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PRE-CHAMBER IGNITION - A ROAD TOWARDS HIGH EFFICIENCY NATURAL GAS ENGINES

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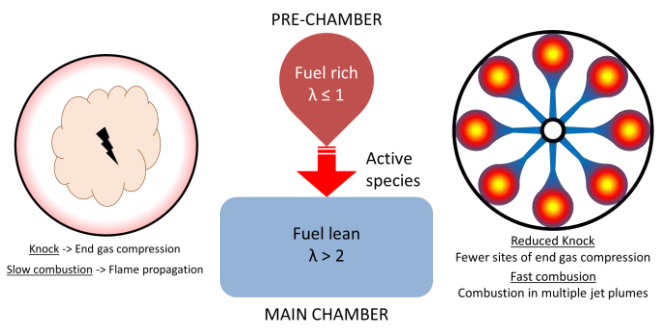
PROJECT AIM

The Gas Engine Project is a part of the Competence Centre for Combustion Processes (KCFP) at Lund University.

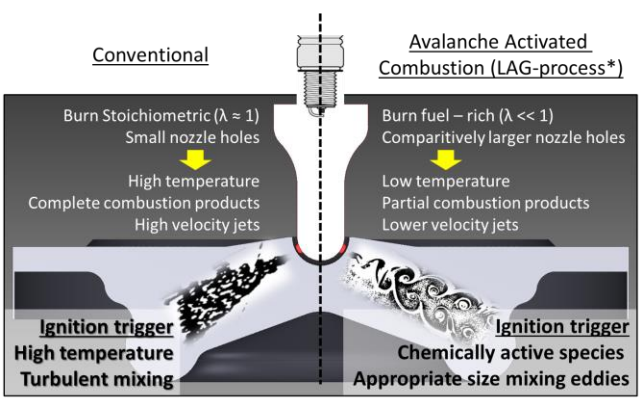
- The project aim is to improve overall fuel efficiency and operating load range for heavy duty natural gas engines
- The current phase, which started June 2011, focuses on alternative ignition techniques

SPARK IGNITION vs. PRE-CHAMBER IGNITION



- ☑ Spatially distributed ignition source
- ☑ Less affected by cyclic variation of main chamber charge motion
- ☑ Burning jets provide much higher ignition energy than a spark
- ☒ Resulting ignition mechanism is less understood due to its fluid dynamic and chemical kinetic complexities
- ☒ Pre-chamber over heating may cause charge pre-ignition

FUEL-RICH PRE-CHAMBER COMBUSTION



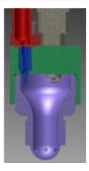
EXPERIMENTAL SETUPS

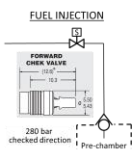
❶ 6-CYLINDER **VOLVO** TRUCK ENGINE

No. of cylinders	6
Displacement	≈ 9.4 liters
Bore	120 mm
Stroke	138 mm
Compression Ratio	12
Charging system	Turbo-charged Inter-cooled
Fuel injection	Multi-port
Pre-chamber	
Volume	0.2 cm³ (0.12 % of V_c)
Nozzle Diameter	1.1 mm
Number of nozzles	5

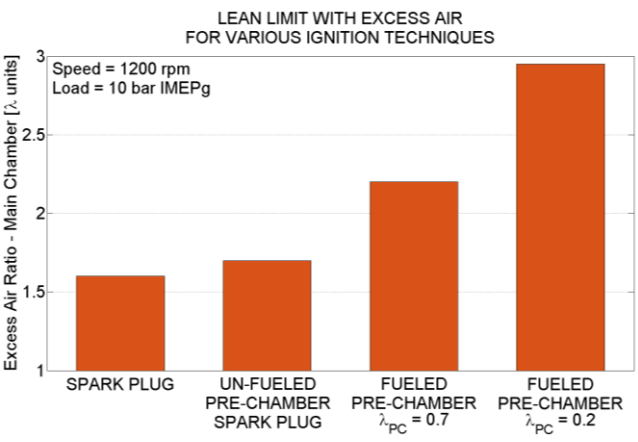
❷ SINGLE CYLINDER **SCANIA** TRUCK ENGINE

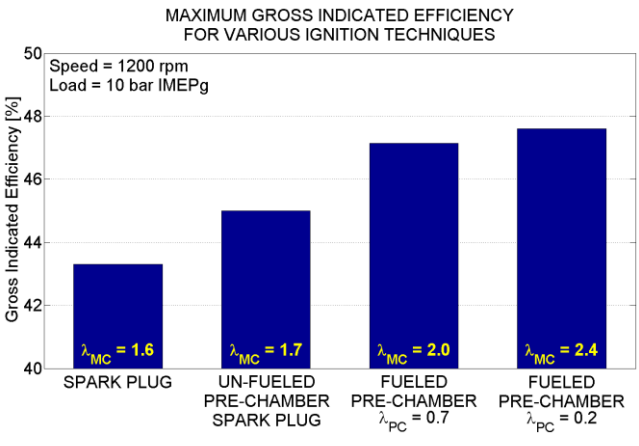
No. of cylinders	1
Displacement	≈ 2.12 liters
Bore	130 mm
Stroke	160 mm
Compression Ratio	12
Pre-chamber	
Volume	4.68 cm³ (2.4 % of V_c)
Nozzle Diameter	1.6 mm
Number of nozzles	8

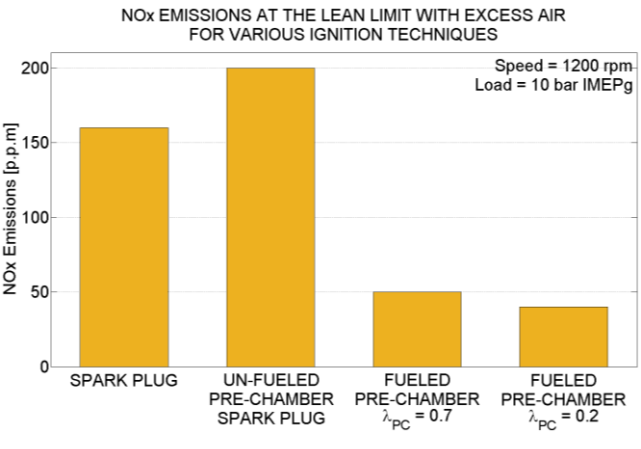


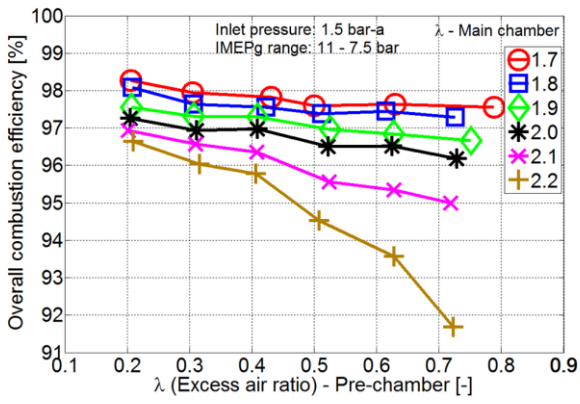


RESULTS

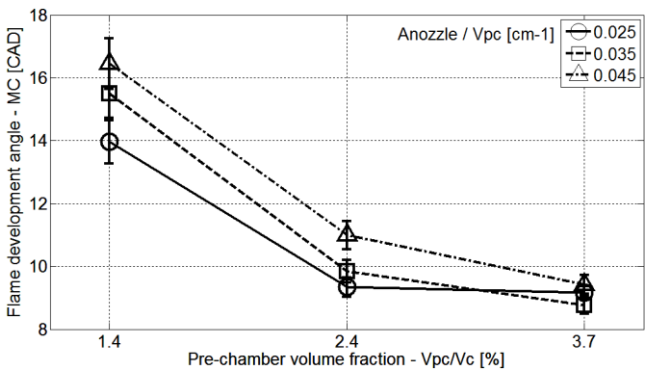


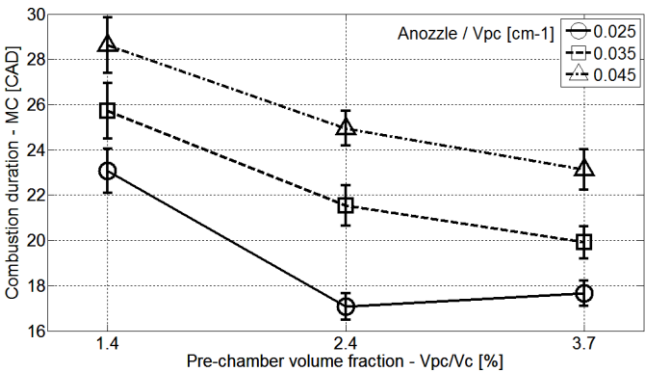


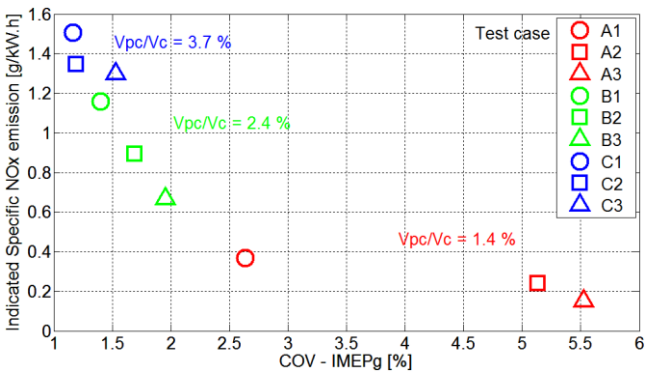




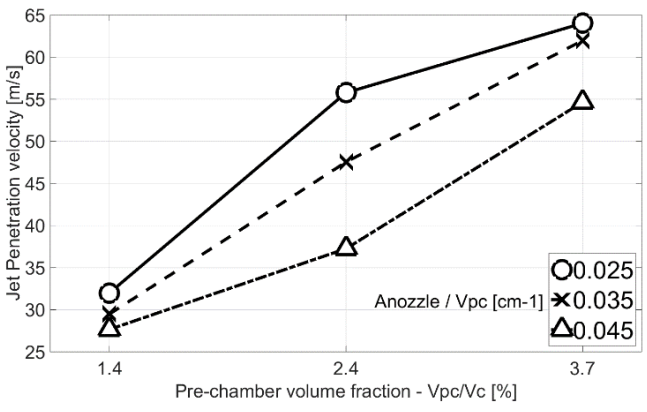
Effect of Pre-Chamber Volume and Nozzle Diameter







CFD Simulations of Pre-chamber Jets



Observations and Conclusions

- A pre-chamber ignition device without additional fuelling reduces cyclic variations of combustion event but is not capable of considerably extending the lean limit.
- A pre-chamber with additional fuelling can considerably extend the lean limit of operation and hence improve indicated efficiency and reduce NOx emissions
- Increasing the pre-chamber volume provides higher ignition energy but the upper limit is restricted by the fraction of pre-chamber combustion before main chamber ignition.
- Reducing the pre-chamber nozzle diameter increases pre-chamber jet velocity and hence promotes turbulent mixing in the main chamber, but the lower limit is governed by discharge coefficient and pre-chamber jet momentum.
- Based on studies so far, a pre-chamber volume fraction of 2.4% with nozzle area ratio of 0.035 cm^{-1} has been found to be an optimal trade-off between ignition improvement in the main chamber and NOx emissions.

Future Plans

- Study the performance of pre-chamber ignition system at full load conditions (IMEPg > 20 bar)
- Optical diagnostics of pre-chamber ignition in the Wärtsilä large bore engine through optical access to the main chamber and/or pre-chamber.
- Optical diagnostics of knock phenomenon with pre-chamber ignition.

References

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- Shah, A., Tunestal, P., and Johansson, B., **SAE Technical Paper 2015-01-0867**, 2015, doi:10.4271/2015-01-0867

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