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Experimental Investigation of Dual-Fuel Diesel Engine with Wet Ethanol

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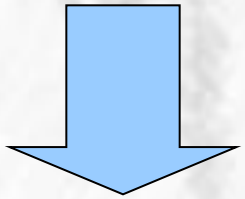
Outline

- Introduction (wet ethanol, dual-fuel diesel engine)
- The goal of the study
- Experimental equipment and procedure
- Experimental results and conclusions
- Summery
- Next steps

Background

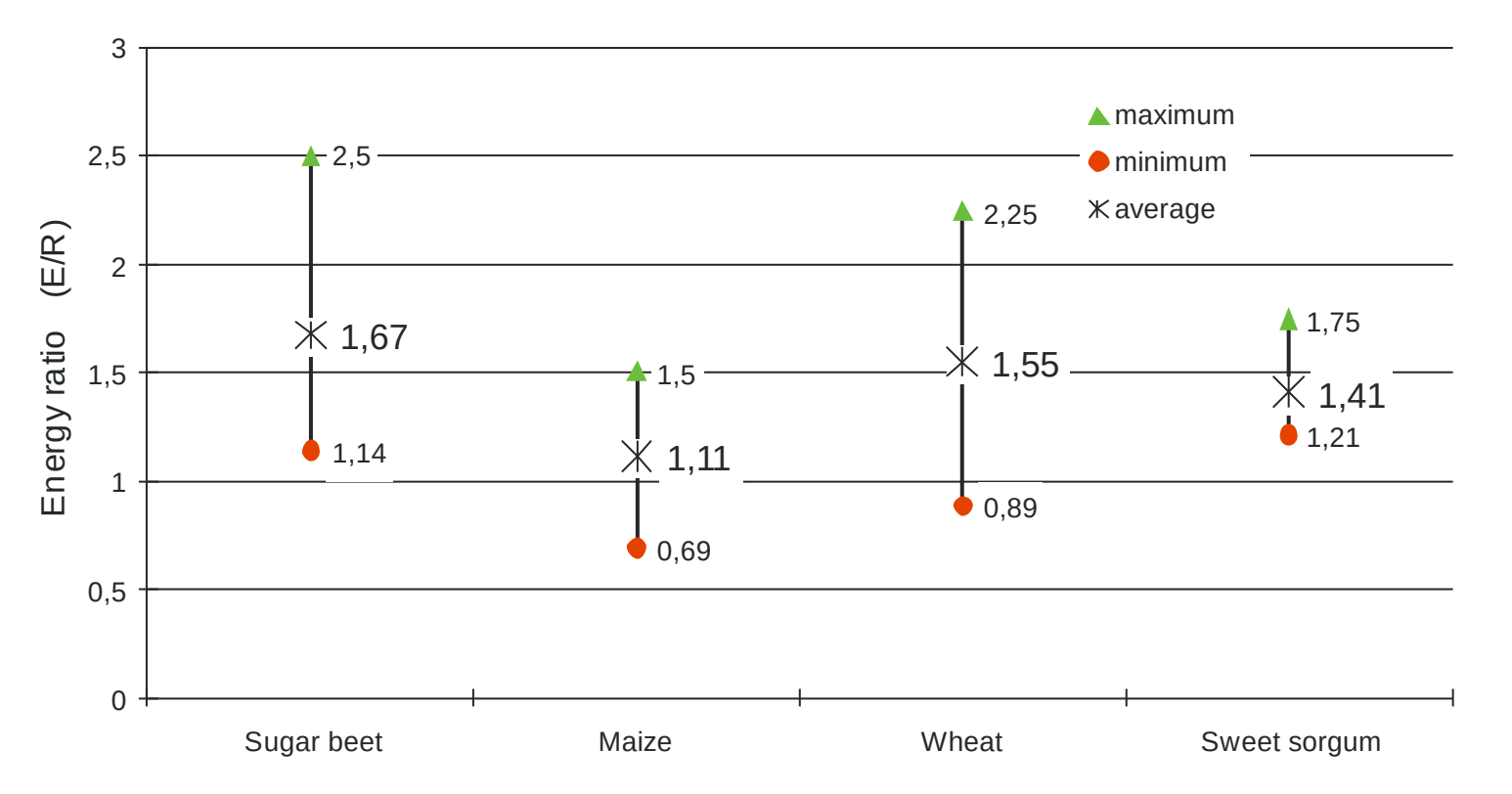
"Biomass based, complex, coupled heat- and electrical power generation" (NKFP3-00006/2005)



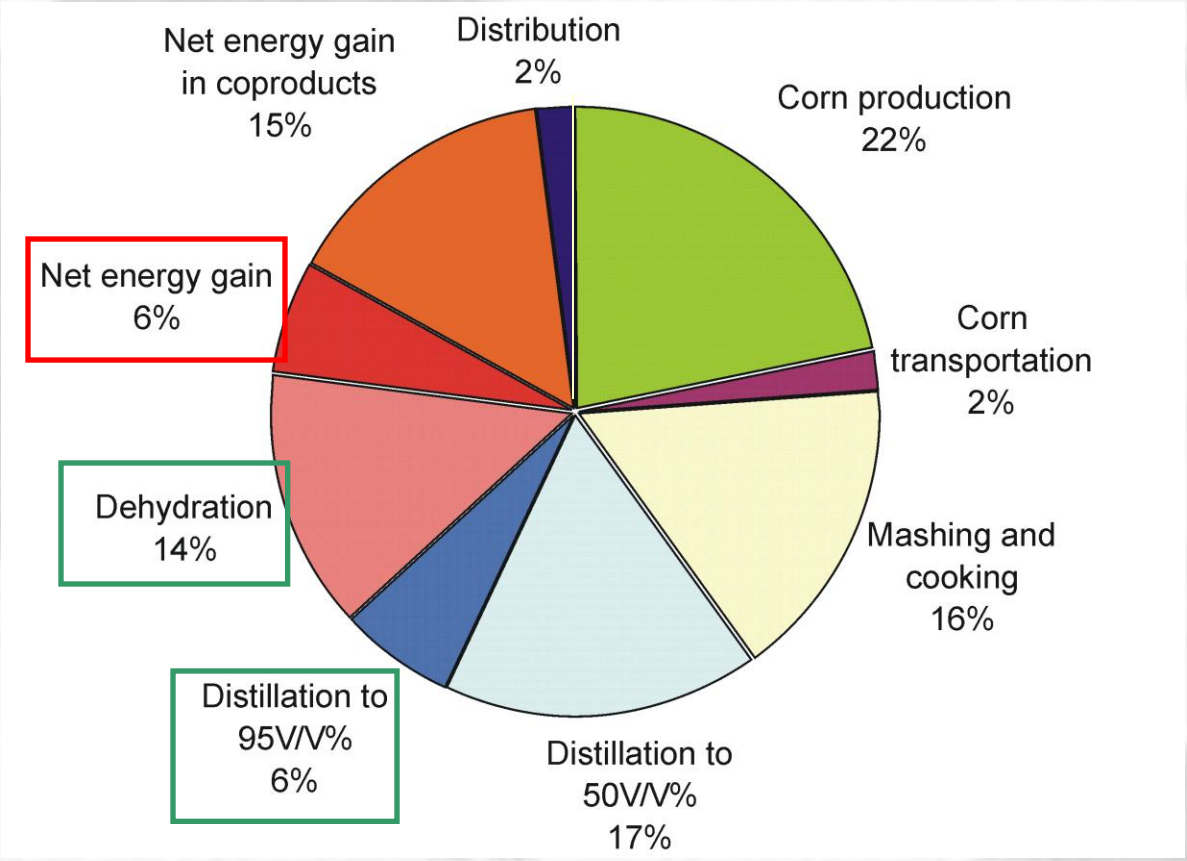
Energetic utilisation of crude alcohol (wet ethanol)

Energy ratio of **anhydrous** ethanol from different feed stocks

Energy ratio = output/input energy of 1kg ethanol



Energy balance of ethanol from maize

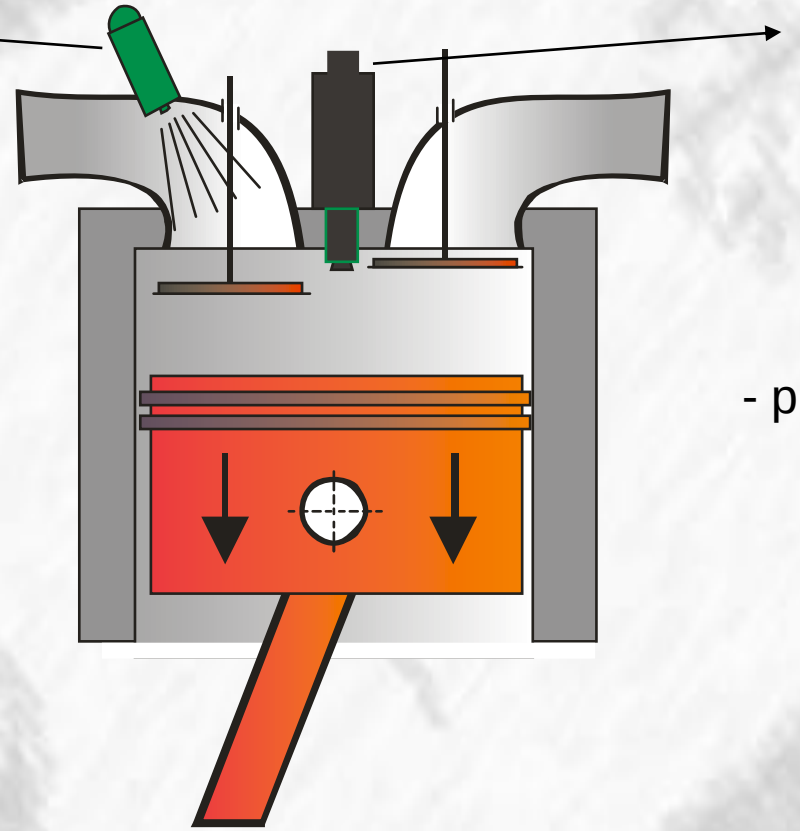


- energy gain of **anhydrous** ethanol : **6%**
- energy gain of **95 V/V%** ethanol : **20%**
- energy gain of **50 V/V%** ethanol : **26%**

Dual-fuel diesel engine

Wet ethanol Injector (primary fuel)

-creating ethanol/air mixture in the cylinder



Diesel Injector (secondary fuel)

- pilot dose for ignition

Ethanol Percentage (EP) = $Q_{wet\ ethanol}$ / ($Q_{wet\ ethanol}$ + $Q_{diesel\ fuel}$)

The goal of the study

- Experimentally investigation of emission, performance and combustion characteristics of a dual-fuel diesel engine fuelled with wet ethanol
- Exploring the operational limits of the system
- Special emphasis is placed on high load operation and high ethanol percentage

Experimental equipment and procedure

The engine

- IVECO AIFO 8031 i06.05
- 3 cyl diesel engine
- Naturally aspirated
- Direct injection
- Displacement: 2,9 liter
- Bore: 104 mm
- Stroke: 115 mm
- Compression ratio: 17:1
- Max. electrical power: 25 kW

Measuring system

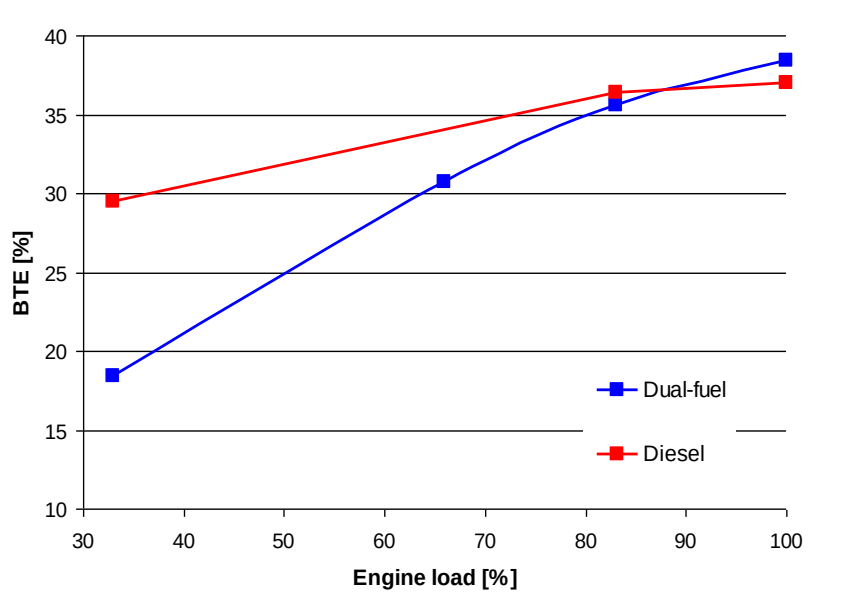
- Diesel fuel consumption (AVL 7031 gravometric meter)
- Wet ethanol consumption (digital scale and elapsed time)
- Engine power (electrical power meter, generator efficiency)
- Exhaust emissions (NOx, CO, HC with HORIBA MEXA; particulate matter with AVL415)
- In-cylinder pressure (piezoelectric sensor)
- Pilot injection timing (piezoelectric sensor attached to the high pressure fuel pipe)
- Heat release rate (HRR) was calculated with zero-dimensional method

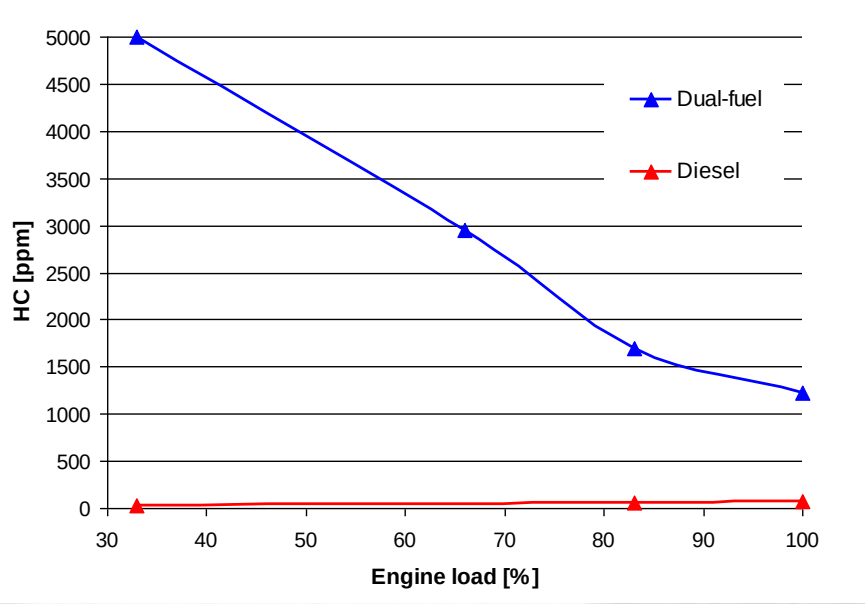
Test procedure

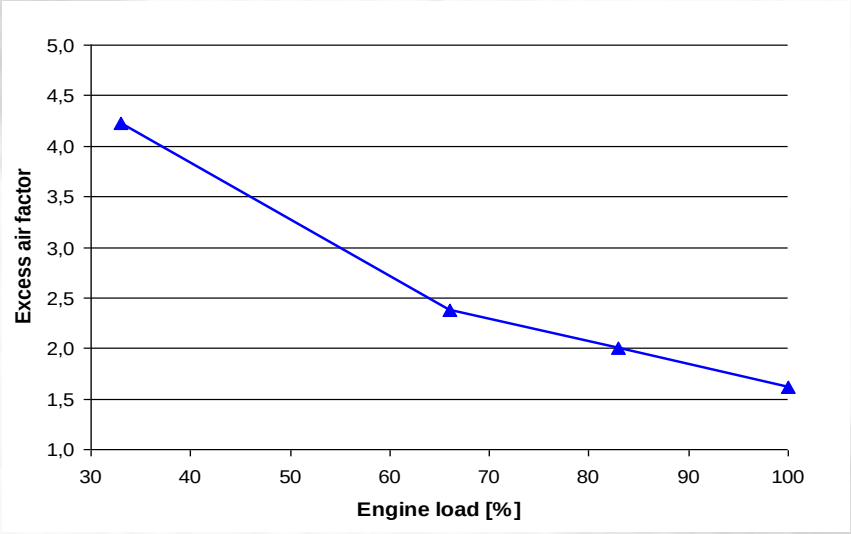
- Fixed speed at 1500 rpm
- Wet ethanol fuel: 95 m/m% ethanol + 5 m/m% water
- Four engine loads (33%, 66%, 83% and 100%)
- The ethanol percentage was varied from 0% to 92%
- The pilot injection timing was changed in 2.5 °CA steps

Results

Low load problem

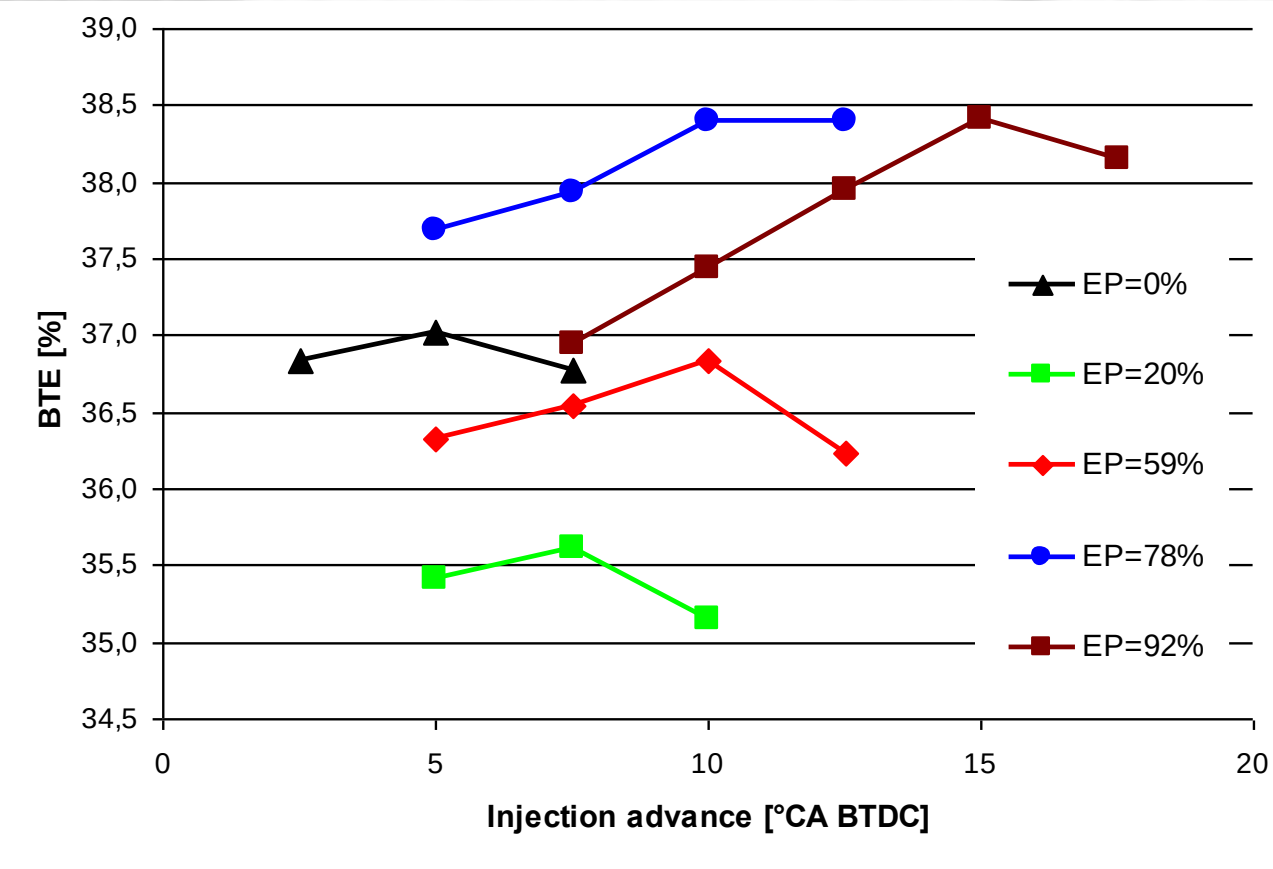




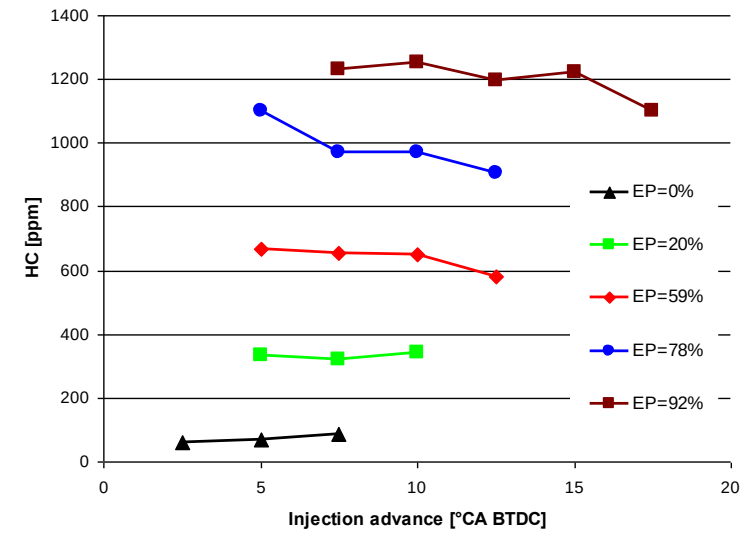


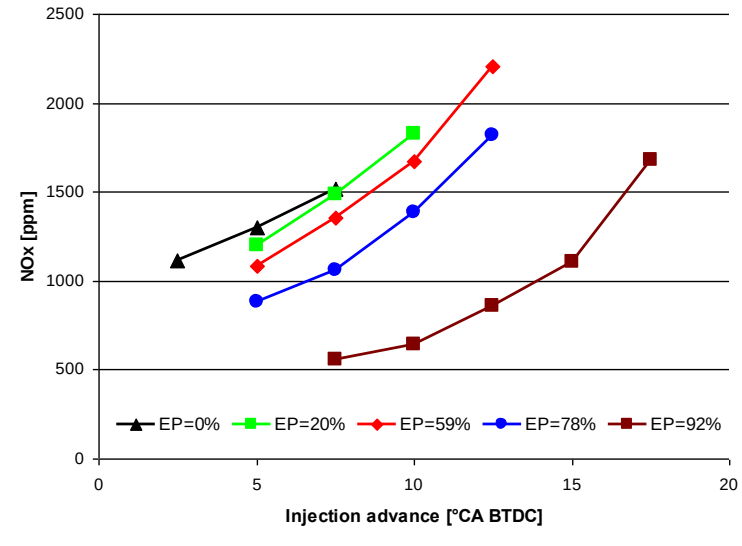
- nearly constant pilot dose (0.46-0.60 [kg/h]) for dual-fuel in these figures

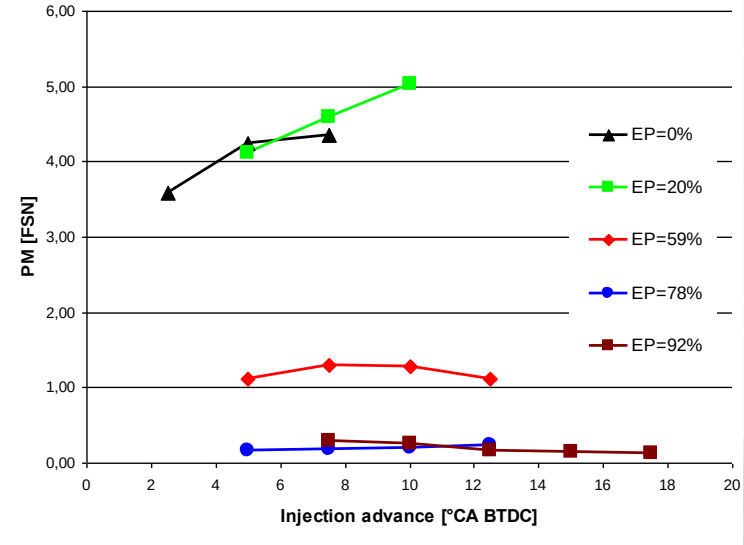
BTE vs. pilot injection advance at **100% load**

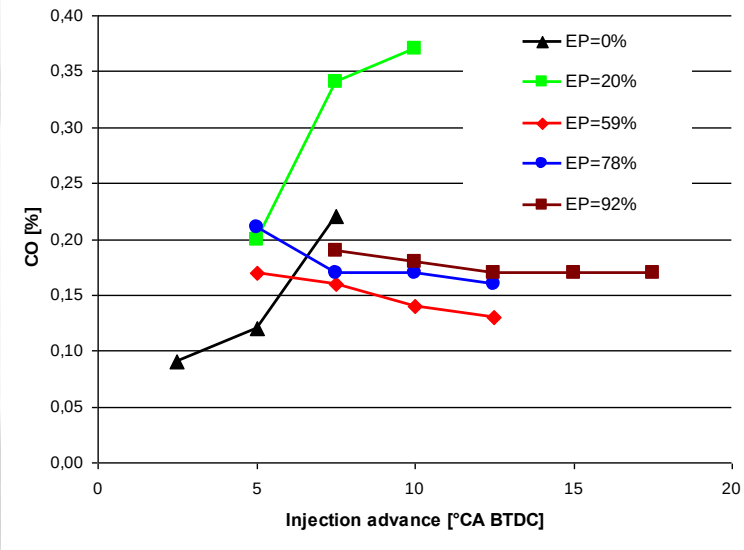


Emissions vs. pilot injection advance at **100% load**





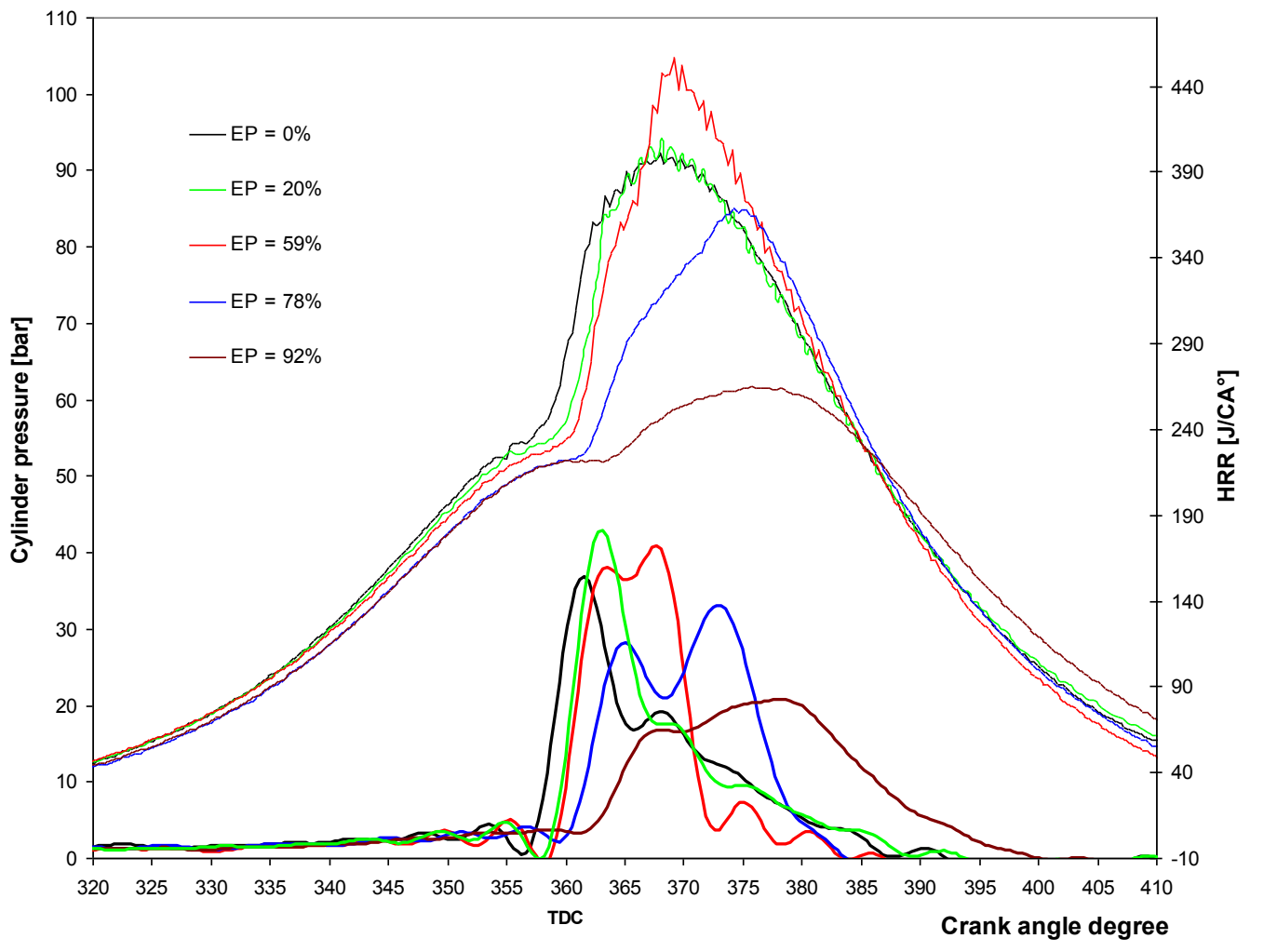




Combustion characteristics

-100% load

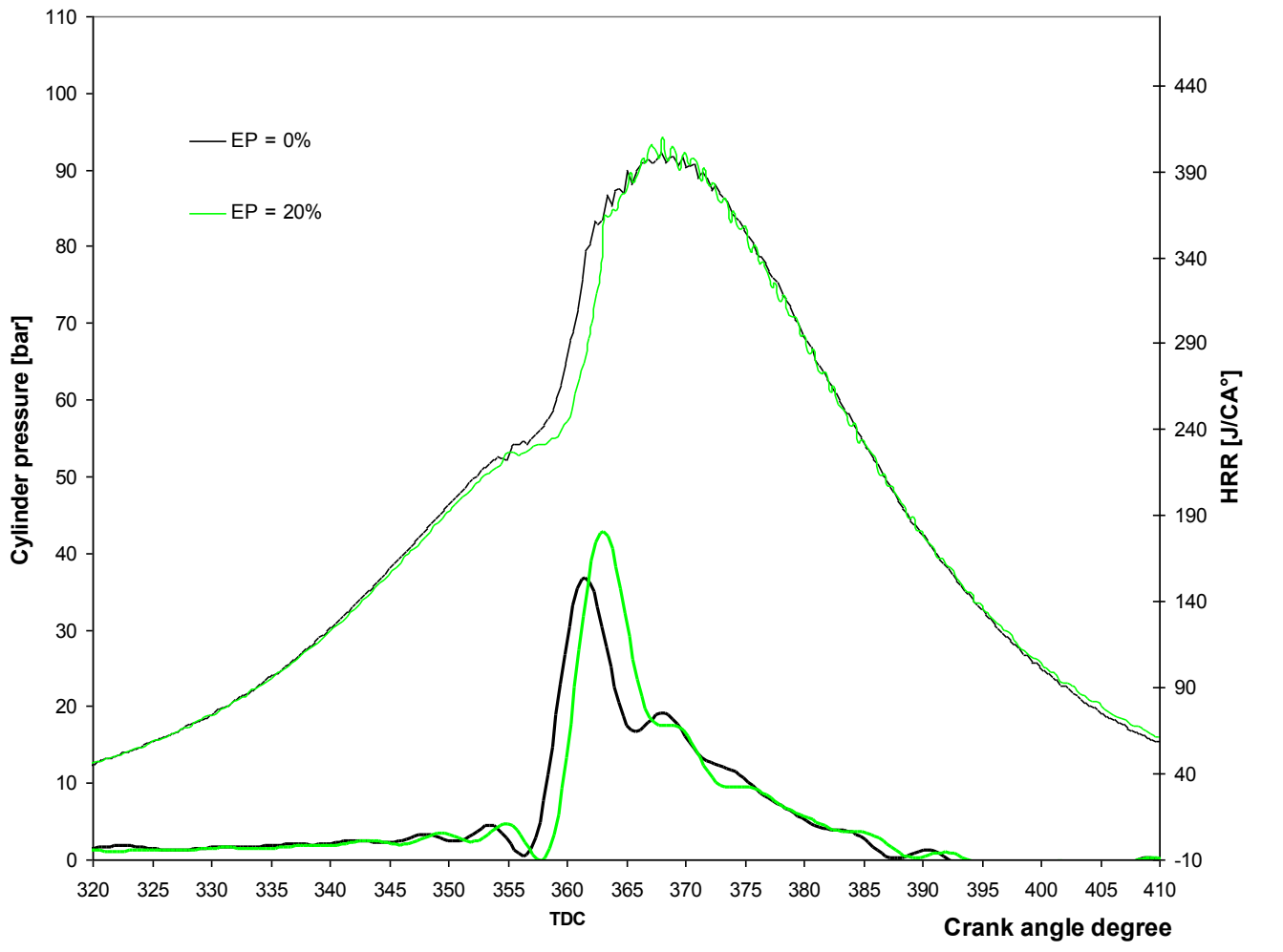
-Pilot timing: 7.5 CA°BTDC



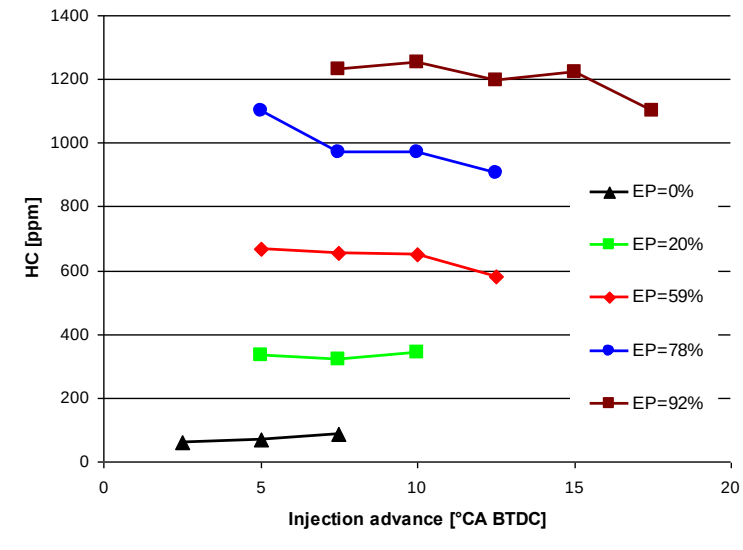
Diesel and close to diesel operation

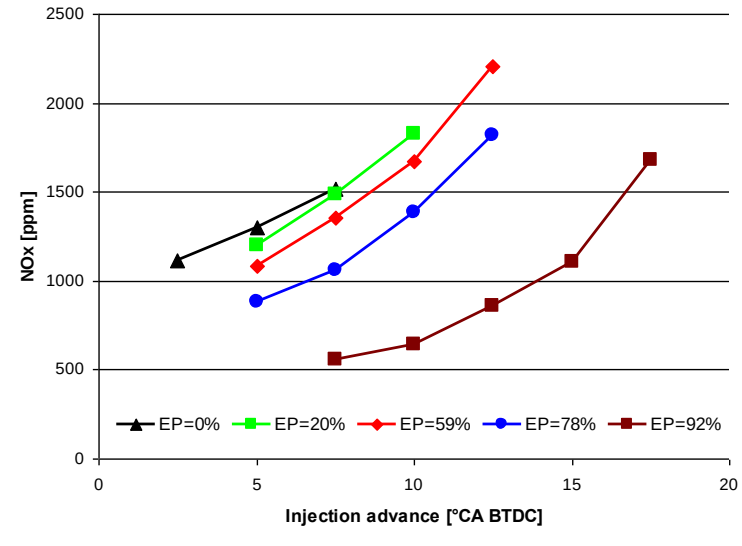
-100% load

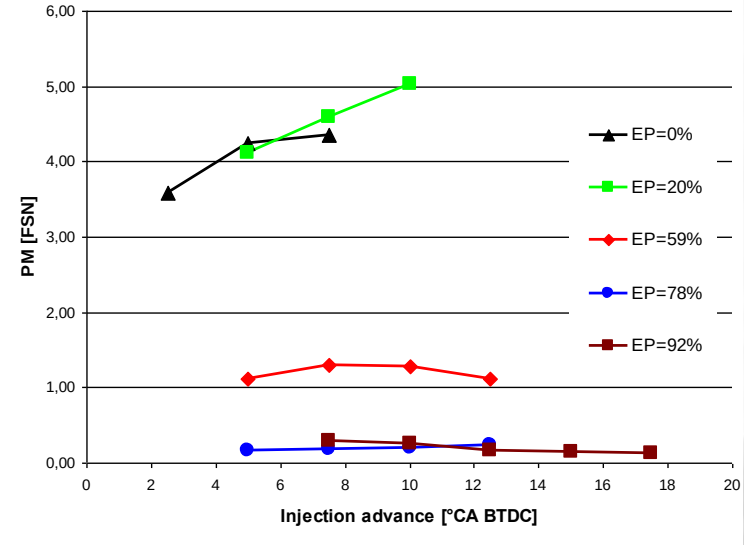
-Pilot timing: 7.5 CA°BTDC

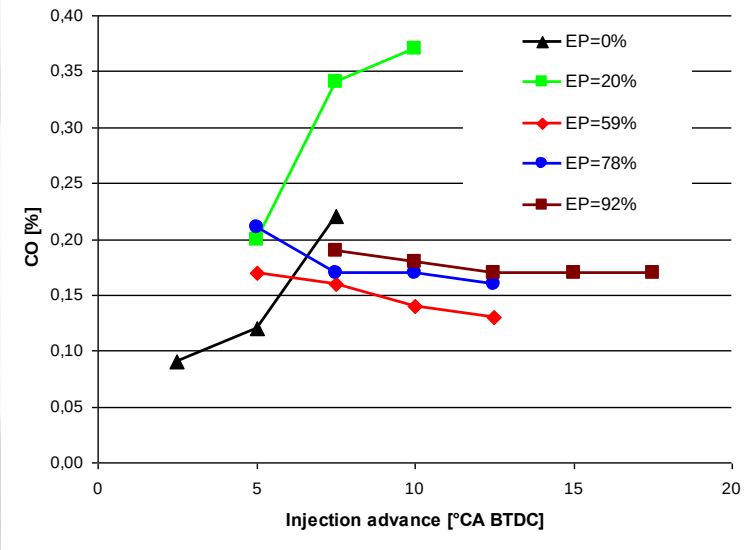


Emissions vs. pilot injection advance at **100% load**





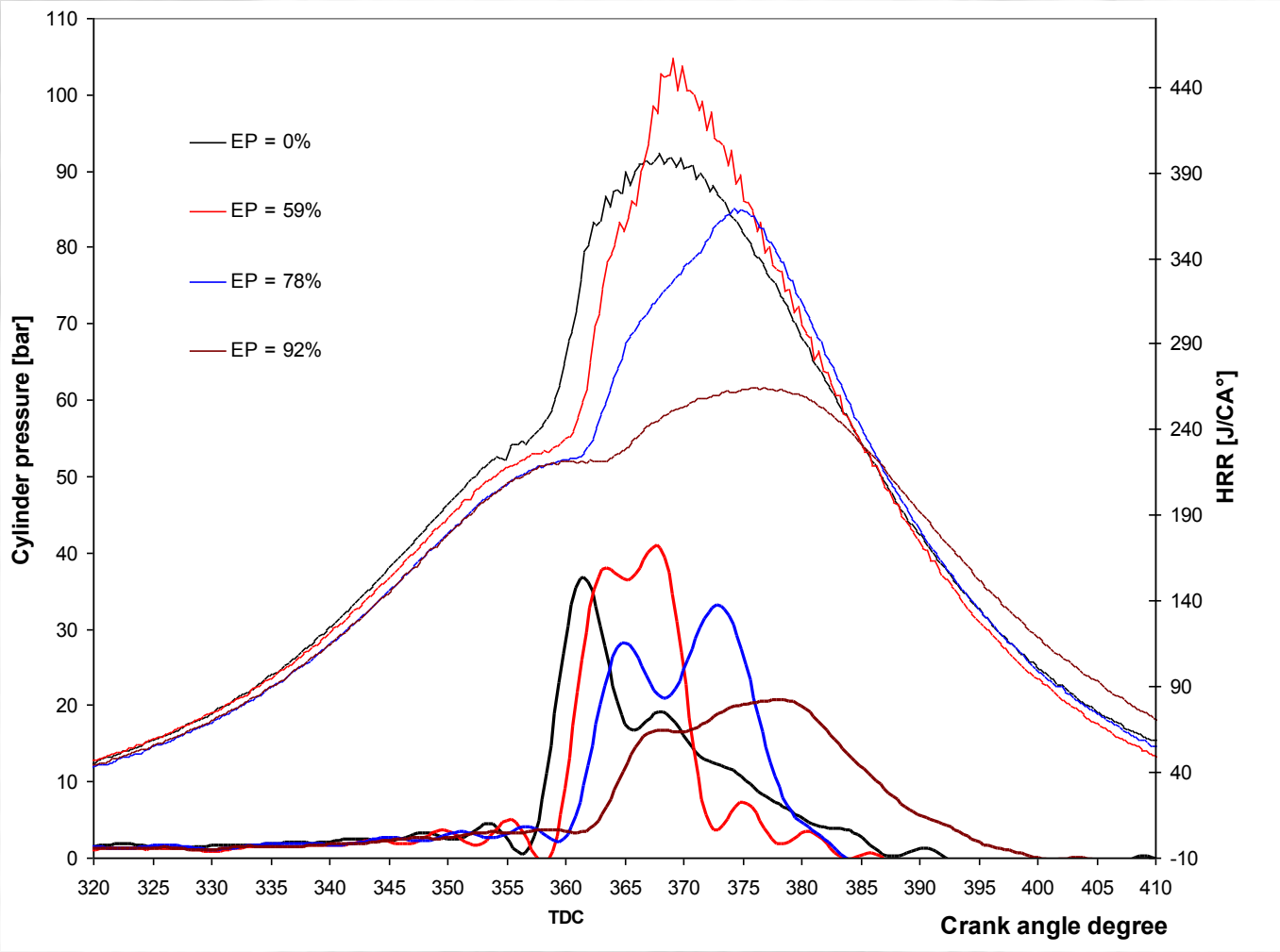




Flame propagation and knocking

-100% load

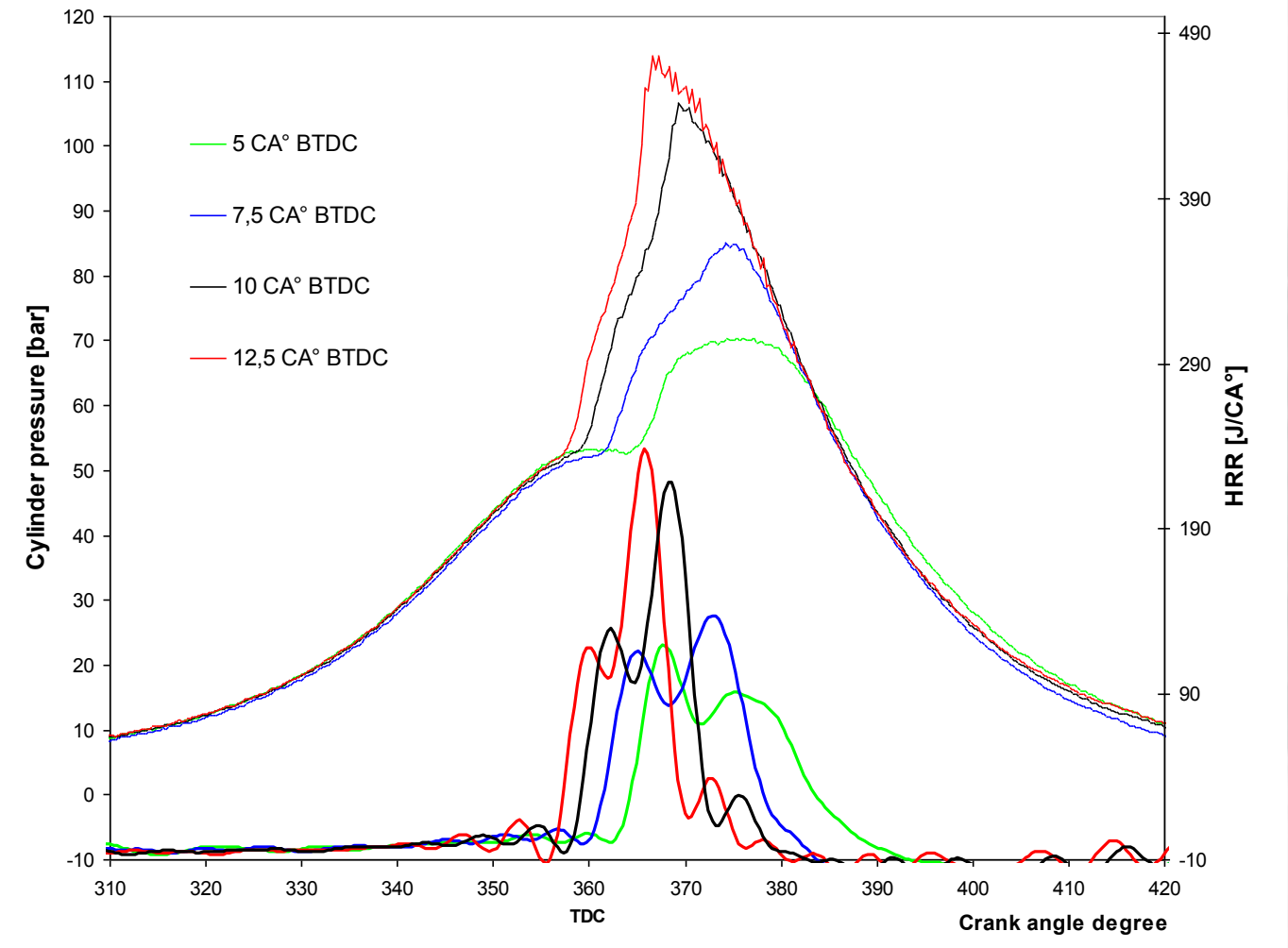
-Pilot timing: 7.5 CA°BTDC



Flame propagation and knocking

-100% load

-EP = 78%



Summary

- Significantly different operating characteristics depending on EP, pilot dose and pilot timing from which the following operating regions can be distinguished:
    1. Diesel and close to diesel operation
    2. SI-like flame propagation within the ethanol/air charge
    3. SI-like knocking operation
    4. Incomplete combustion within the ethanol/air charge
- At 100% load with high ethanol percentages distinct brake thermal efficiency (BTE) increment can be achieved compared to diesel operation.
- At 100% load dual-fuel operation with wet ethanol (except for EP=20%) is beneficial in the point of view of emission. The difficultly aftertreatable components like NOx and especially PM emissions radically decrease. The elevated HC and CO emissions can easily be aftertreated by means of conventional oxidation catalytic converter.
- At 66% and especially at 33% load remarkable decrement of BTE and high HC and CO emissions were observed.

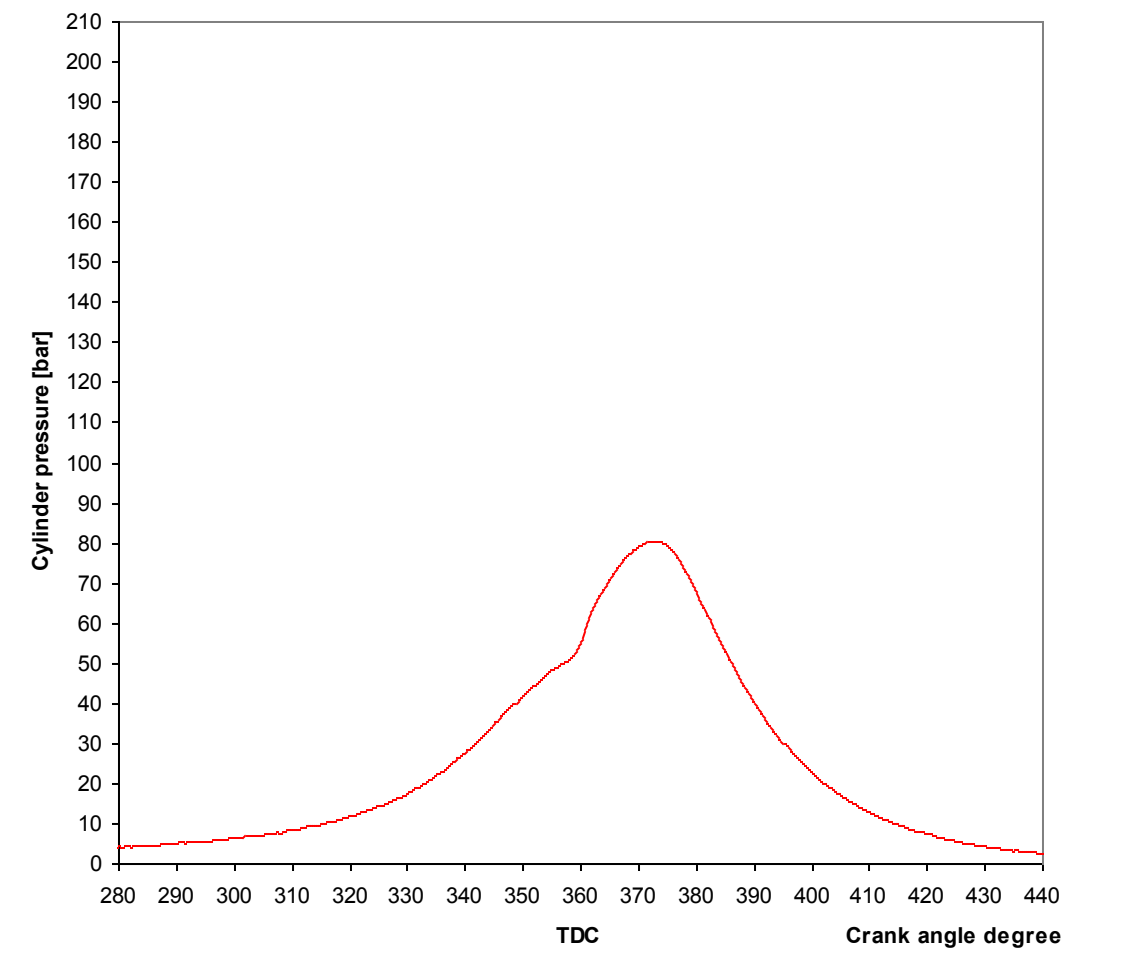
Next steps

- More measurements are needed to map the boundaries of the operating regions
- The influence of intake air temperature would be important

9 successive cycles

- 88% load
- EP = 89%
- Pilot timing: 15 CA°BTDC

Cycle 1


Cylinder pressure [bar]
210
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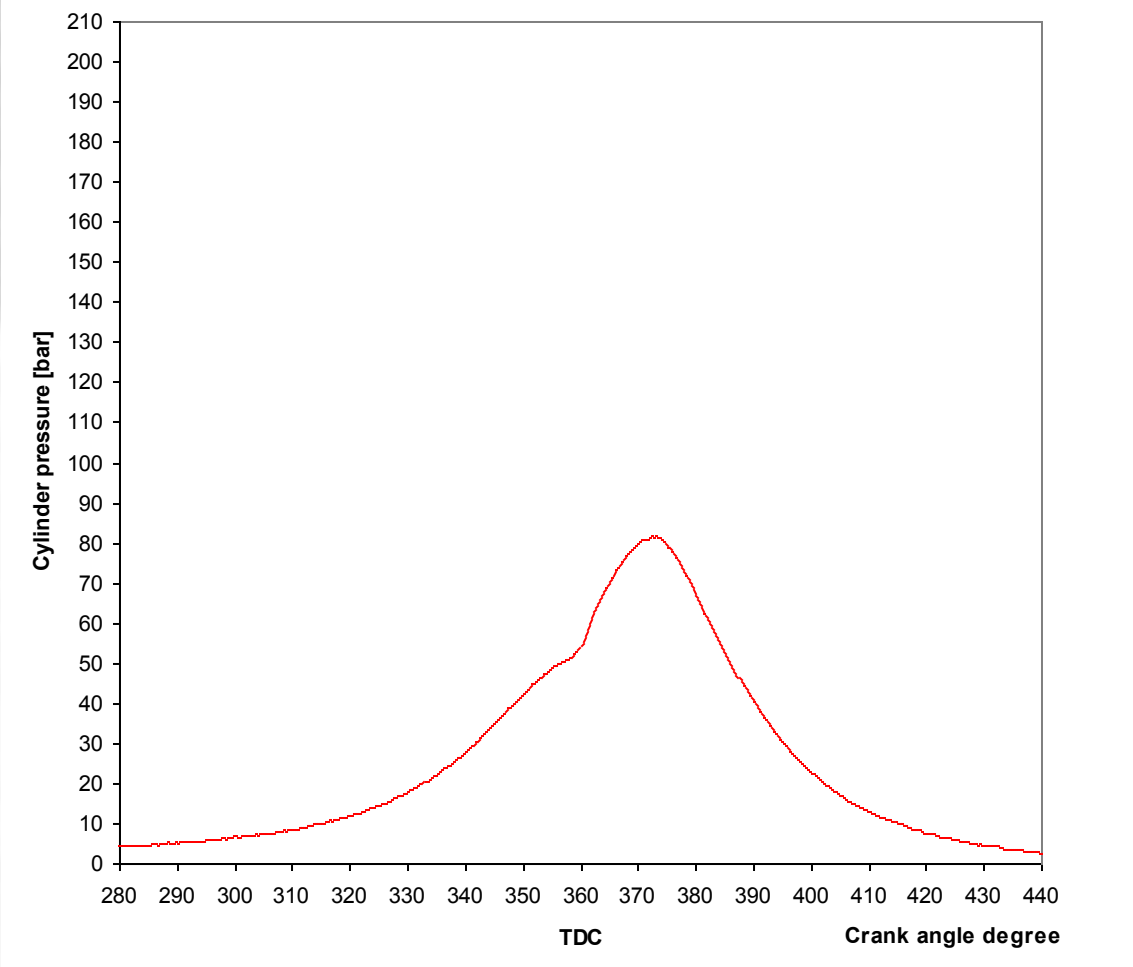
280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440
TDC
Crank angle degree

Cycle 2


Cylinder pressure [bar]
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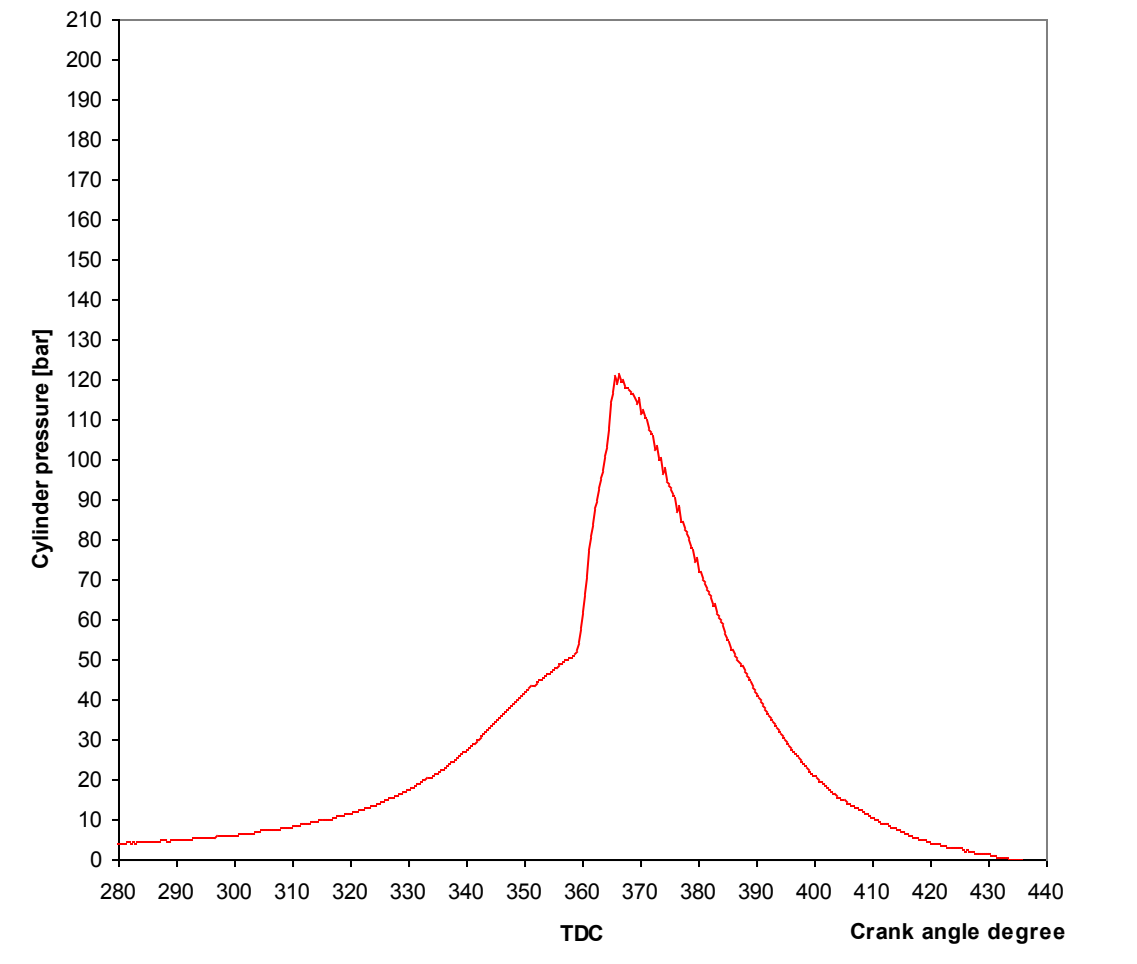
TDC
Crank angle degree

Cycle 3


Cylinder pressure [bar]
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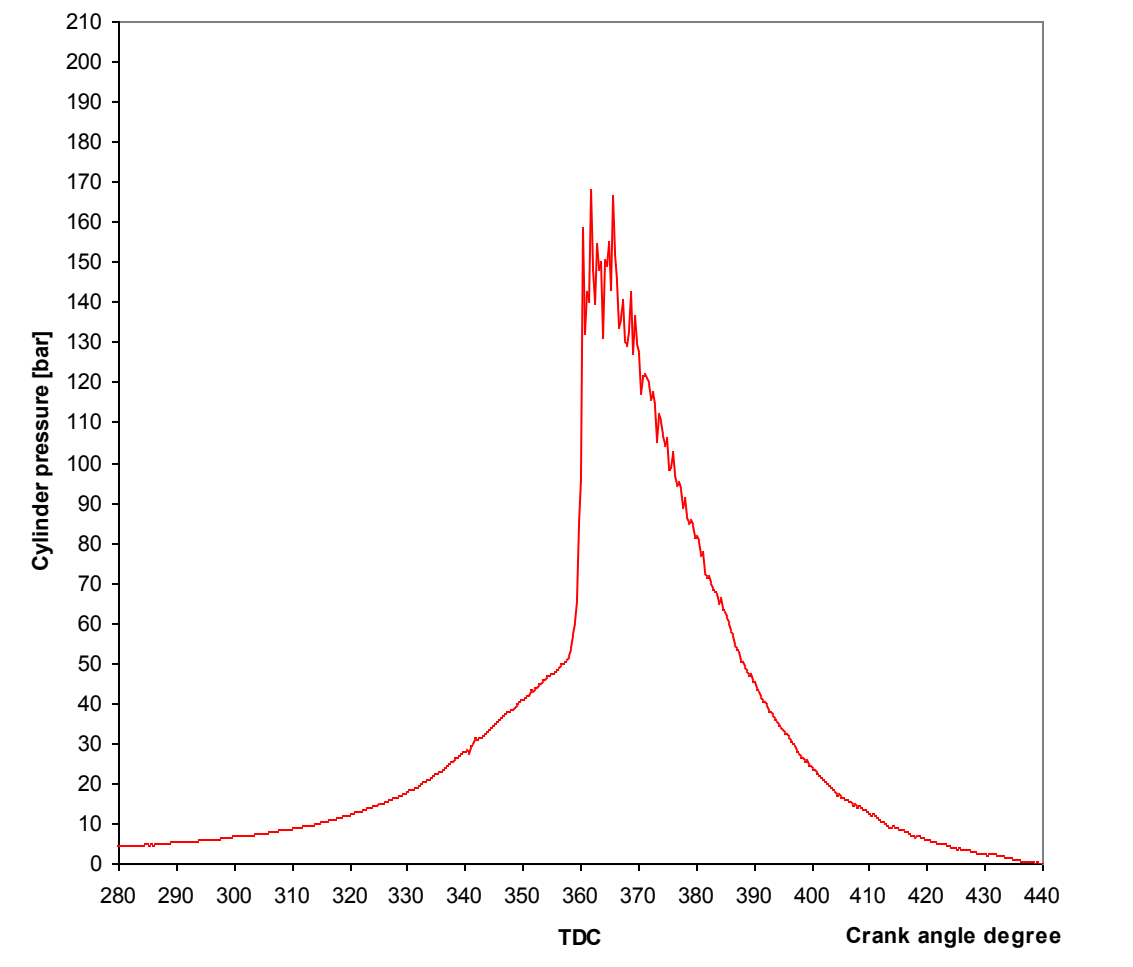
TDC
Crank angle degree

Cycle 4


Cylinder pressure [bar]
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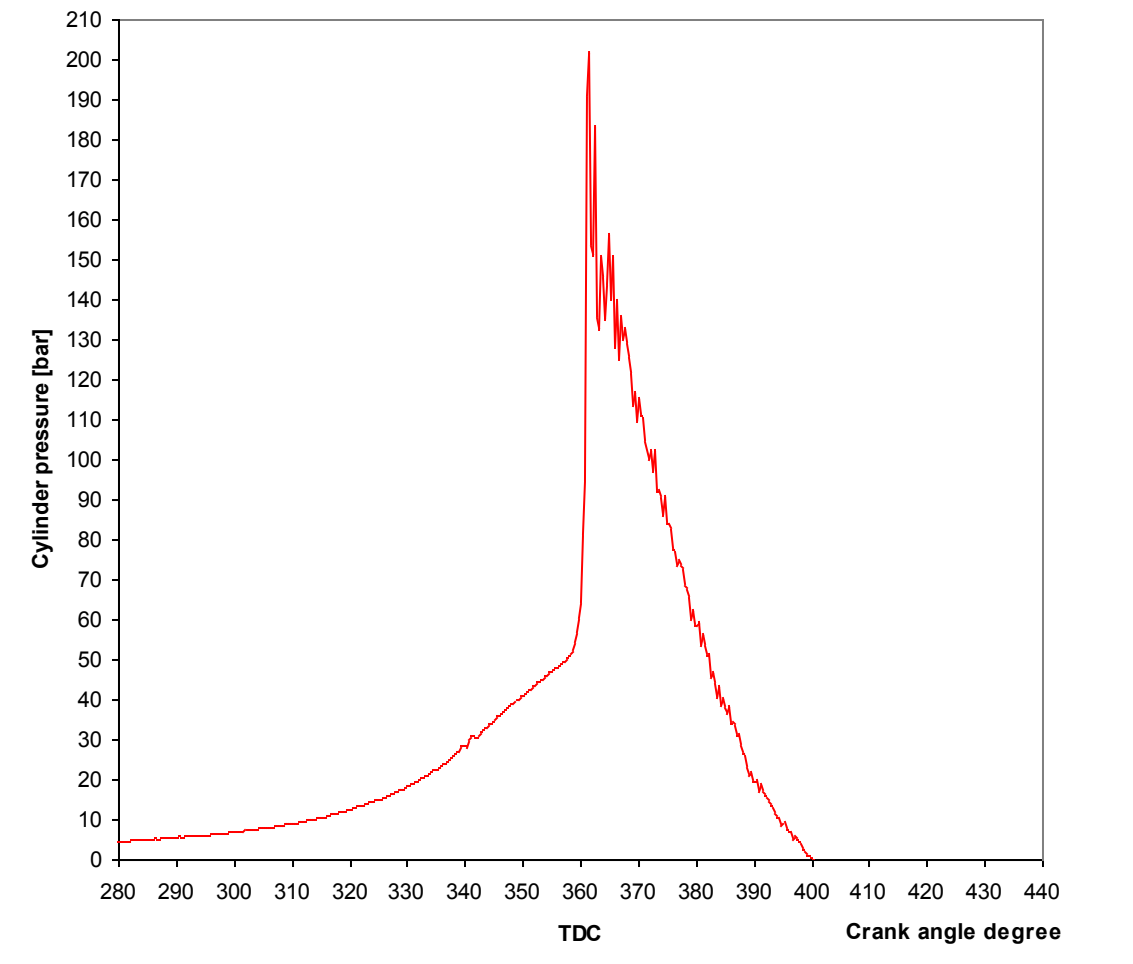
TDC
Crank angle degree

Cycle 5


Cylinder pressure [bar]
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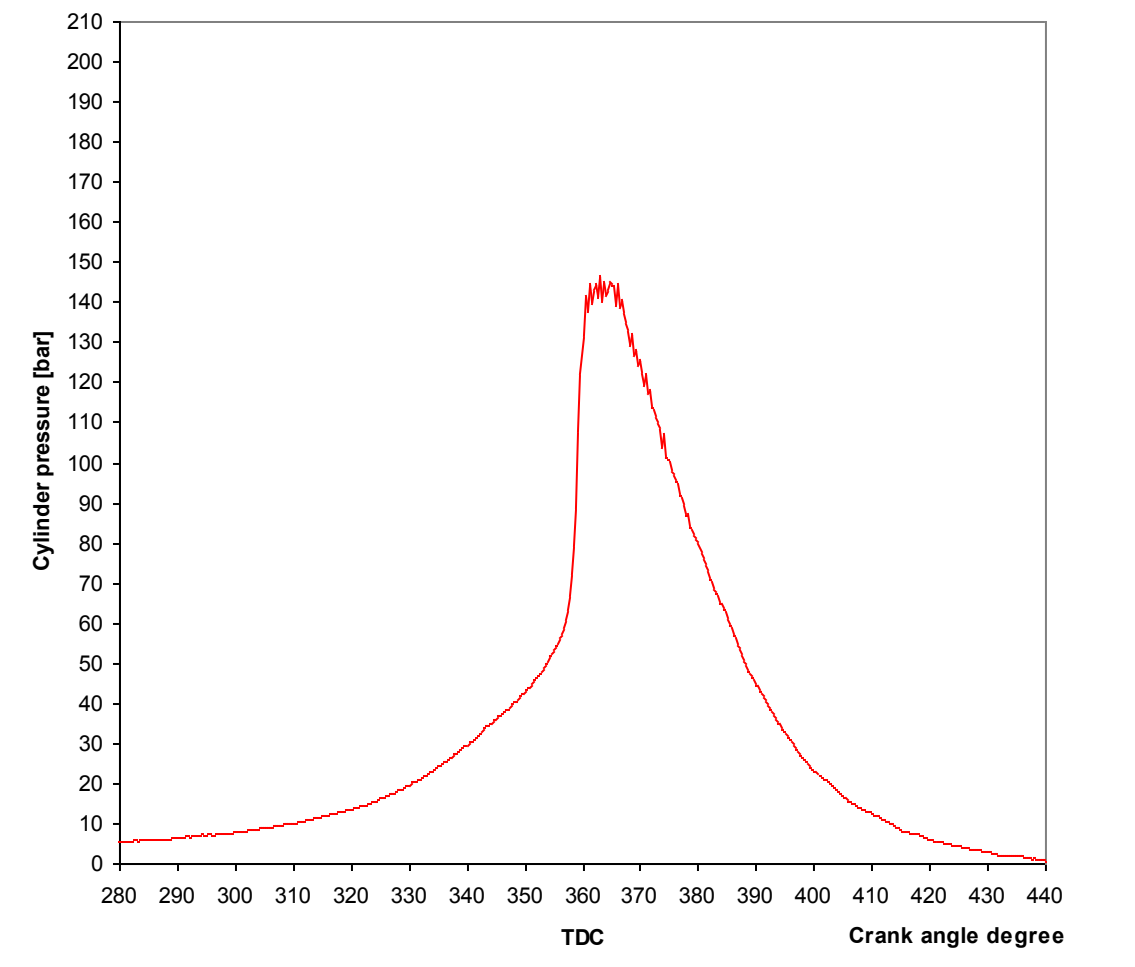
TDC
Crank angle degree

Cycle 6


Cylinder pressure [bar]
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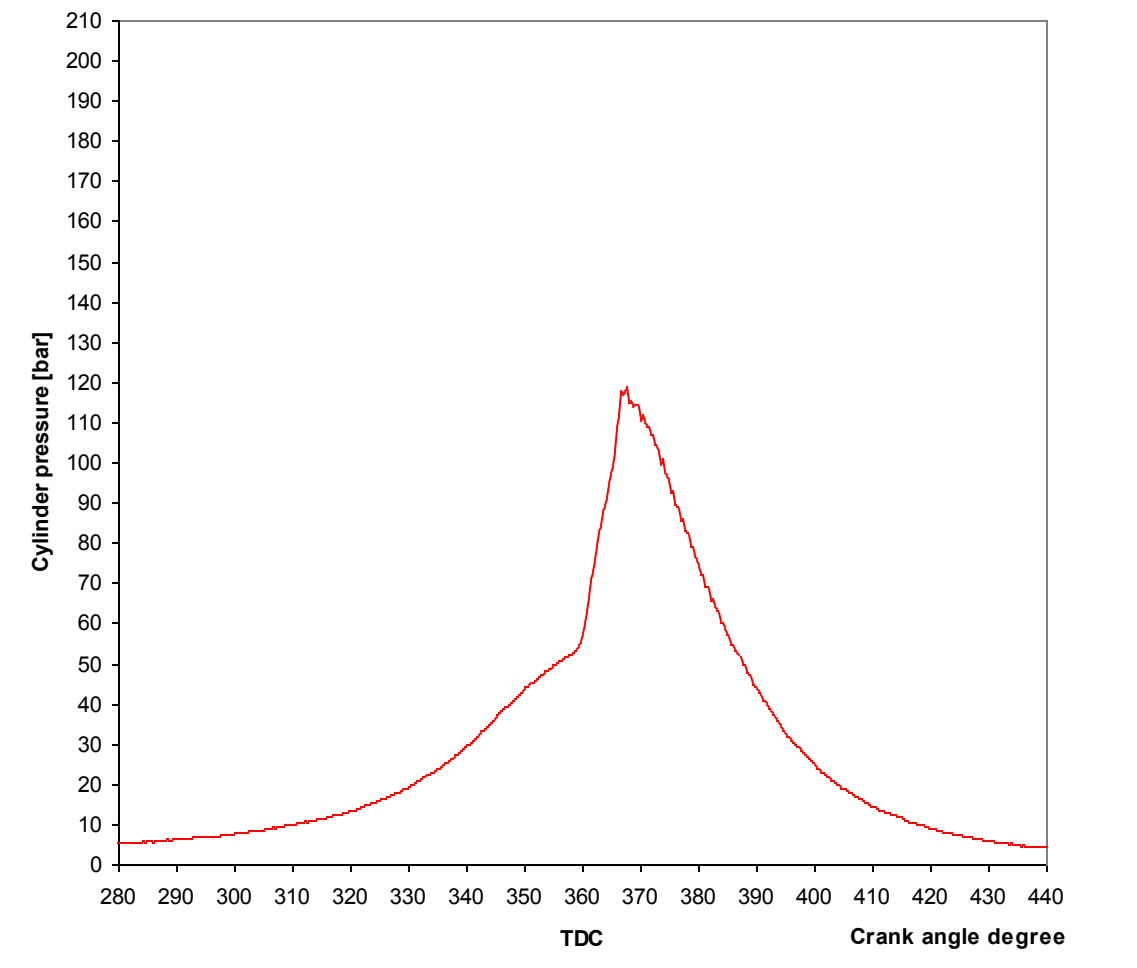
TDC
Crank angle degree

Cycle 7


Cylinder pressure [bar]
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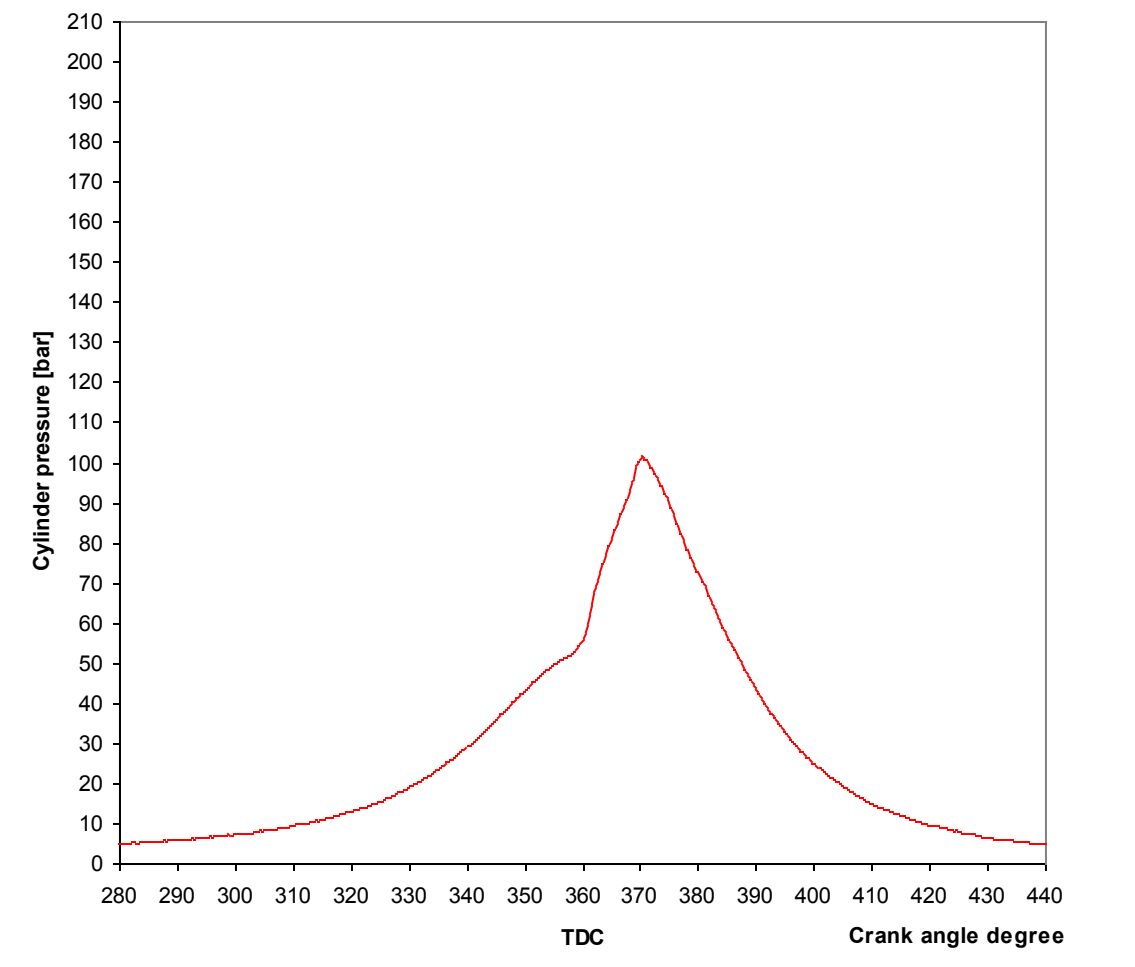
TDC
Crank angle degree

Cycle 8


Cylinder pressure [bar]
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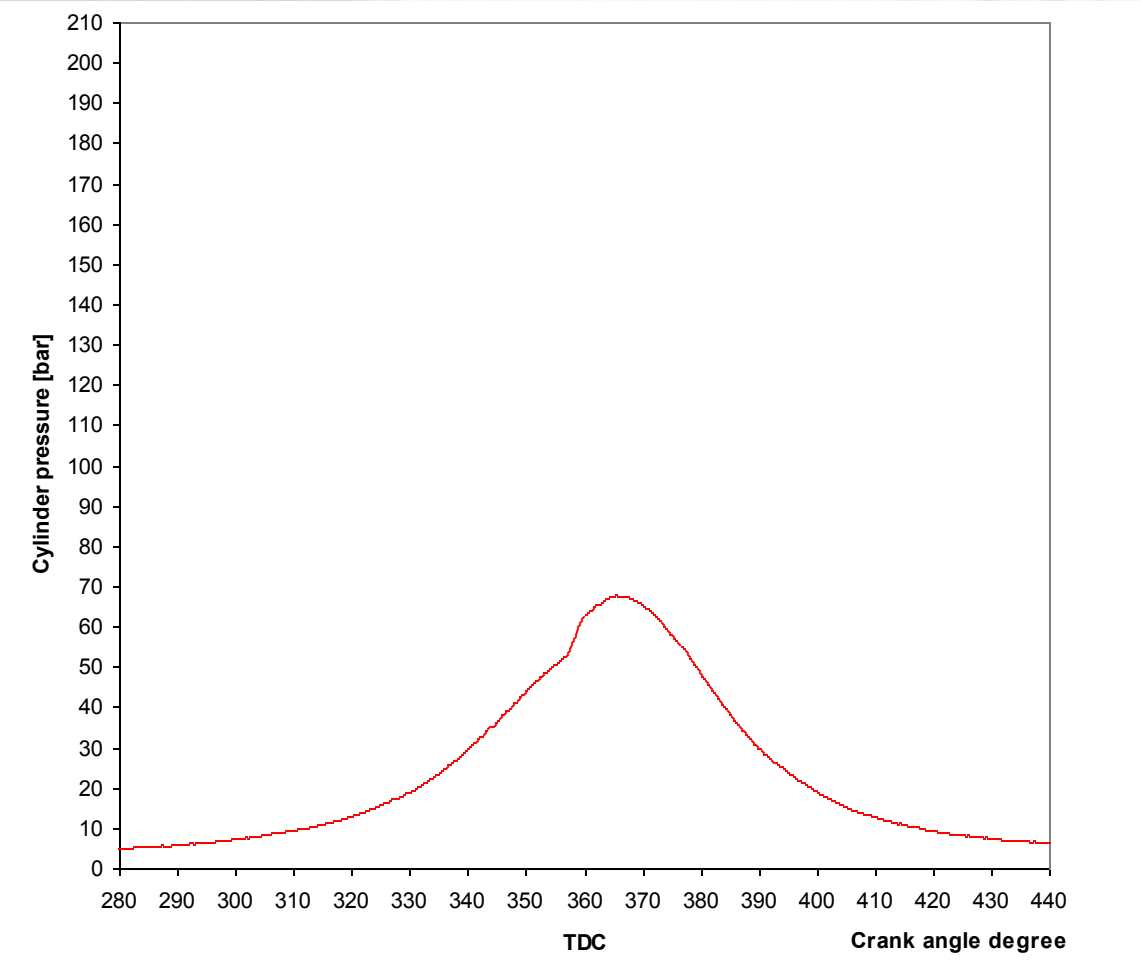
TDC
Crank angle degree

Cycle 9


Cylinder pressure [bar]
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TDC
Crank angle degree

Thank you for your attention!