Biodiesel's Enabling Characteristics in Attaining Low Temperature Diesel Combustion

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MECHANICAL ENGINEERING

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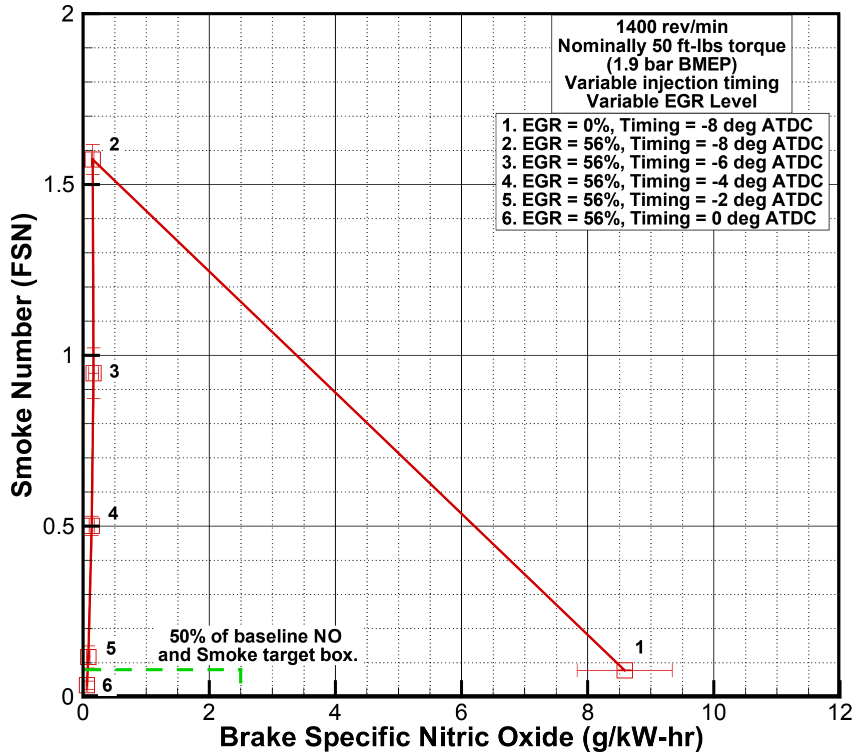
Motivation

- Low temperature diesel combustion (often called diesel premixed charge compression ignition combustion) offers opportunities to substantially and simultaneously decrease nitric oxide and smoke concentrations.

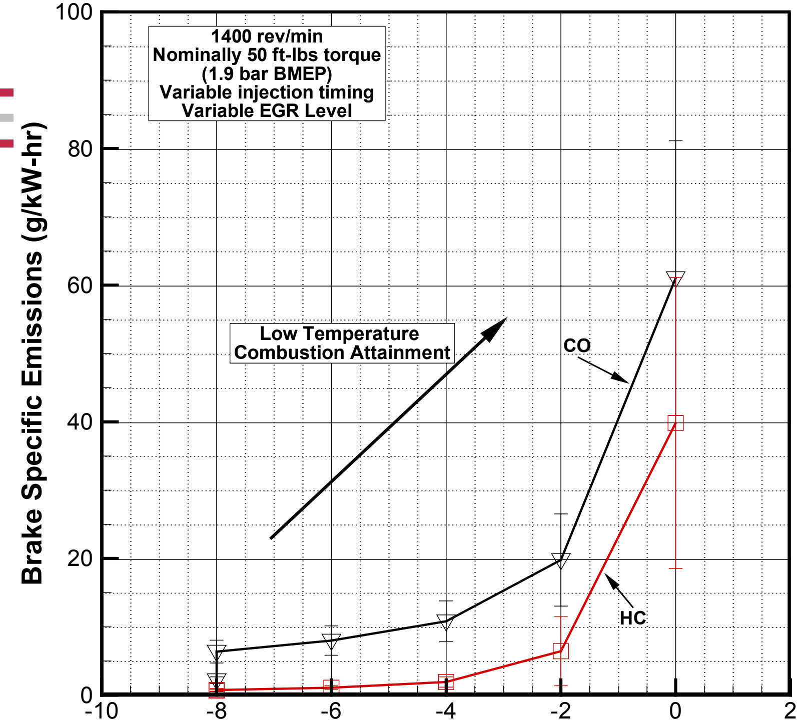
- Depending on manifestation, low temperature combustion may require large quantities of exhaust gas recirculation and retarded injection; such "control techniques" create complications for maintaining high efficiency. Further, low temperatures manifest high concentrations of CO and HC.

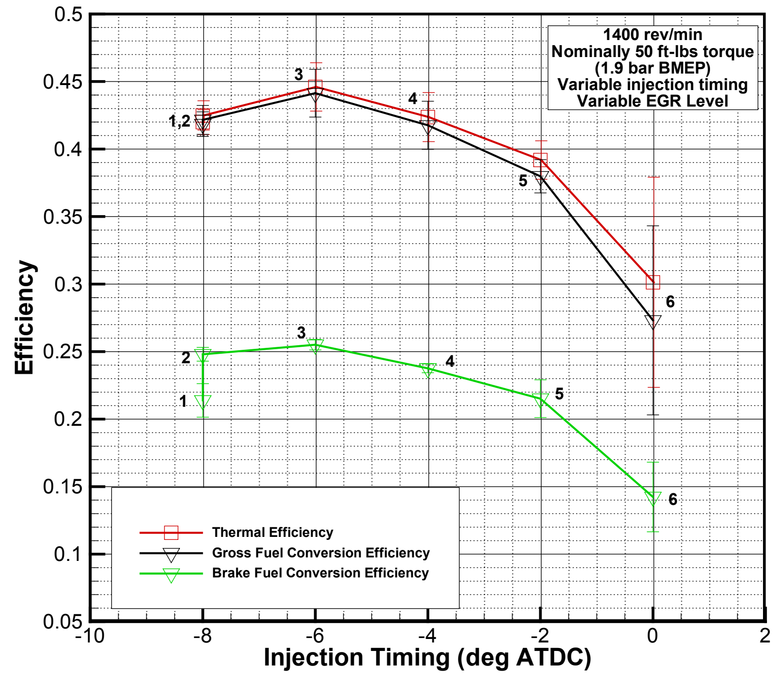
- Biodiesel, perhaps due to several reasons including oxygenation and fewer unique species, may offer improvements (relative to petroleum diesel) to efficiency and CO/HC emissions with low temperature combustion.

Background



- As shown, low temperature combustion substantially and simultaneously decreases nitric oxide and smoke concentrations.
- In this manifestation of low temperature combustion, however, CO and HC emissions increase substantially and fuel conversion efficiency decreases.





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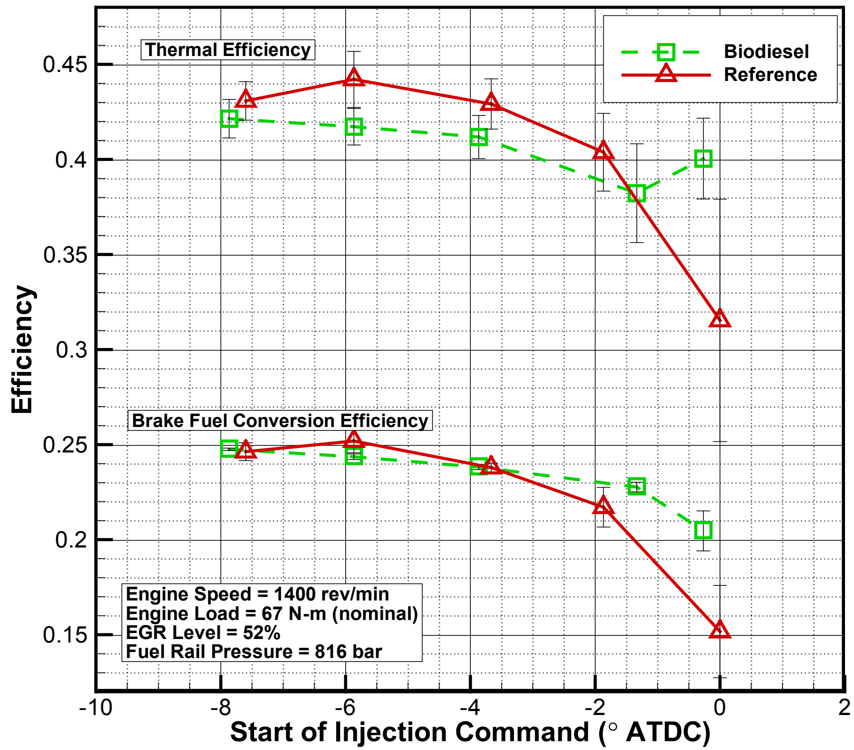
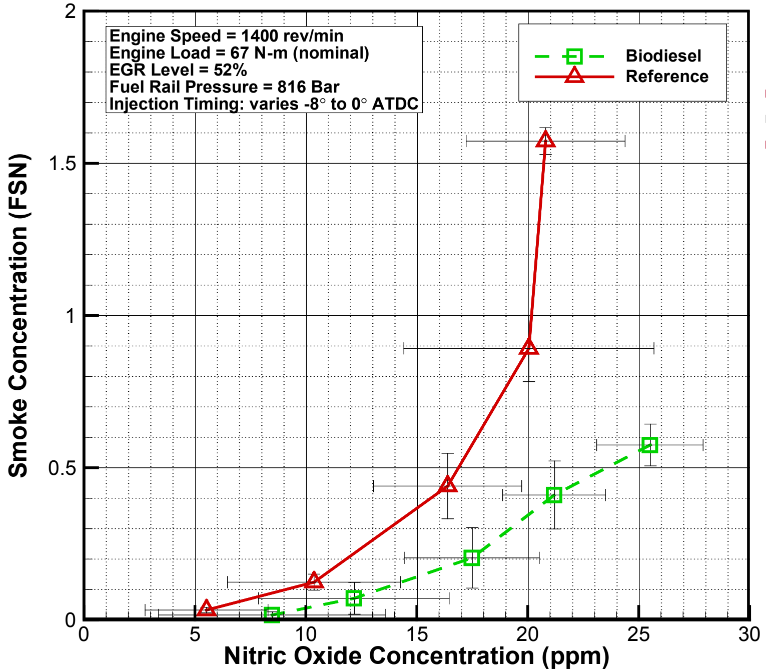
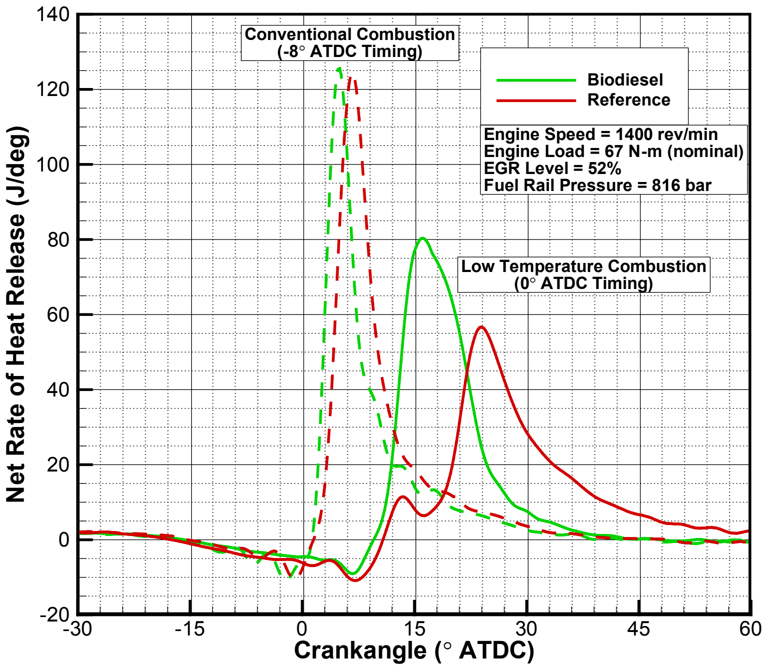






- The use of biodiesel under similar LTC control parameters yields similar NO and smoke concentrations, but much improved efficiency.
- The improved in efficiency is believed to be linked to absence of cool flame duration in the heat release.

Objective

Research Questions

- Are the improvements in efficiency real, or unique to this set of tests?
- What causes the cool flame duration to be minimal with biodiesel, relative to petroleum diesel?

- The objective of the current research is to explore the reasons and physical significance of the cool-flame behavior of biodiesel low temperature diesel combustion on improving low temperature diesel combustion efficiency.

Methodology

Bore	106 mm
Stroke	127 mm
Displacement	4.5 L
Rated Power	115 kW at 2400 rev/min
Compression Ratio	17.0:1 (nominal)
Ignition	Compression
Fuel System	Electronic common rail, direct injection
Air System	Variable geometry turbocharger with exhaust gas recirculation

Capabilities Include:

- In-cylinder pressure measurement (Kistler 6056A)
- Injector command current and needle lift motion
- Gaseous species (Horiba MEXA 7000D)
- Exhaust smoke concentrations (AVL 415S)

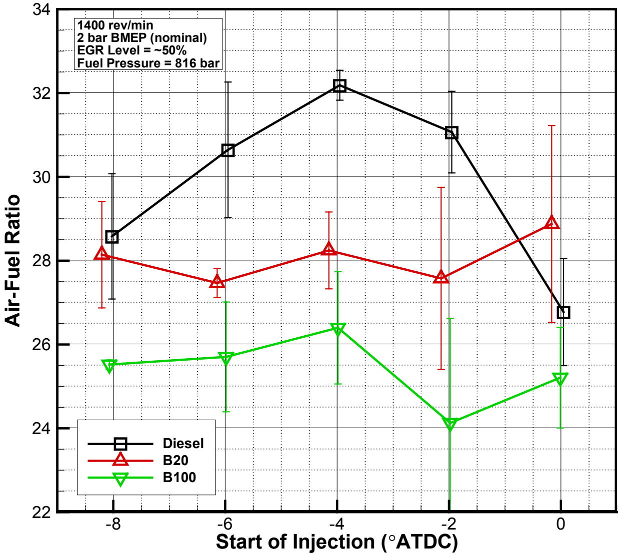
Methodology

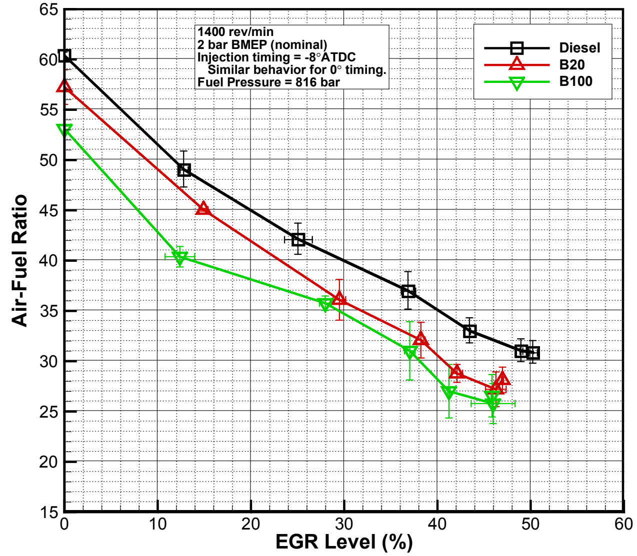
Property	ULS 2007 Certification Diesel	Palm Olein Biodiesel
Density (kg/m^3)	845	876
Net heating value (MJ/kg)	42.89	37.14
Gross heating value (MJ/kg)	45.11	39.77
Sulfur (ppm)	8.2	2.1
Viscosity (cSt)	2.1	4.53
Cetane #	44	63.5
Hydrogen (%-m)	13.10	12.44
Carbon (%-m)	86.90	76.63
Oxygen (%-m)	0	10.93

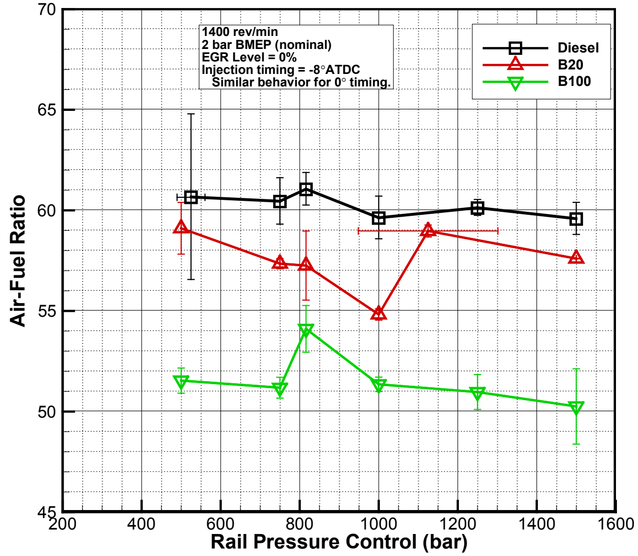
Comparisons are between D100 and B100

Methodology

- Injection timing sweep at ~50% EGR, 816 bar rail pressure
- EGR sweep at -8°ATDC and 0°ATDC, 816 bar rail pressure
- Rail pressure sweep at -8°ATDC and 0°ATDC, 0% EGR

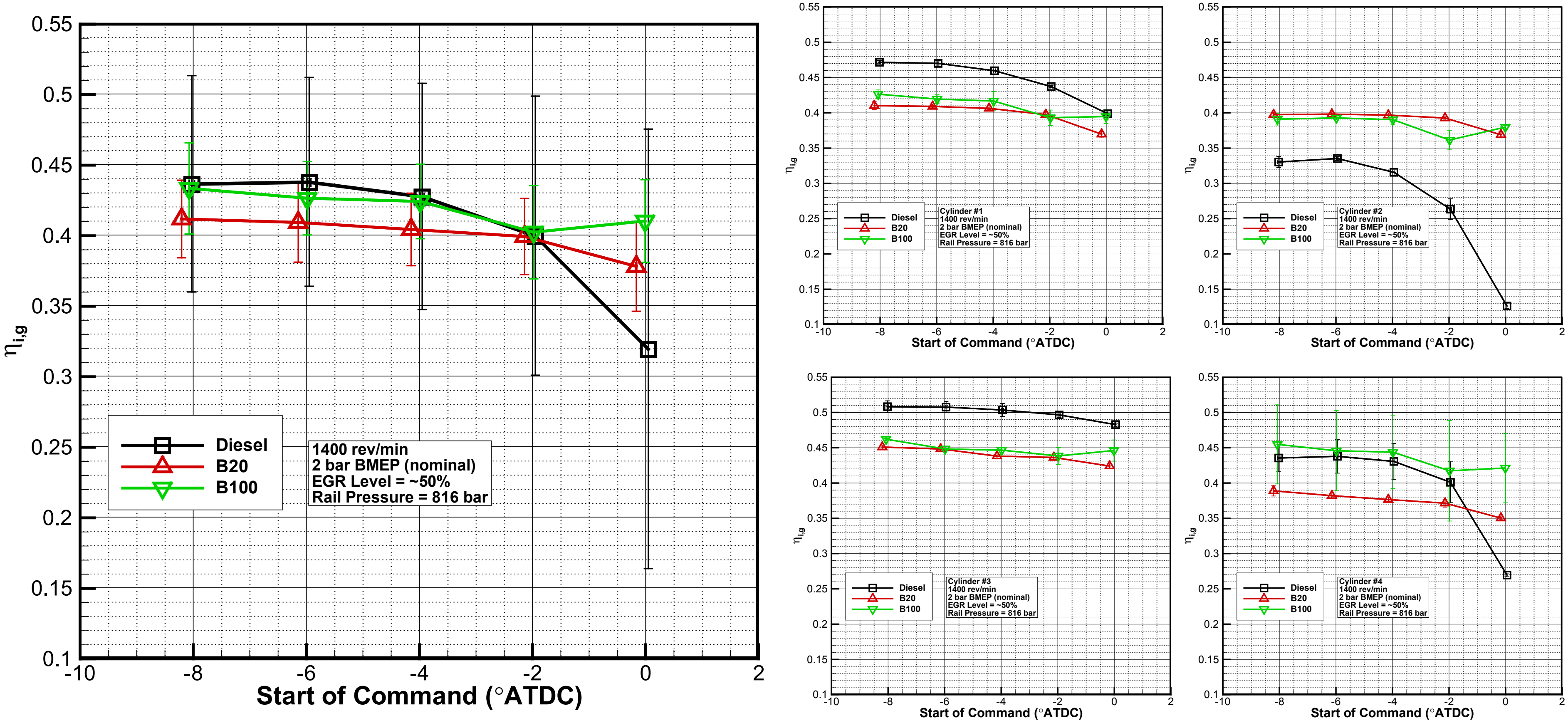






N.B. A/F ratio changes with fuels, as increased fuel-bound oxygen decreases demand for air at same torque conditions.

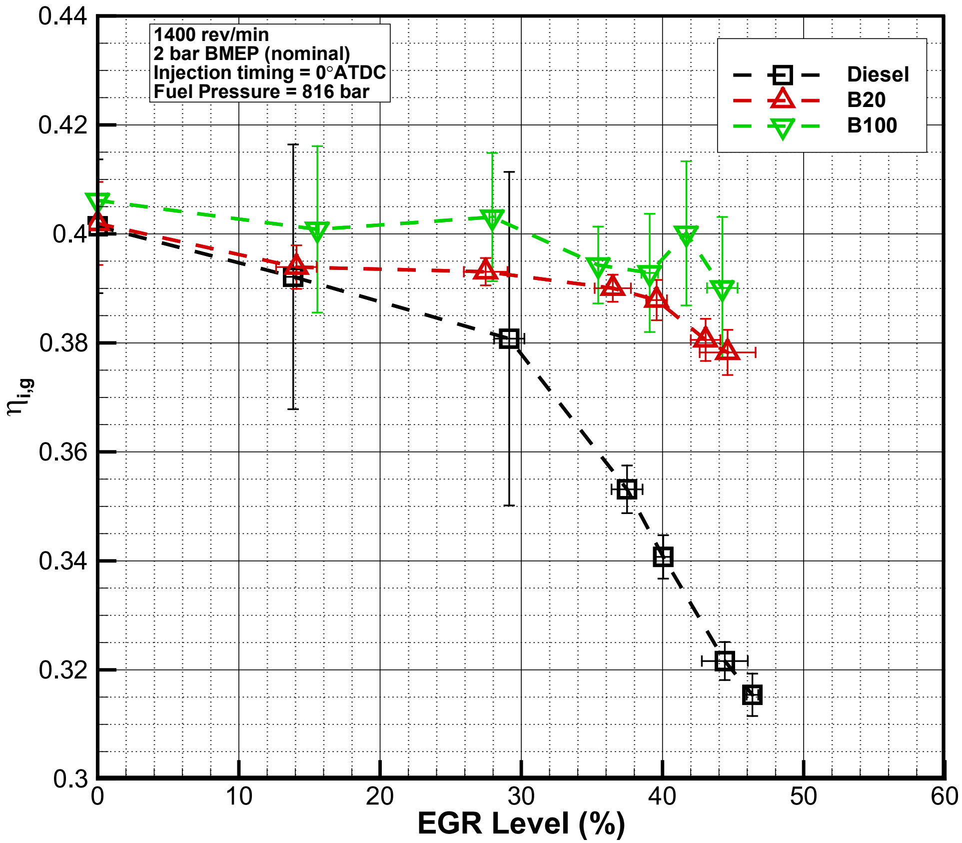
Results

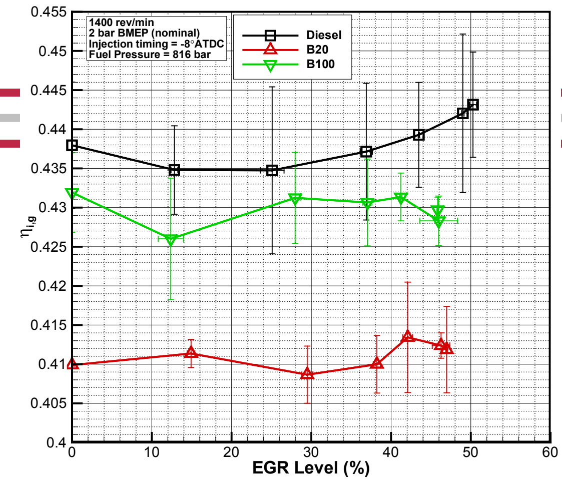


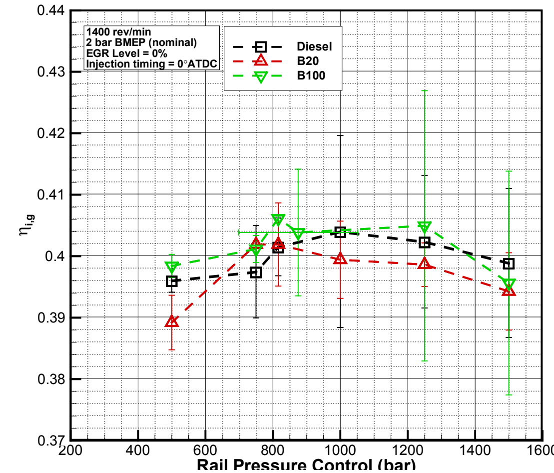
First Question: Are results real?

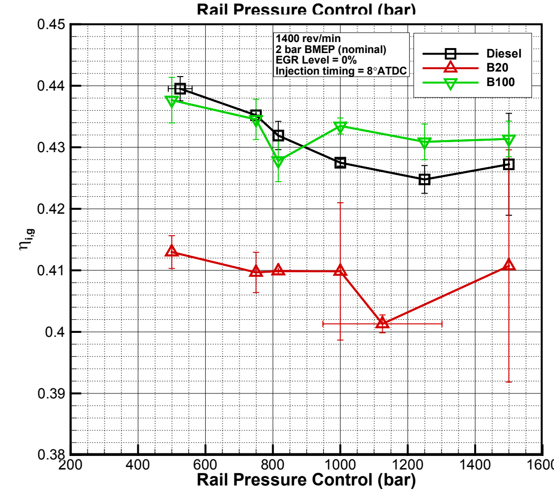
- Among all four cylinders (and averaged over all four cylinders), the biodiesel cases do not suffer the same efficiency drop at late timing as does diesel.
- The "more consistent" efficiencies among cylinders with biodiesel fuels may result from the lower needed A/F, if cylinder to cylinder variations are caused by air maldistribution.

Results



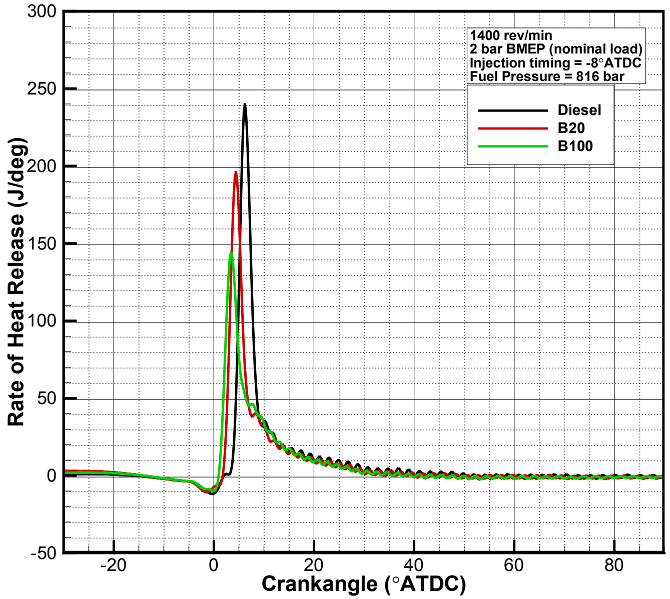


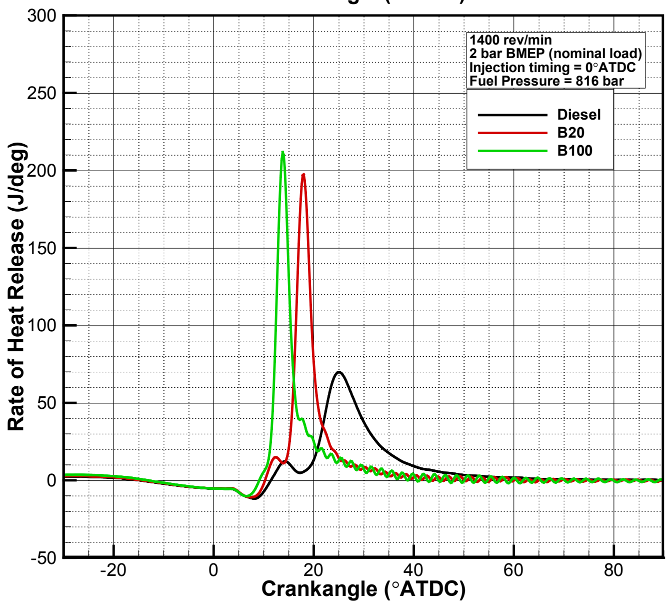




Similar behavior is seen when the extreme LTC condition is approached in a different fashion (i.e., an EGR Level Sweep). Other non-LTC conditions, however, show variable trends among fuels.

Results





- The apparent single-stage ignition of the biodiesel seems to improve its combustion phasing relative to B20 and Diesel, enabling it to offer the higher combustion efficiency.

- Work by Siebers (as early as 1985[1]) identified issues in characterizing ignition delays of fuels having different ignition temperatures and type of ignition (single-stage versus two-stage).

→ It seems this lack of two-stage ignition with biodiesel renders it a desirable fuel for enabling efficient later-phased LTC combustion.

[1] Siebers, D. (1985). *SAE Transactions* **94** (852102), pp. 673 – 686.

Conclusions

The major conclusions of this study are as follows:

- The efficiency improvement observed with B100 under later-phased LTC conditions is real across all cylinders and via different approaches to LTC attainment.
- The improvement in efficiency is linked to B100's distinct single-stage ignition behavior, enabling improved combustion phasing.

Future work will continue to explore the features of biodiesel that render it a single-stage ignition fuel and how this can be exploited for improved engine efficiency.

Thank you!

Thank you for your attention!

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