

Dave Foster

Jaal Ghandhi



Rolf Reitz



Chris Rutland

Scott Sanders

Plus many active collaborations with other faculty

ERC Research Projects

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Diesel HCCI/LTC

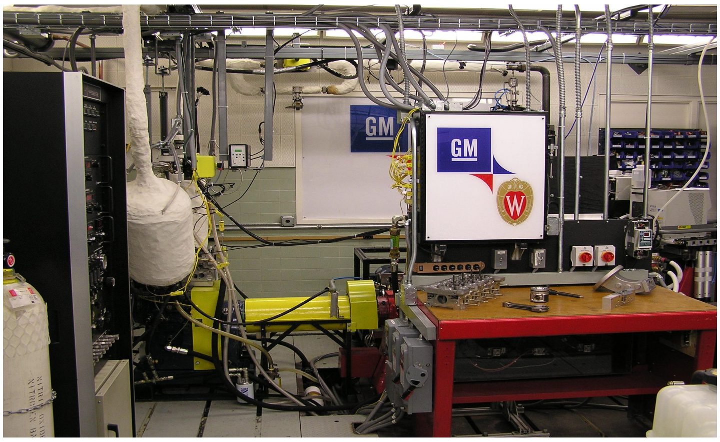
Dave Foster, Rolf Reitz, Chris Rutland, Youngchul Ra, Manuel Gonzalez, Roger Krieger, Richard Opat, Ryan Butts

GM-ERC-CRL, DOE, BP-Amoco

Diesel LTC (HCCI) Single-cylinder Lab

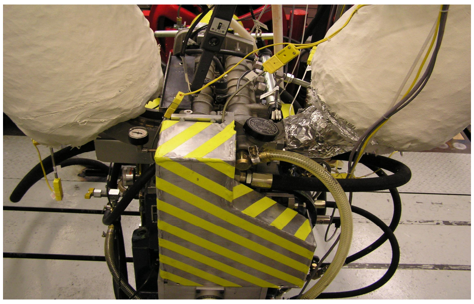
- *Objective: To explore injection, in-cylinder conditions and fuel effects on mixing and combustion regimes in a High Speed DI LTC-D engine*
- *Approach:* To incorporate a study fuel volatility and cetane number effects (focus on properties similar to those of naptha's, light kerosene and cyclo-alkanes) on LTC-D, knowing the non-linear coupling between the ignition kinetics (both two stage and single stage), the temperature and pressure time histories of the cylinder gases and the mixing processes occurring within the cylinder

SCE lab (June ’06)

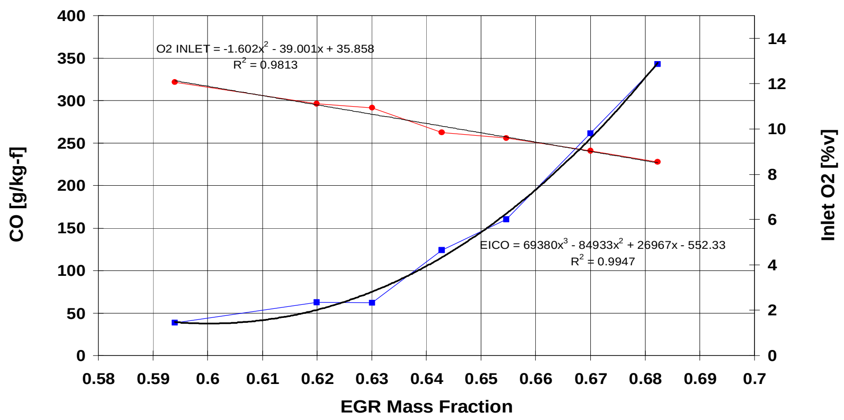


SCE

- 16.5 Compression Ratio
- 4 valves/cylinder
- 0.477 liters Displacement
- 90.2 mm Stroke, 84 mm Bore
- Common-Rail 1600 Bar Injectors flow 440mm^3/30 sec., included angle 155 to 143 °
- Bosch CRIP2-MI Injectors CP3 Injection Pump EDC16 ECU



Experimental CO and inlet O_2



5 Bar IMEP, 2000 rpm

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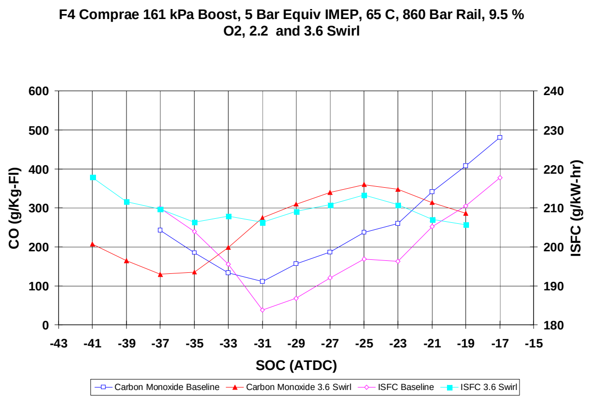
For CO oxidation both temperature and mixing are important

- **An optimal swirl ratio exists at which the lowest CO emission and best fuel conversion efficiency are observed likely due to mixing processes occurring after the premixed burn period.**
- **CO emission generally exhibits a rapid decrease from the maximum as SOI is advanced, particularly at the highest swirl ratios.**



Recent data corroborates data of Miles et al. SAE 2006-01-0197

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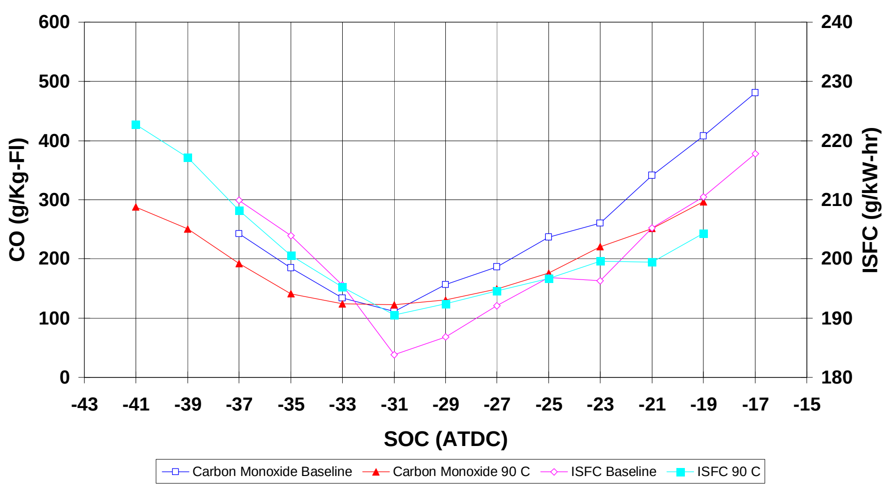
Impact of Injection Rail Pressure

- A similar minimum in CO and ISFC is observed at different injection rail pressures
- The location of this minimum shifts with changes in rail pressure

F4 Compare 161 kPa Boost, 5 Bar Equiv IMEP, 65 C & 90 C, 860 Bar Rail, 9.5 % O2, 2.2 Swirl



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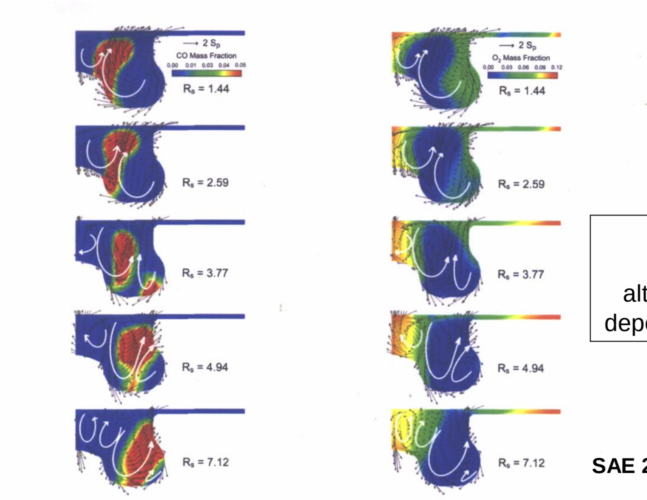
Fluid Mechanics and Chemical Kinetics are Critical!



Could it be significantly altered by fuel dependencies ?

SAE 2006-01-0197

Figure 6 The mean $r - z$ plane flow structure and the spatial distribution of CO at 3 CAD for various swirl ratios, as predicted by numerical simulation. SOI = -22.25 CAD, cut-plane 22° down-swirl from the fuel jet

Figure 7 Changes in the spatial distribution of O_2 at 3 CAD for various swirl ratios, as predicted by numerical simulation. SOI = -22.25 CAD, cut-plane 22° down-swirl from the fuel jet

Initial Observations

- **Experimental approach using intake O_2% rather than EGR level works well**
- **UHC/CO/ISFC "sweet spot" found with this engine**
- **Sweet spot still observed as parameters were varied**
- **Mixing related control parameters (Prail, swirl) show strong effects as observed at Sandia**