Fuel Effects on Low Temperature Combustion in a Light-Duty Diesel Engine

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Fuel Effects on Low Temperature Premixed Compression Ignition (PCI) Combustion in a Light-Duty Diesel Engine

Project Goals

- To examine which **fuel properties are desirable for PCI combustion** and can therefore be used to extend the PCI combustion regime over the engine operating map without increasing HC emissions and brake specific fuel consumption (BSFC).

- The **six fuels** were selected in such a way that the effects of various fuel properties on combustion and emissions could be isolated.

- Several **petroleum based diesel fuels, a pure Gas to Liquid (GTL) fuel and a blend of base diesel and 20% soy based biodiesel (B20)** were tested.

- Each fuel underwent a detailed **thermodynamic analysis**.

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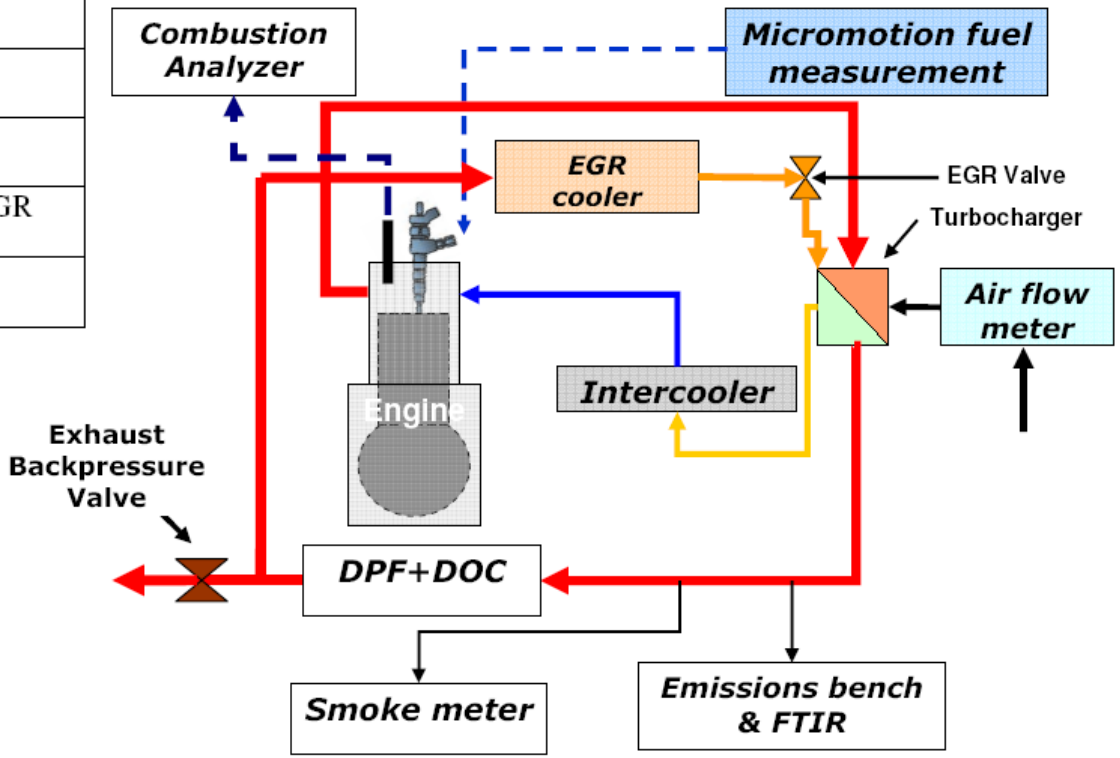
Overview of Premixed Compression Ignition Combustion Strategy

- Compression ratio was reduced below **16:1**
- Main injection **timing was retarded to after TDC**.
- **LP cooled EGR** was used.
- To shorten the injection duration **rail pressure was increased to 1600 bar** even at part load points.
- All approaches resulted in an **ignition delay that was longer than the injection duration**.

Engine Specifications and Setup

Engine Power	125 kW @ 4000 RPM
Peak Torque	300 Nm @ 1500-4000 RPM
Number & arrangement of cylinders	4 cylinder inline
Displacement	1.995 L
Compression Ratio	< 16
Fuel Injection System	Common Rail
Turbocharger	VGT
EGR	Low pressure cooled EGR
Aftertreatment	DOC+DPF



Fuel Specifications

		Fuel 1	Fuel 2	Fuel 3	Fuel 4	Fuel 5 (GTL)	Fuel 6 (B20)
Description	Unit						
Specific Gravity @ 15C		0.835	0.846	0.835	0.846	0.768	0.853
Distillation (ASTM D86)							
Initial Boiling Point	Deg. C	172	190	172	190	128	198
10% Recovery Temperature	Deg. C	193	221	193	221	175	229
50% Recovery Temperature	Deg. C	238	278	238	278	261	299
90% Recovery Temperature	Deg. C	319	325	319	325	329	337
End Point	Deg. C	344	356	344	356	352	351
Cetane (CN)	#	**44**	**48.5**	**58.5**	**58.5**	**75**	**48.6**
Heating Value NET	MJ/kg	43.28	43.57	43.28	43.57	44.2	42.45
Sulfur	ppm wt.	<6	13	<6	13	<6	10
Aromatics	%	9.1	25.3	9.1	25.3	0.5	
Carbon	wt. %	85.9	86.7	85.9	86.7	84.8	84.8
Hydrogen	wt. %	14.1	13.3	14.1	13.3	15.2	13
Oxygen	wt. %	0	0	0	0	0	2.2

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Test Strategy

- All fuels in the study were tested at **7 part load points** specified by engine speed (RPM) and brake mean effective pressure (BMEP).

N rpm	BMEP bar	Main MD µs
1500	3	PME*
1500	6	PME*
1750	7	PME*
2000	1	PME*
2000	6	PME*
2250	8	PME*
2750	9	PME*

* Parameter adjusted to reach engine point BMEP

- **EGR rate was kept the constant** for all fuels and the maximum EGR rate used was limited to keep the smoke number below 3.0 at all points.

- **Engine parameters were not adjusted or optimized for each fuel**. Only the main injection quantity was adjusted to achieve the same BMEP.

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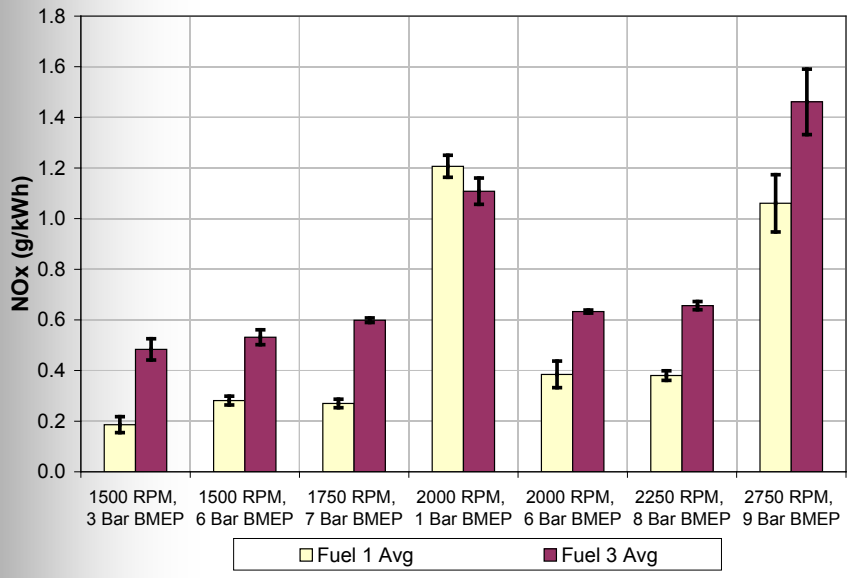
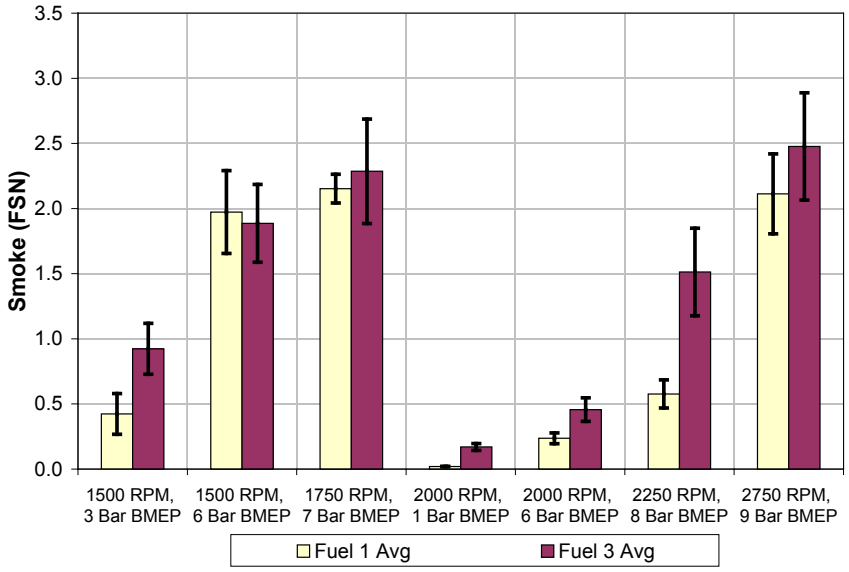
Results and Discussion – Influence of Cetane Number

Specific NOx emissions as well as smoke were higher for Fuel 3 (CN = 58.5) compared to Fuel 1 (CN = 44).

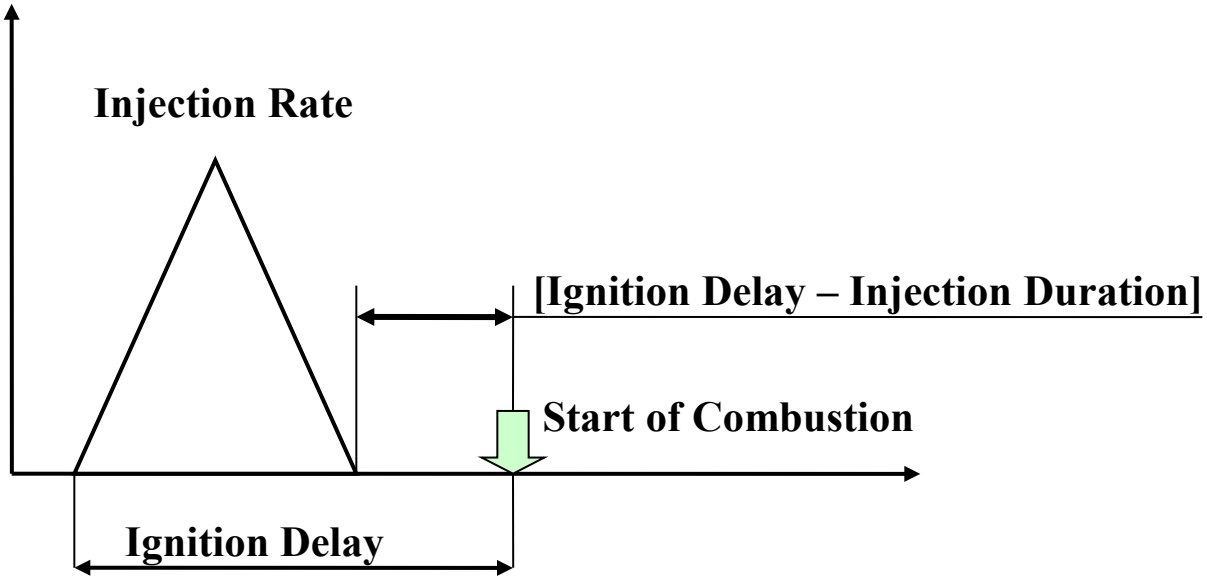




Fuel 1 **Fuel 3**

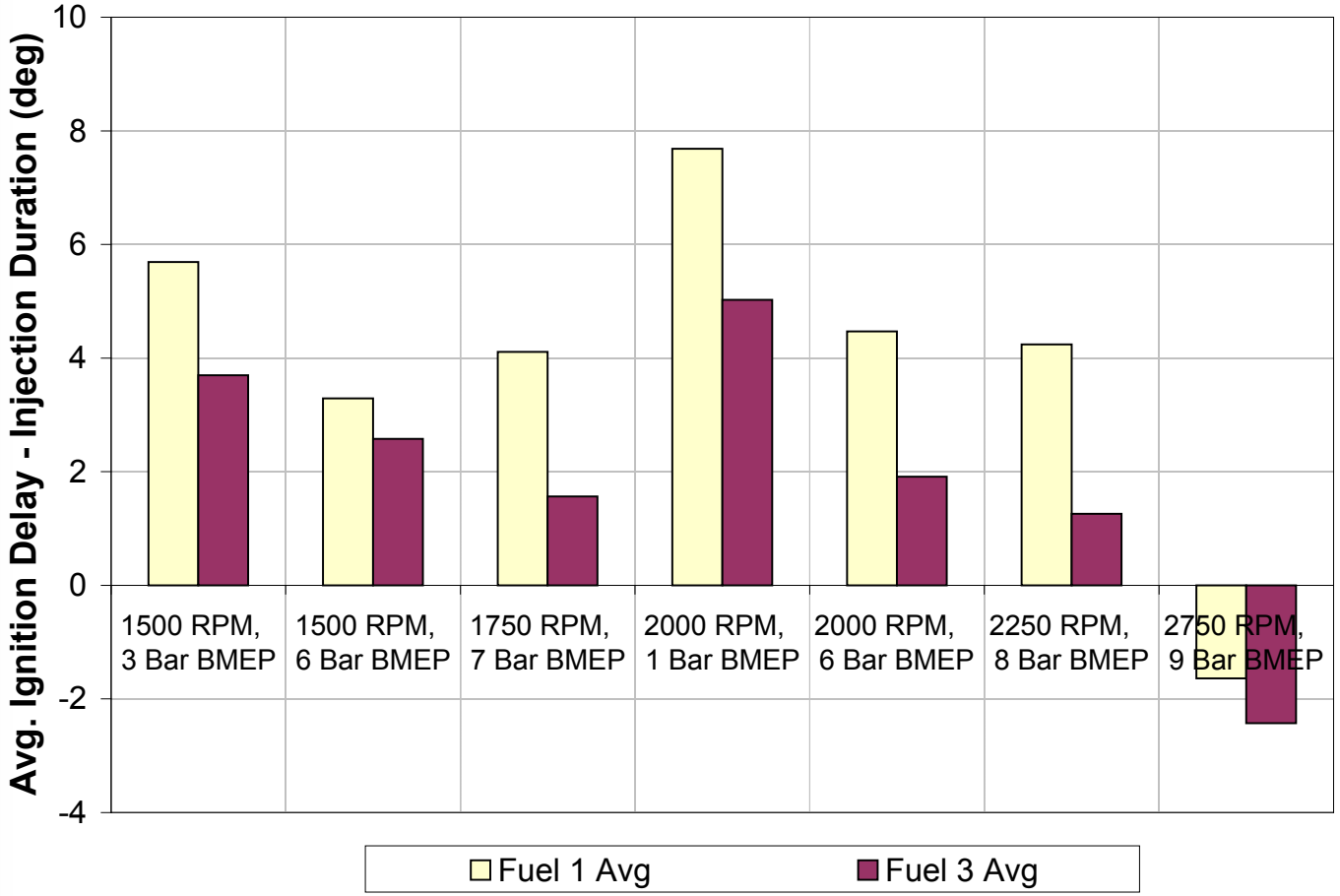
Results and Discussion – Influence of Cetane Number

[Ignition delay-Injection Duration] was used to compare premixing duration for the different fuels



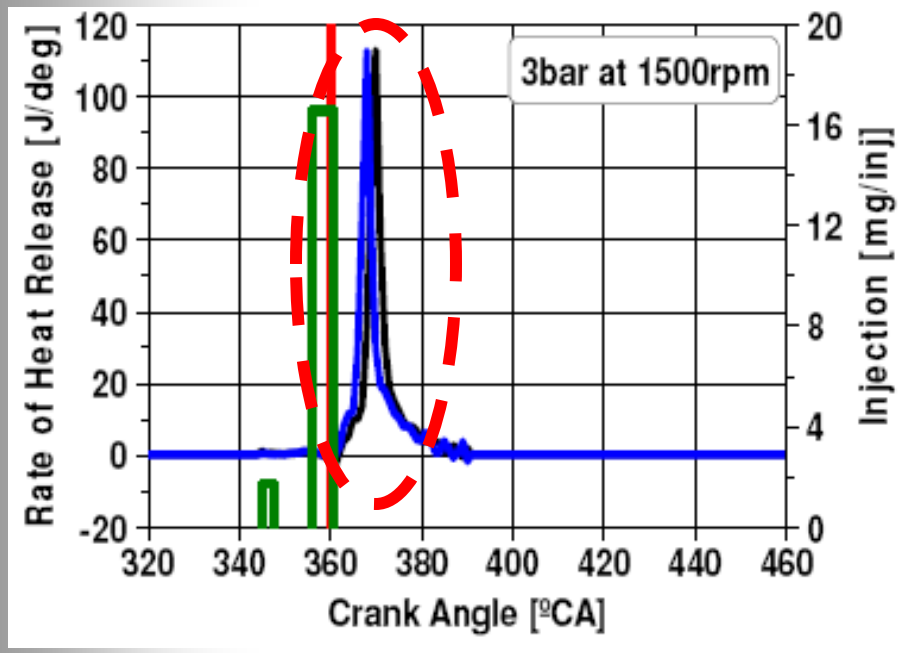
Results and Discussion – Influence of Cetane Number

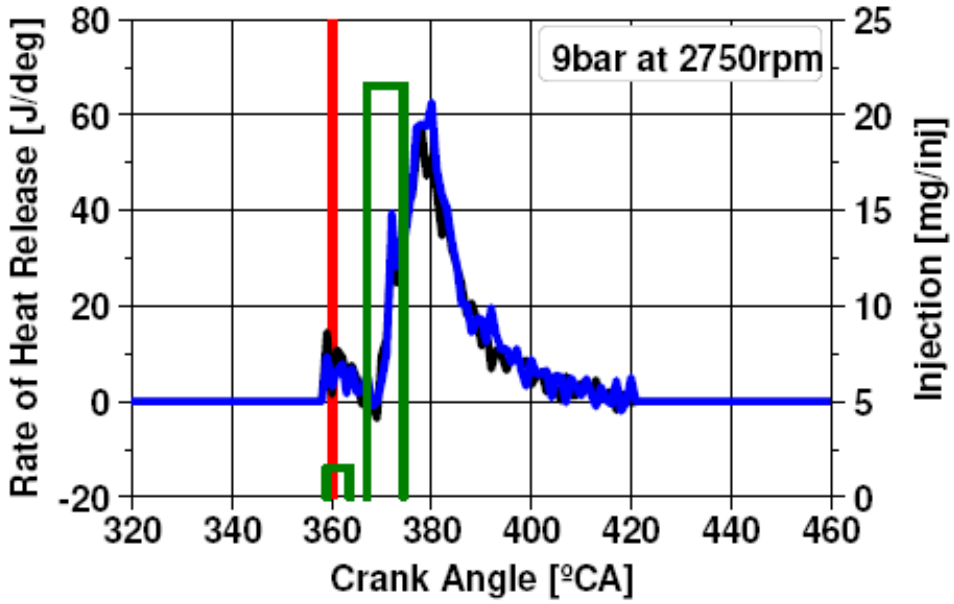
[Ignition delay-Injection Duration] was shorter for Fuel 3 (CN = 58.5) compared to Fuel 1 (CN = 44).



Results and Discussion – Influence of Cetane Number

Apparent net rate of heat release curve for the **1500 RPM and 3 bar BMEP test point** shows a **single stage profile of entirely premixed combustion**

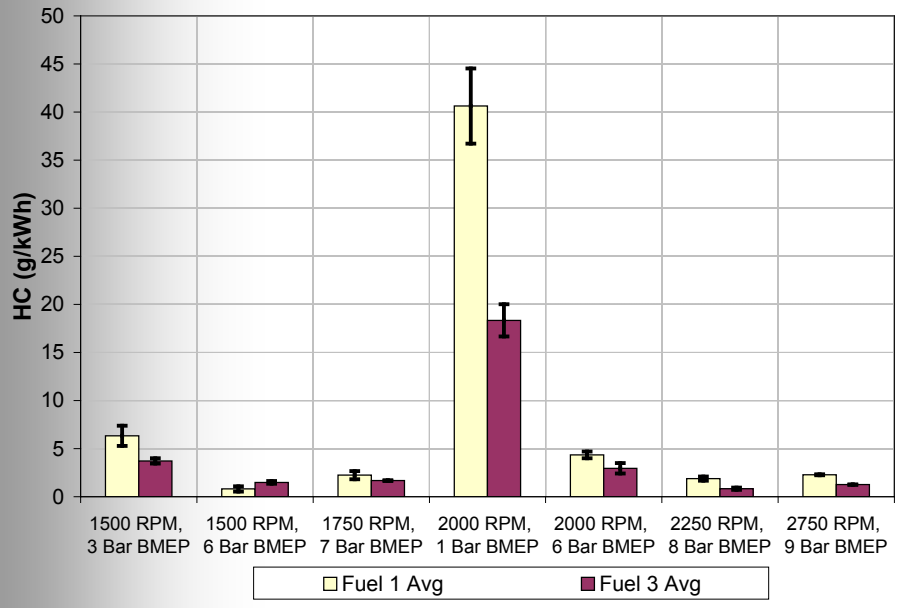


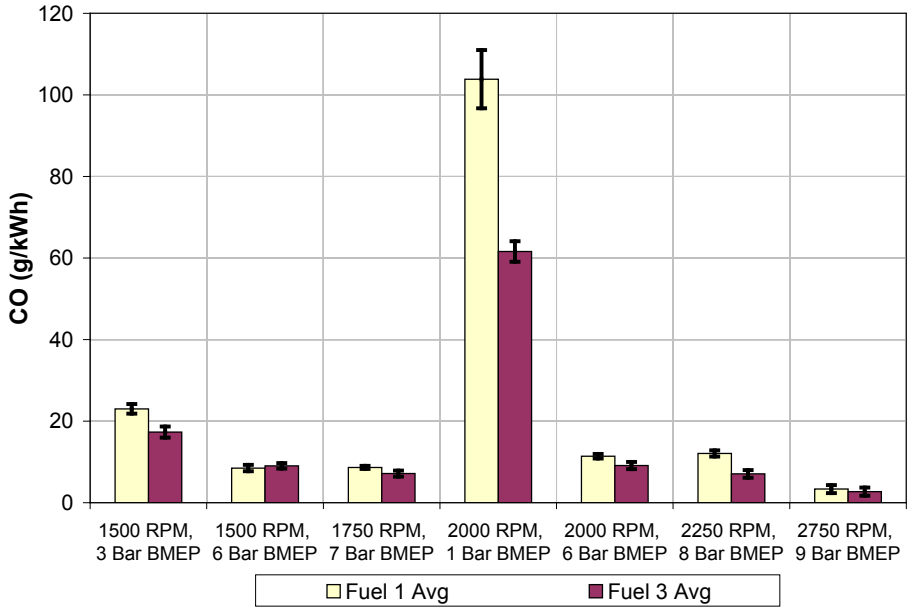


Fuel 1 — Fuel 3 — TDC — Injection Signal

Results and Discussion – Influence of Cetane Number

HC and CO emissions were lower for Fuel 3 (CN = 58.5) compared to Fuel 1 (CN = 44).



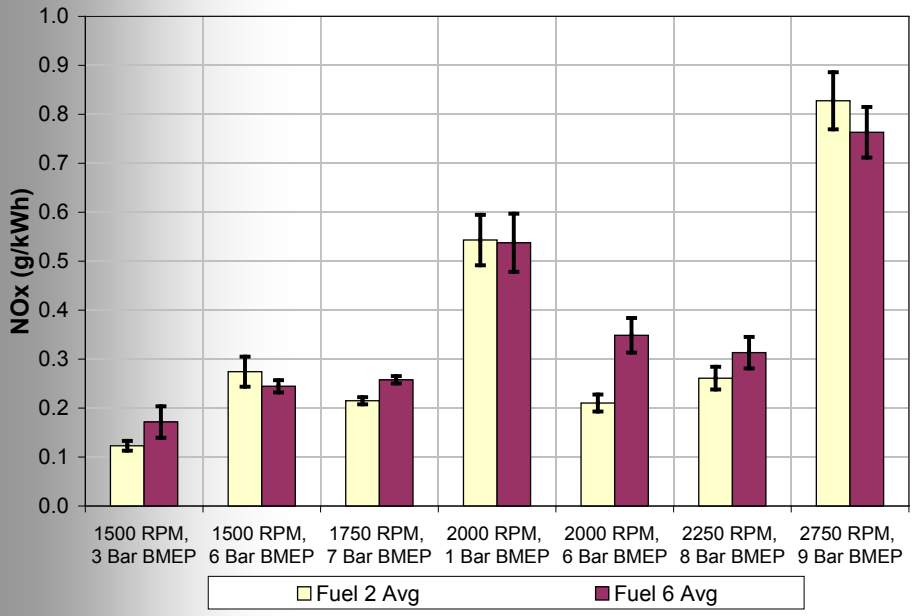


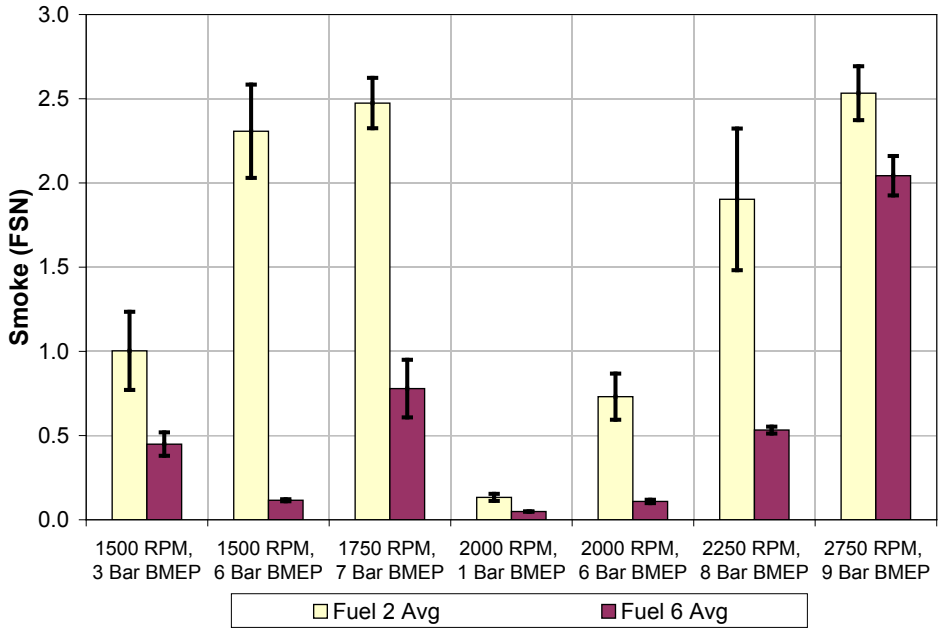
Fuel 1 **Fuel 3**

Results and Discussion – B20 vs. Base Diesel

- **Specific NOx emissions were higher for the biodiesel blend (Fuel 6)** compared to the base diesel fuel (Fuel 2) **at some points**, while **smoke emissions were significantly lower**.

- **Smoke emissions for the B20 blend were the lowest observed in the study**.

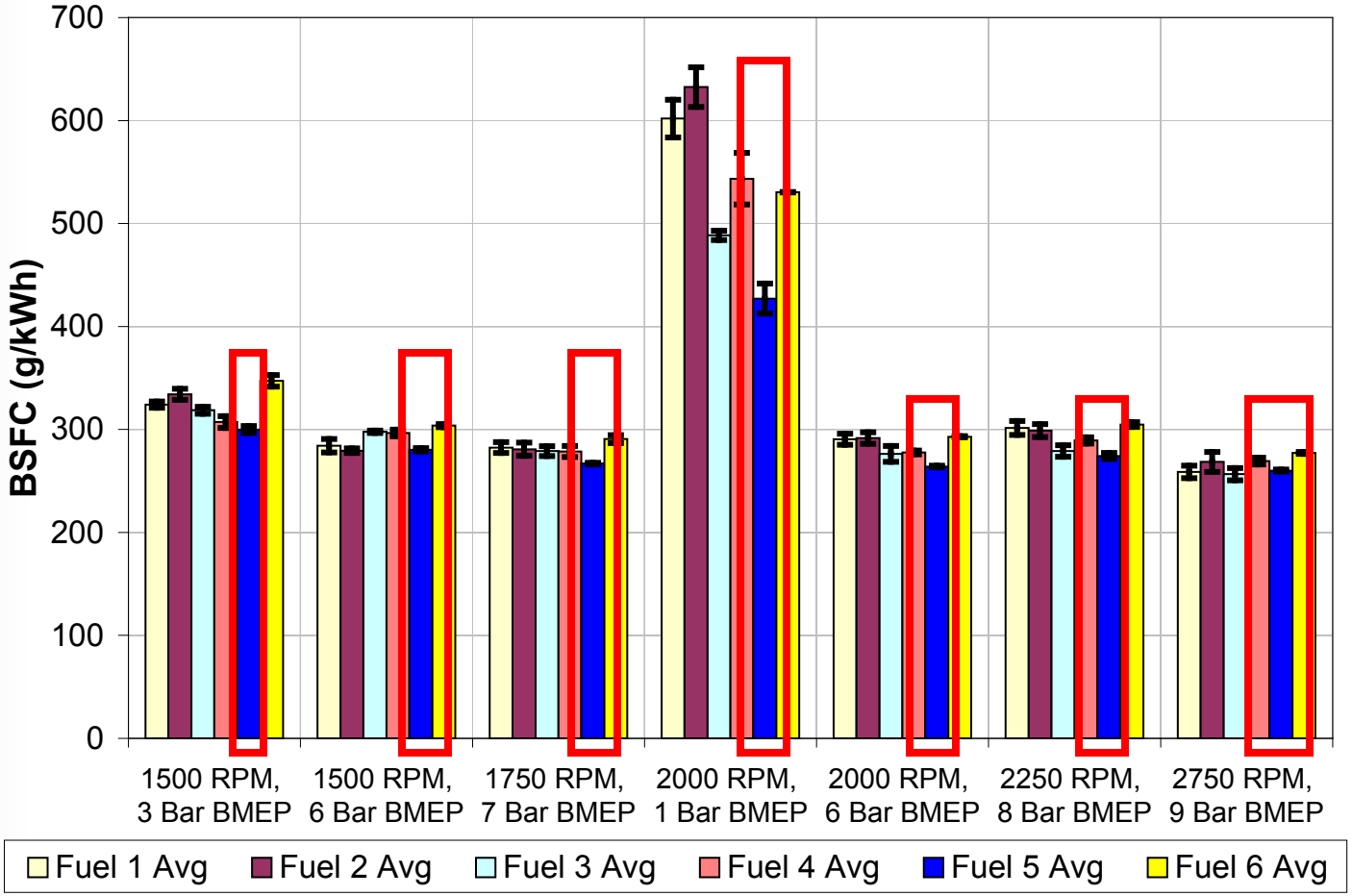




Fuel 2 (Base Diesel) **Fuel 6 (B20)**

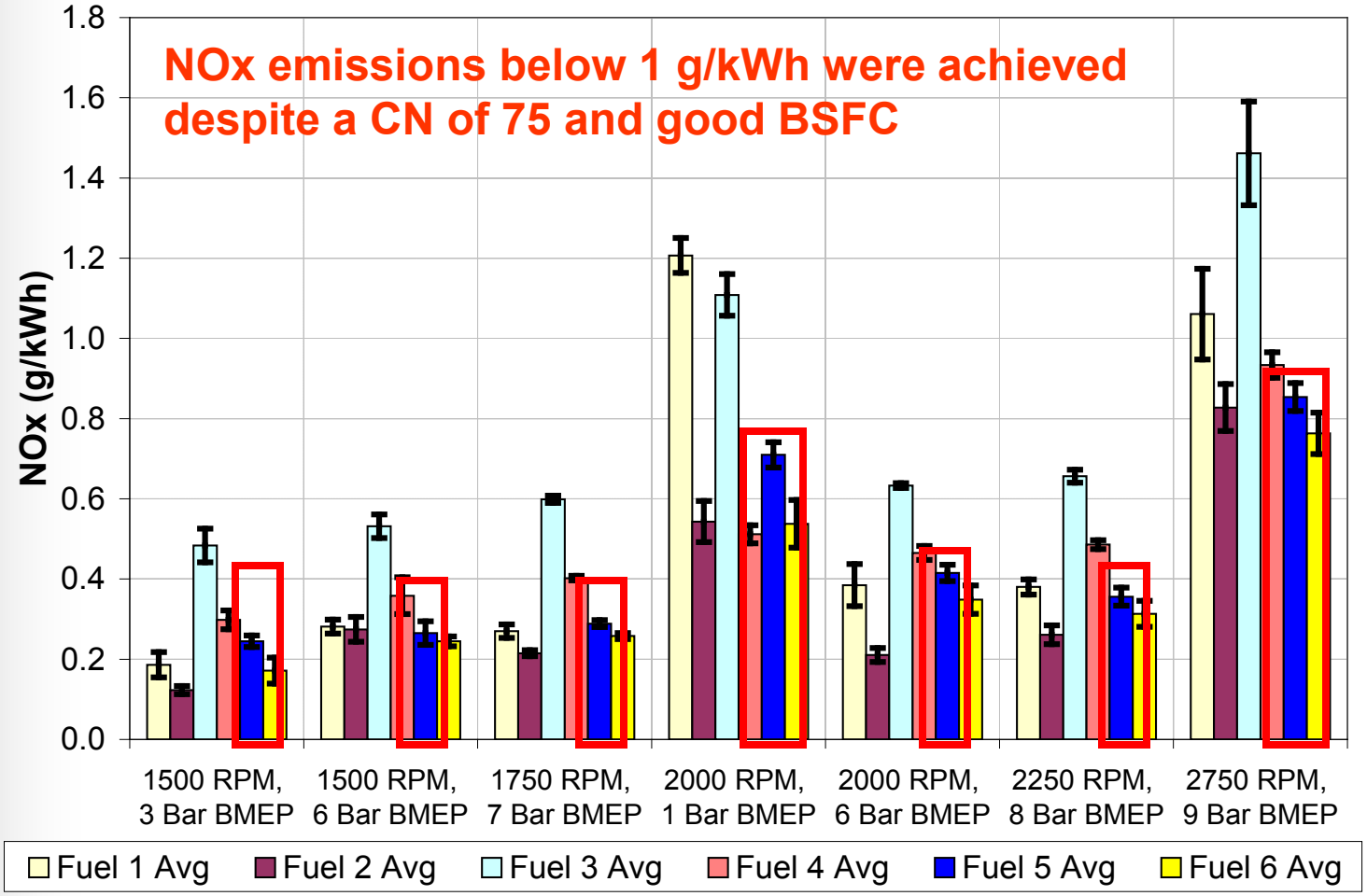
Results and Discussion – All Fuels

Overall the **GTL fuel (Fuel 5) had the best BSFC in the study**.



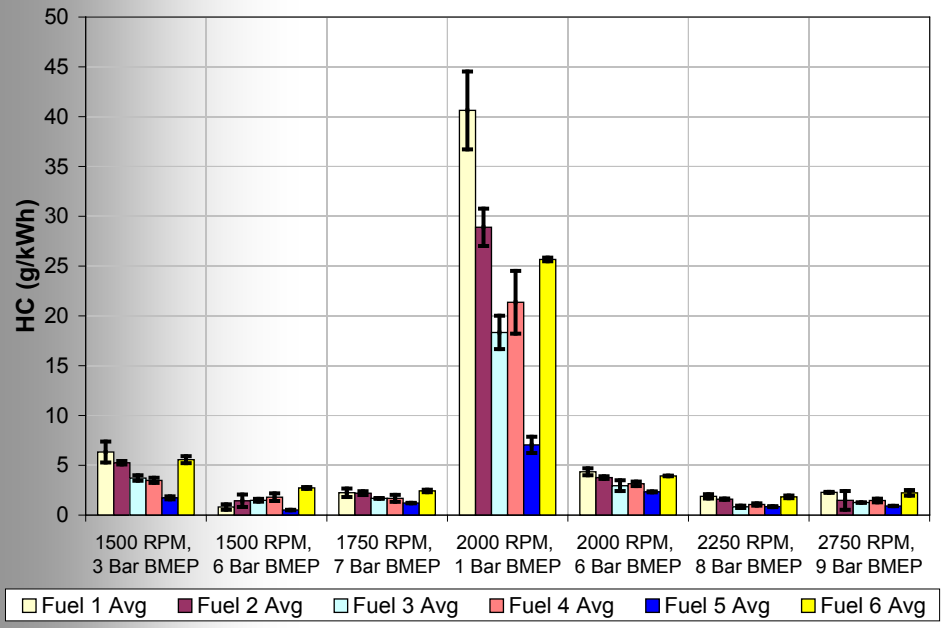
Results and Discussion – All Fuels

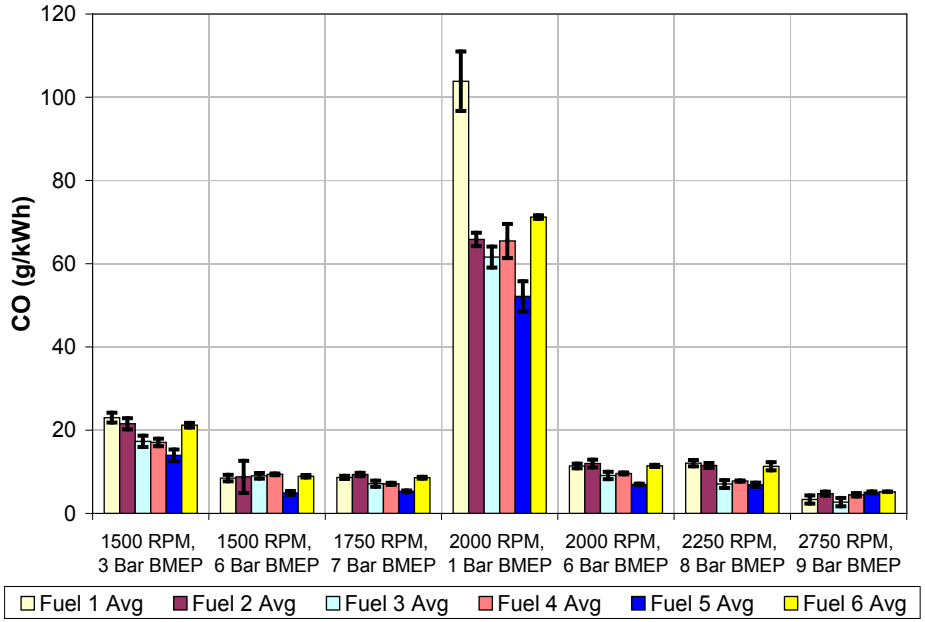
Specific NOx emissions for all fuels including GTL fuel (Fuel 5)



Results and Discussion – All Fuels

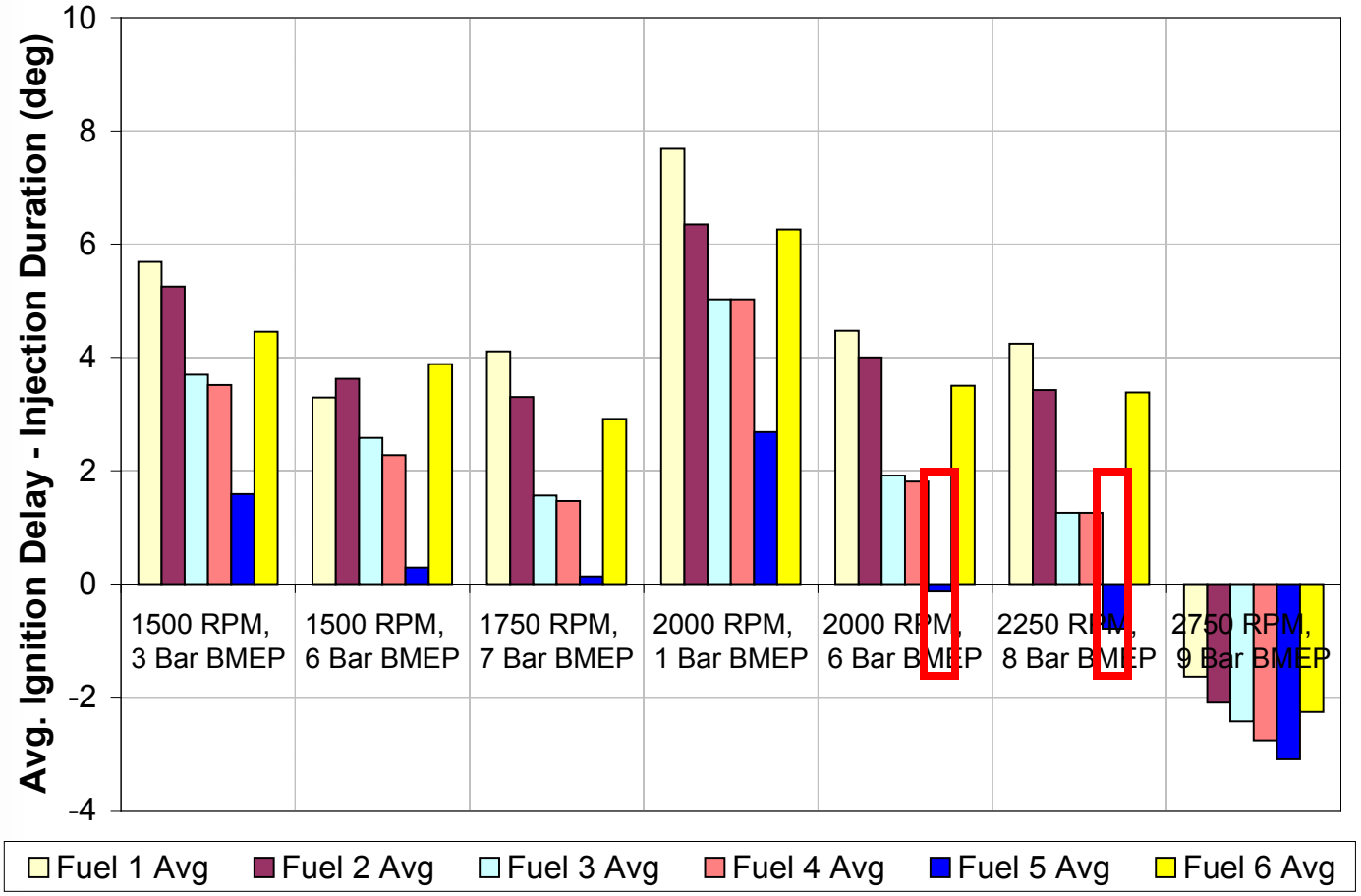
GTL fuel (Fuel 5) had the lowest HC and CO emissions observed in the study.





Results and Discussion – All Fuels

Premixed combustion was impeded for the GTL fuel (Fuel 5) at some points since the ignition delay was shorter than the injection duration.



Conclusions

- **NOx and PM emissions could be simultaneously reduced** at part load by low temperature and premixed combustion. However **it was not possible to achieve PCI combustion at the 2750 RPM and 9 bar BMEP** test point.
- In general, **lower cetane number fuels had lower NOx and smoke emissions** in the low temperature PCI combustion regime due to their longer ignition delay, but had **higher HC and CO emissions**.
- The **B20 biodiesel blend (Fuel 6) had higher NOx** at some points and significantly lower smoke emissions compared to the base diesel fuel (Fuel 2) due to oxygen availability in the fuel.
- The **B20 blend had the lowest smoke emissions** observed in the study among all fuels.
- The **GTL fuel (Fuel 5) had the lowest BSFC in the study**. If the engine and injection parameters are optimized for GTL fuel then a combination of PCI combustion and GTL fuel can be used at part load to achieve reductions in NOx and smoke emissions without adverse effects on BSFC and HC emissions.
- **The results for the GTL fuel and the B20 blend are the most encouraging**. Both fuels with further optimization of injection and engine operating parameters offer the potential to reduce engine out HC and CO emissions in the low temperature PCI combustion regime and extend the high load limits of PCI combustion.

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Thank you

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