Fuel-Induced System Responses The Role Unconventional Fuels May Play in Altering Exhaust Conditions from Conventional and Low Temperature Modes of Combustion

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MECHANICAL ENGINEERING

Objective

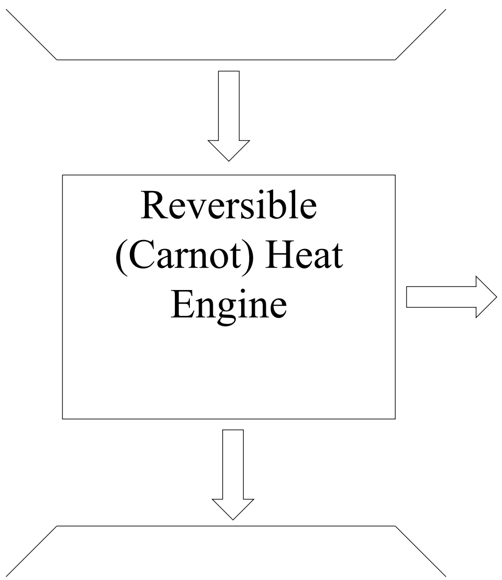
The objective of this presentation is to highlight some developments in advanced internal combustion engines, with particular consideration given toward novel fuels and modes of combustion, and their impact on potential waste heat recovery applications.

Basic Message

- For improving IC engine efficiency, thermodynamics will favor lower temperature exhaust and lower exhaust flow rates, potentially decreasing the availability of energy for exhaust-based waste heat recovery.

- In spite of this, opportunities will still exist and available energy should be exploited when possible.

“Waste Heat” of an IC Engine



The exergy (available energy to do useful work) of an IC engine’s exhaust is primarily composed of the temperature of the exhaust (T_H) and the thermal energy flow rate ($\dot{Q}_H$)

$$\dot{W}_{rev} = \dot{Q}_H\left(1 - \frac{T_L}{T_H}\right)$$

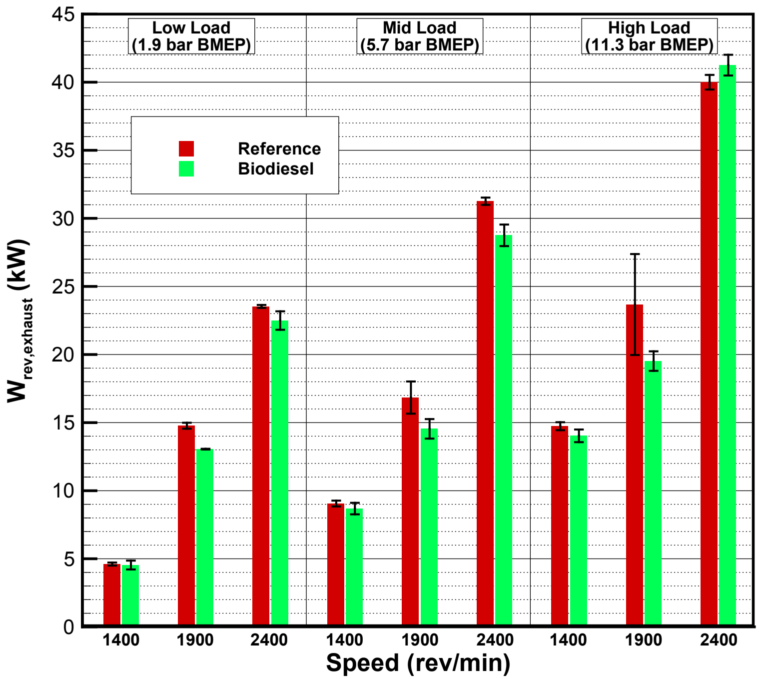
For an IC Engine:

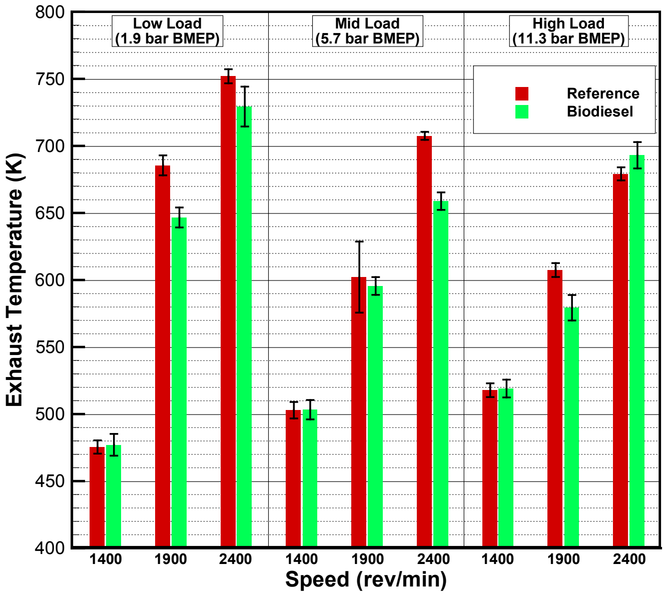
T_H = f(φ, r_c, fuel, combustion phasing, heat transfer characteristics)

$$\dot{Q}_H = \dot{m}C_P(T_H - T_L)$$

$\dot{m}$ = f(V_d, N, φ, EGR, load, VGT position)
C_P = f(φ, fuel, EGR, T_H)

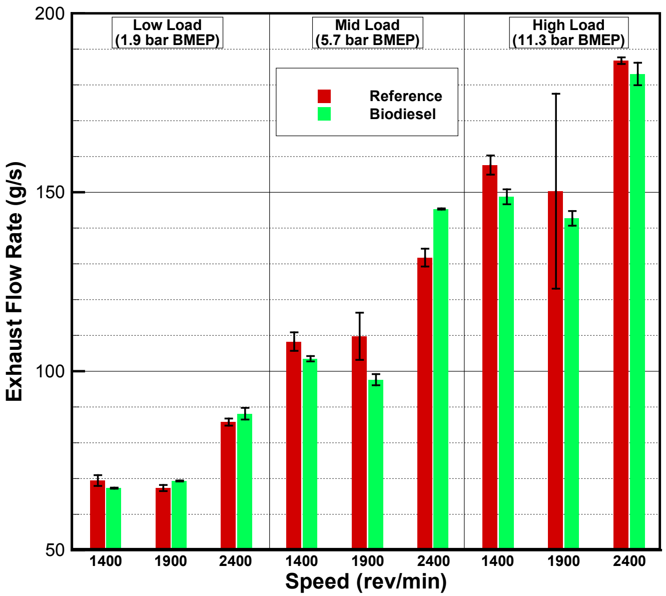
Biodiesel and Petroleum Diesel



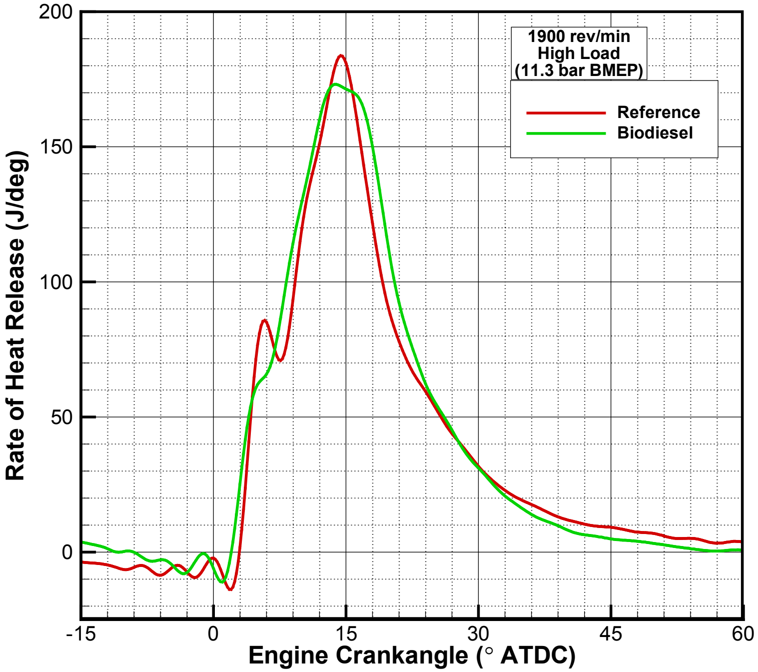


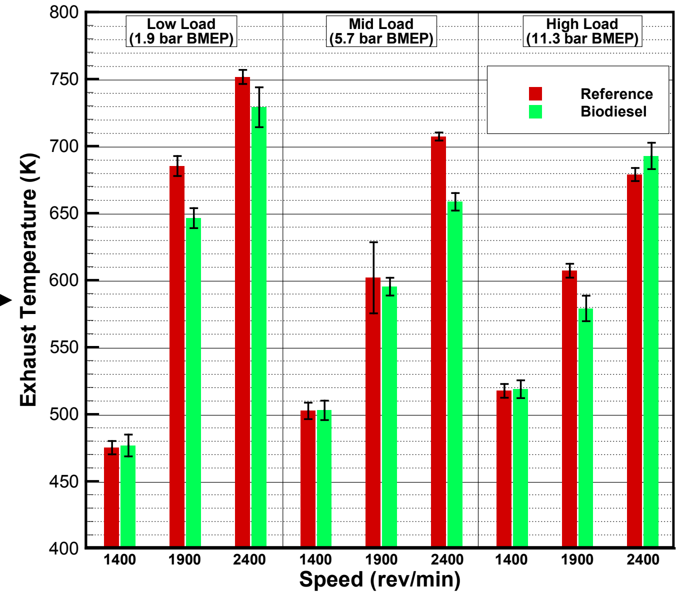
When statistical differences exist, biodiesel tends to have a lower exhaust exergy than petroleum diesel for equivalent operating conditions.

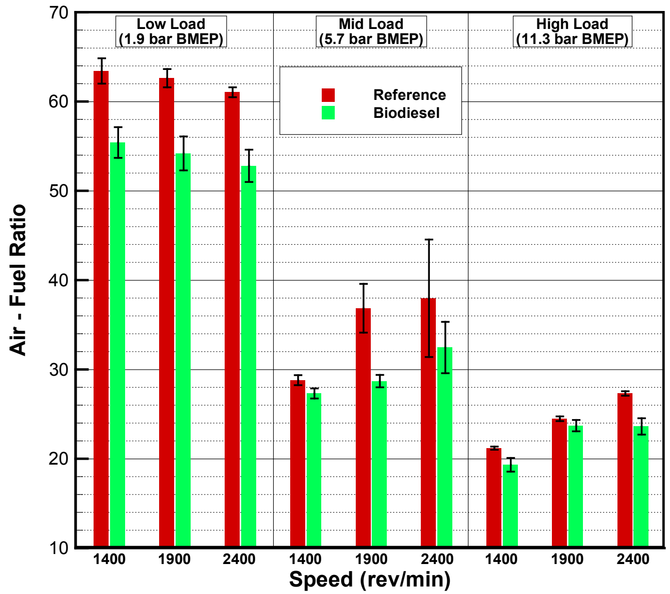
This can be manifested by either lower exhaust temperatures or lower exhaust flow rates.

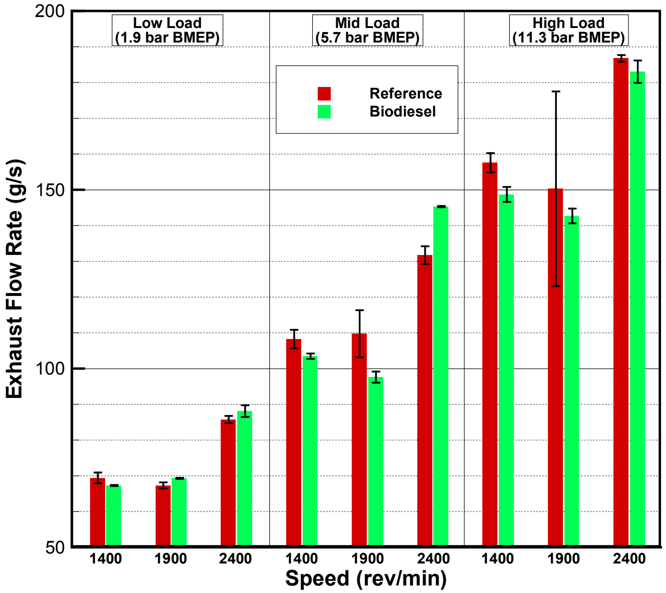


Biodiesel and Petroleum Diesel

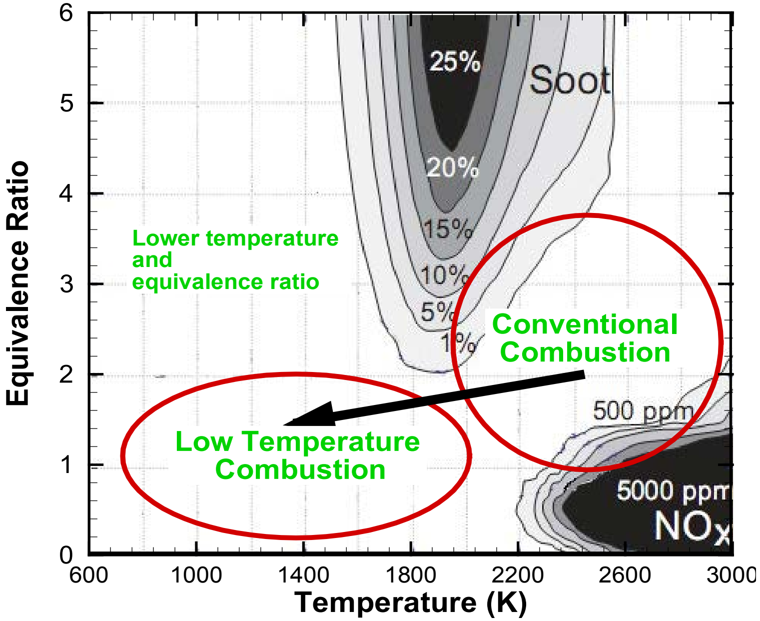


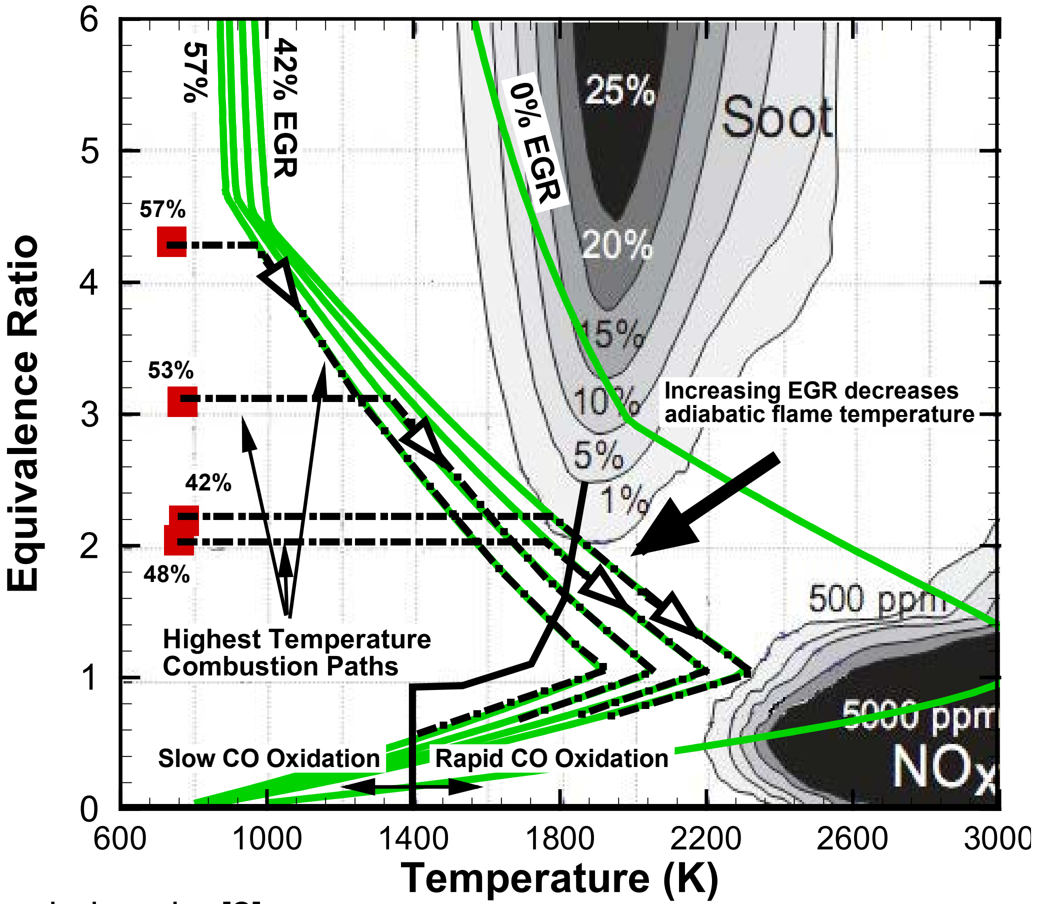






Background (Low Temperature Combustion)

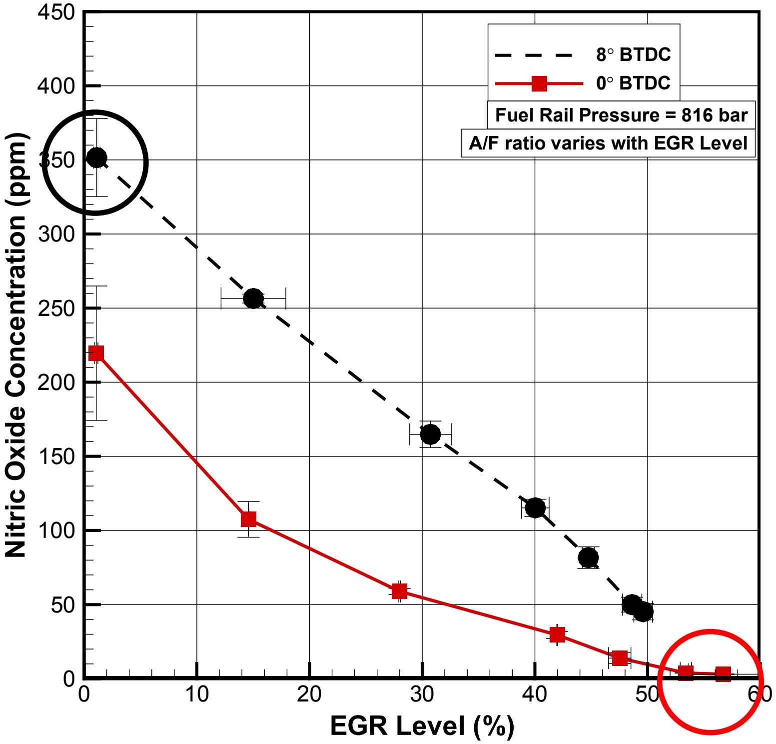


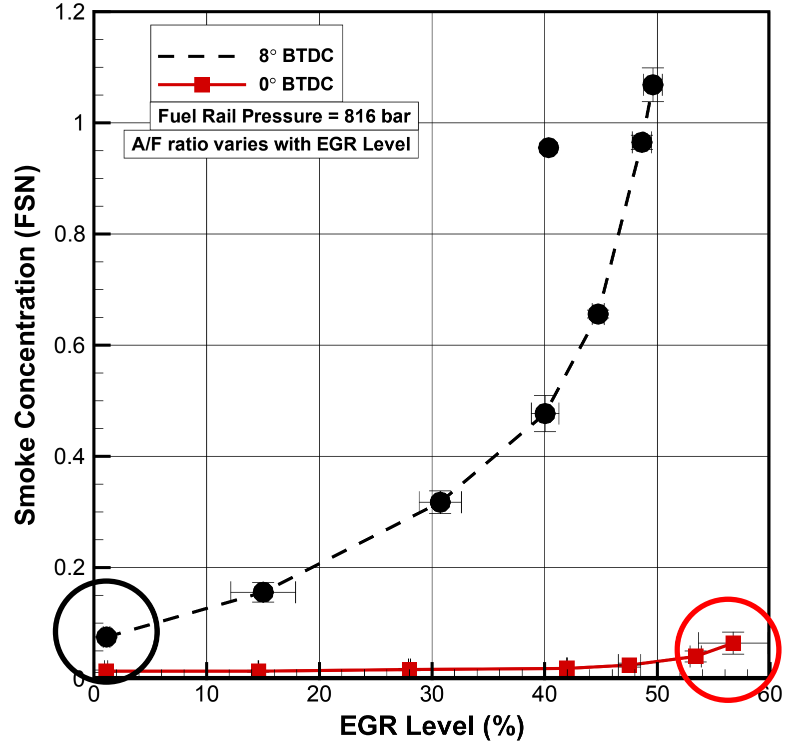


Data overlaid on work adapted from [1] based on work done by [2].

[1] Kitamura, T. et al., 2003, SAE Transactions - Journal of Fuels and Lubricants, 112(SAE Paper No. 2003-01-1789).
[2] Kamimoto, T. et al., 1988, SAE Transactions – Journal of Engines, 97(SAE Paper No. 880423).

Low Temperature Diesel Combustion



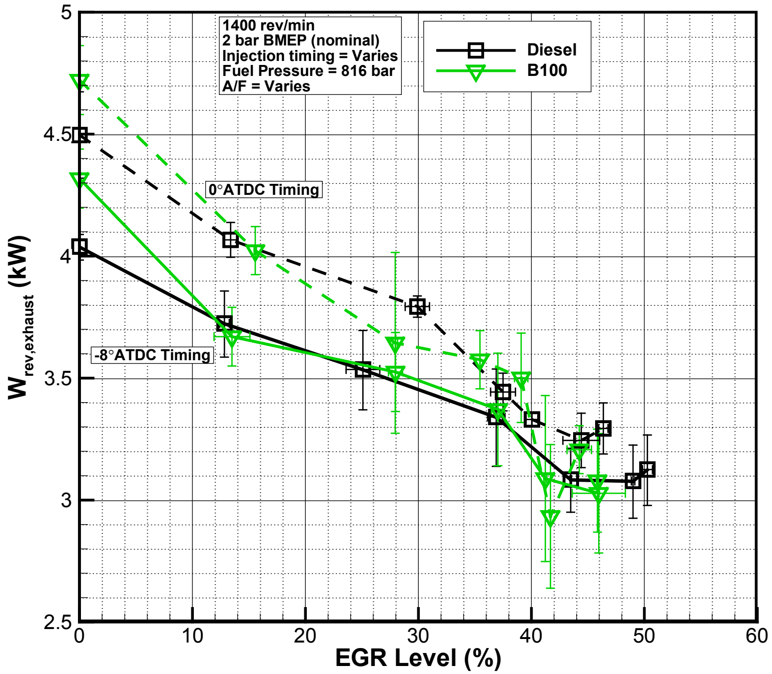


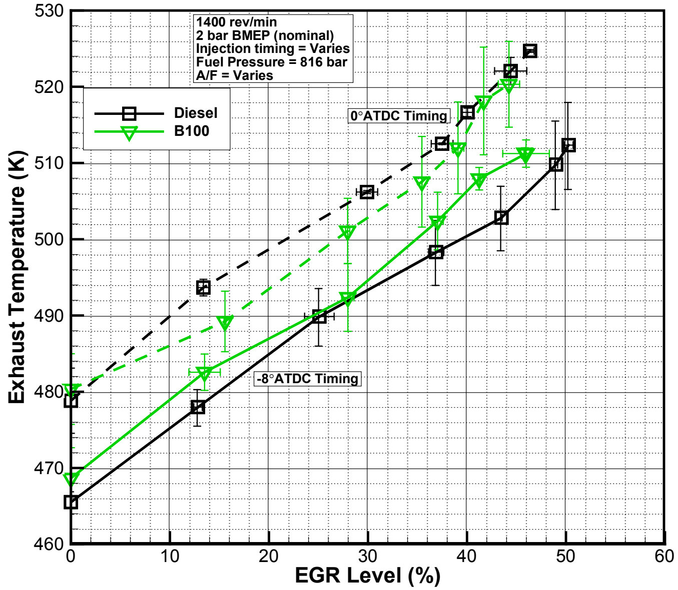
- Conventional Diesel Combustion

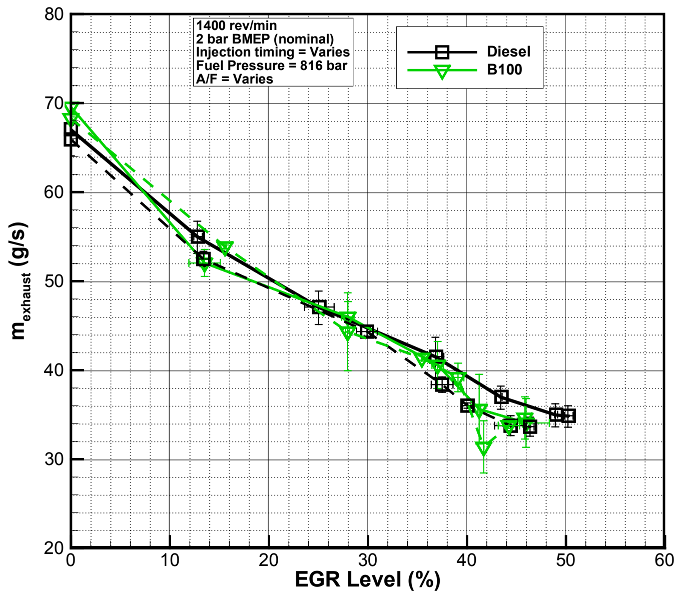
- Low Temperature Diesel Combustion

Low temperature combustion is able to simultaneously reduce NO and soot concentrations, the latter of which is the “building block” for PM.

Combustion Effect





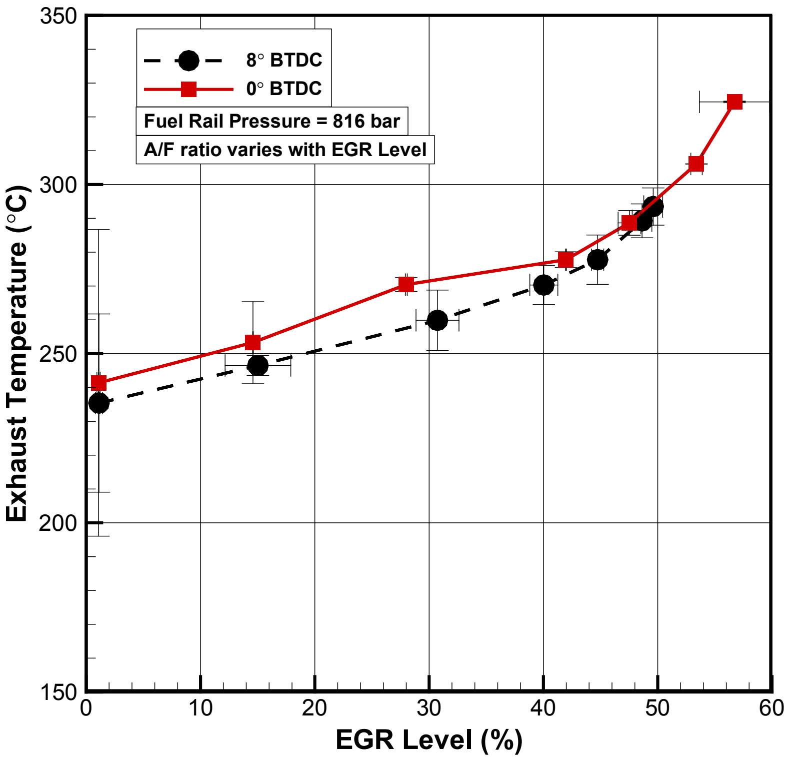


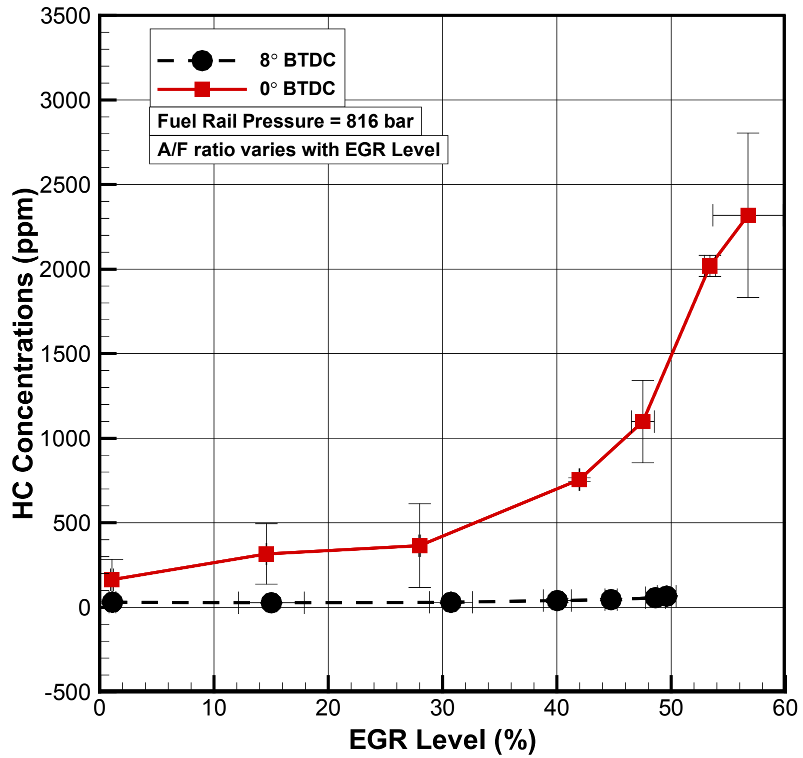
Generally, approaching “ultra-clean” combustion modes results in a decrease in exhaust exergy.

In the case of EGR, exhaust temperature increases (later phased combustion), but exhaust energy flow rate decreases as mass flow rate decreases.

A Challenge and an Opportunity

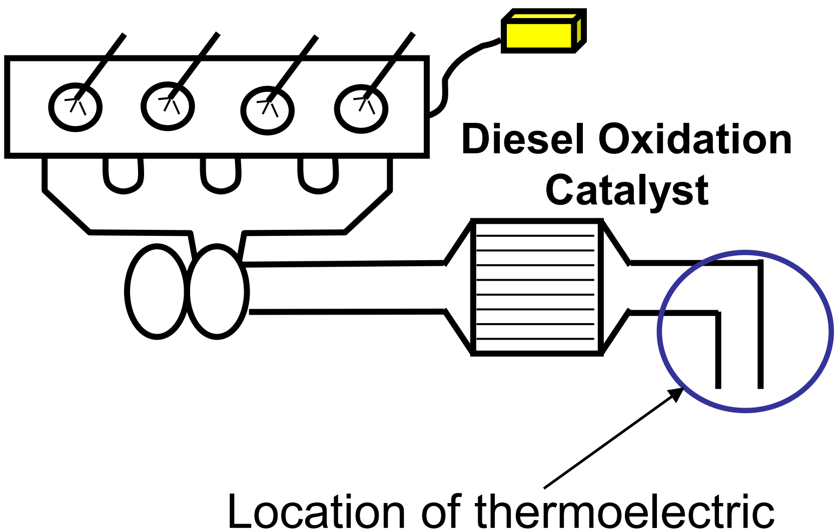
- Mostly due to combustion phasing, and in spite of its name, low temperature diesel combustion may actually yield higher exhaust temperatures (but lower exhaust flow rates) than conventional combustion.
- One challenge facing low temperature diesel combustion is its excessively high HC (and CO) concentrations. But this may create an opportunity. . .

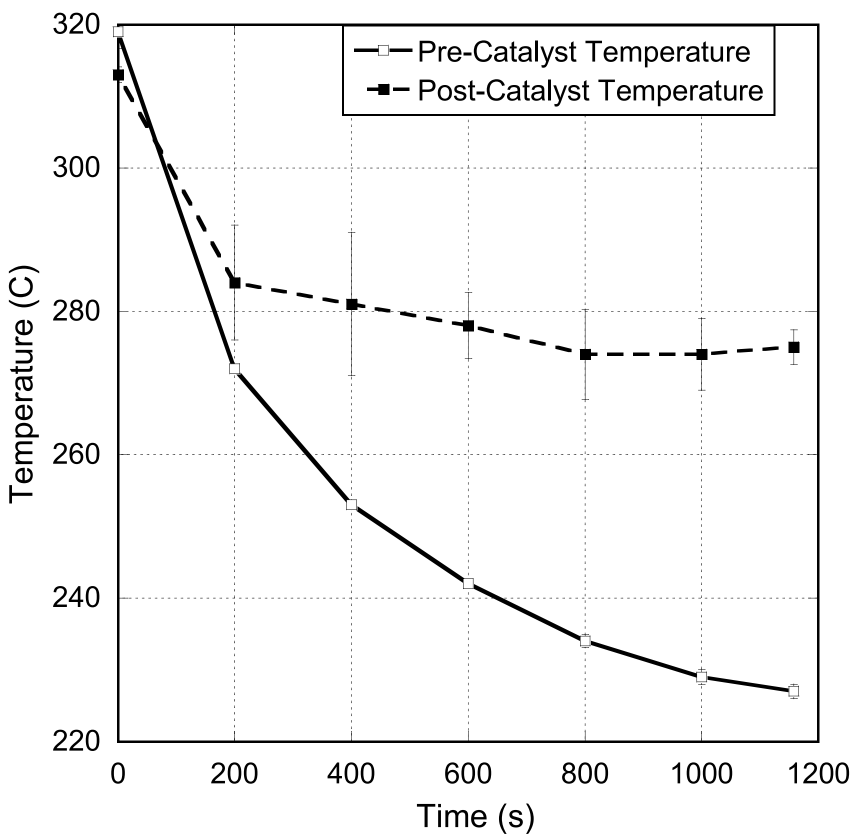




Exhaust Exotherm to Support Thermoelectric

- The use of a diesel oxidation catalyst, with primary purpose to reduce low temperature diesel combustion hydrocarbon and carbon monoxide concentrations, also provides exothermic heating of the exhaust.
- Such action could improve the combination efficiency of a clean low temperature diesel engine / thermoelectric system.





The Trend in Engine Technology

A few examples of developed engine technology:

- Gasoline direct injection (GDI) – In production
  Stratify a lean fuel/air mixture near the spark plug for ignition. Enables increased compression ratio due to stratified charge and leaner mixture.

- Variable Displacement / Cylinder Cut-out – In production
  Disable cylinders of a multi-cylinder engine to enable more open throttle at part-load operation. Firing cylinders still burn stoichiometric, but non-firing cylinders dilute exhaust thereby lowering exhaust temperature.

- Homogeneous charge compression ignition – R&D
  Induct ultra-lean fuel-air mixture and, with high compression ratio, compressively ignite mixture. Ultra-lean mixture contributes to low combustion temperatures; this, along with high compression ratio, contribute to low exhaust temperatures.

- Low Temperature Diesel Combustion – R&D
  "LTC" intends to simultaneously and substantially lower nitric oxide and particulate matter emissions from diesel engines.

Conclusion

Coupling clean low temperature diesel combustion engine with exhaust-based thermoelectric device can create a system with high efficiency, and create opportunities for further advanced combustion development.

Thank you!

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Thank you for your attention!

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Backup

A Pie in the Sky Idea: