Adaptive Control to Improve Low Temperature Diesel Engine Combustion

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U.S. Department of Energy
2006 Diesel Engine Emission Reduction Conference
Detroit, Michigan, August 21-24 2006

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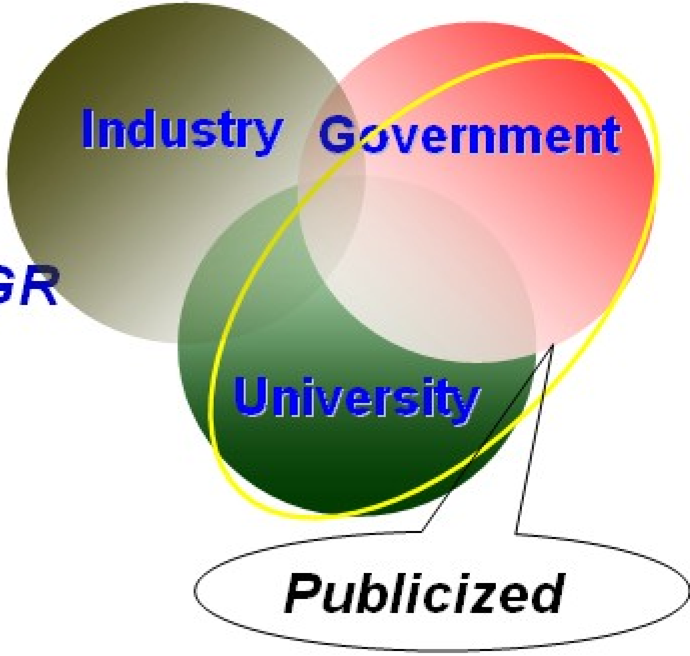
Acknowledgements: International Truck and Engine Corporation, Ford Motor Company, Imperial Oil Canada, NI, SIEMENS, BOSCH, DELPHI, NRCan, CRD and:

Research Themes



Premixed Diesel Combustion

- ***Low temperature combustion with high EGR***
- ***Diesel HCCI***
- ***On-fly combustion control***

Active Flow Control Aftertreatment

- Flow reversal, parallel flow, flow stagnation
- Active flow control valve innovation
- Real-time control

Modeling, Diagnosis, and Dynamometer Tests

Diesel Low Temperature Combustion

- Heavy EGR
- Late Injection
- Multiple early injection

Ignition delay: from end of injection > 1.5 ms or 50% prolonging from conventional → < 15 ppm NOx & near zero soot

IMEP > 6bar

Cylinder charge:
Locally lean
Halved O_2

Adaptive Control

Navigate through narrow operating corridors

Diesel HCCI

Phasing

Injection scheduling
Boost modulation

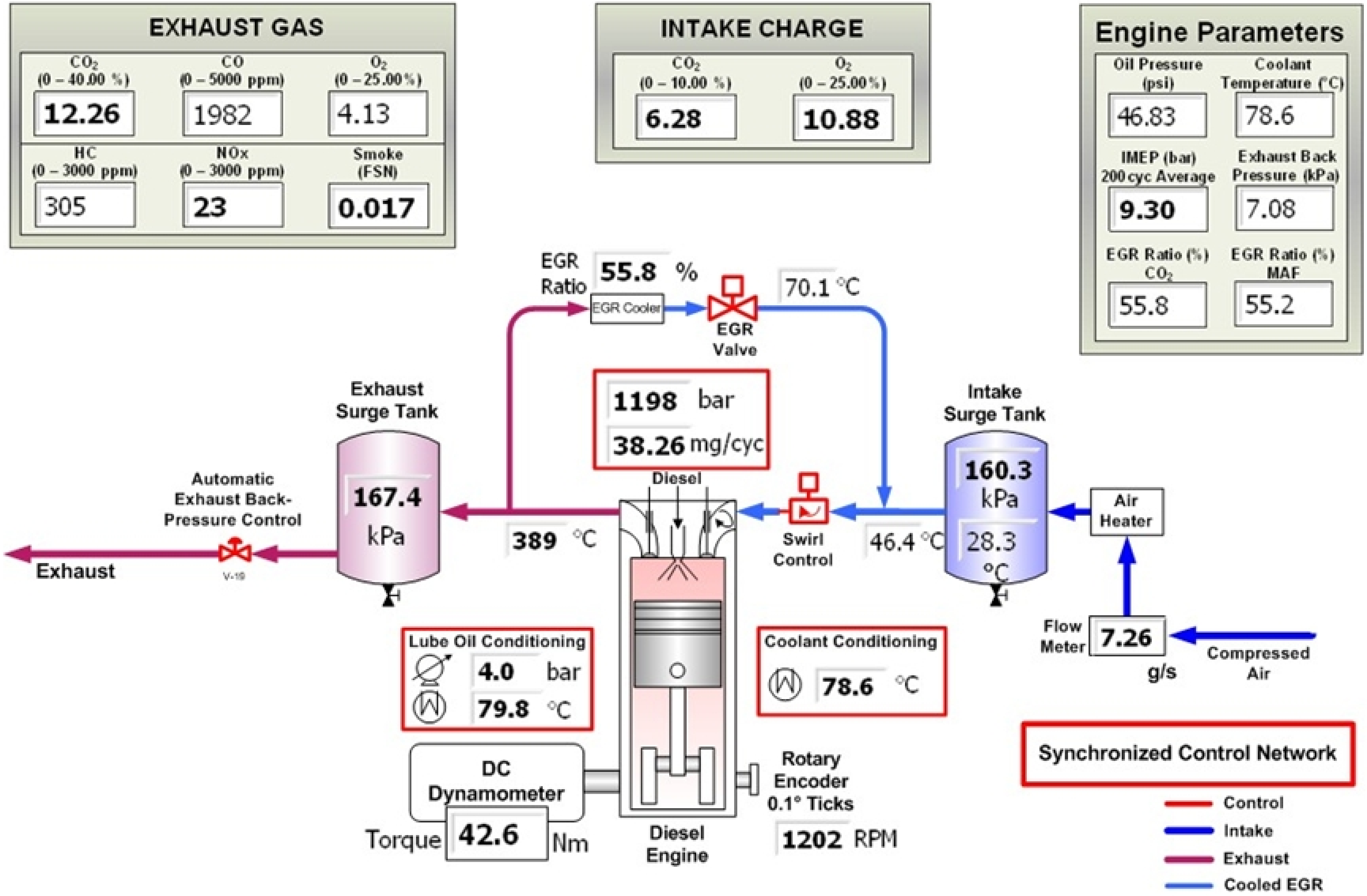
Efficiency
Emission
Power
Robust
Roughness

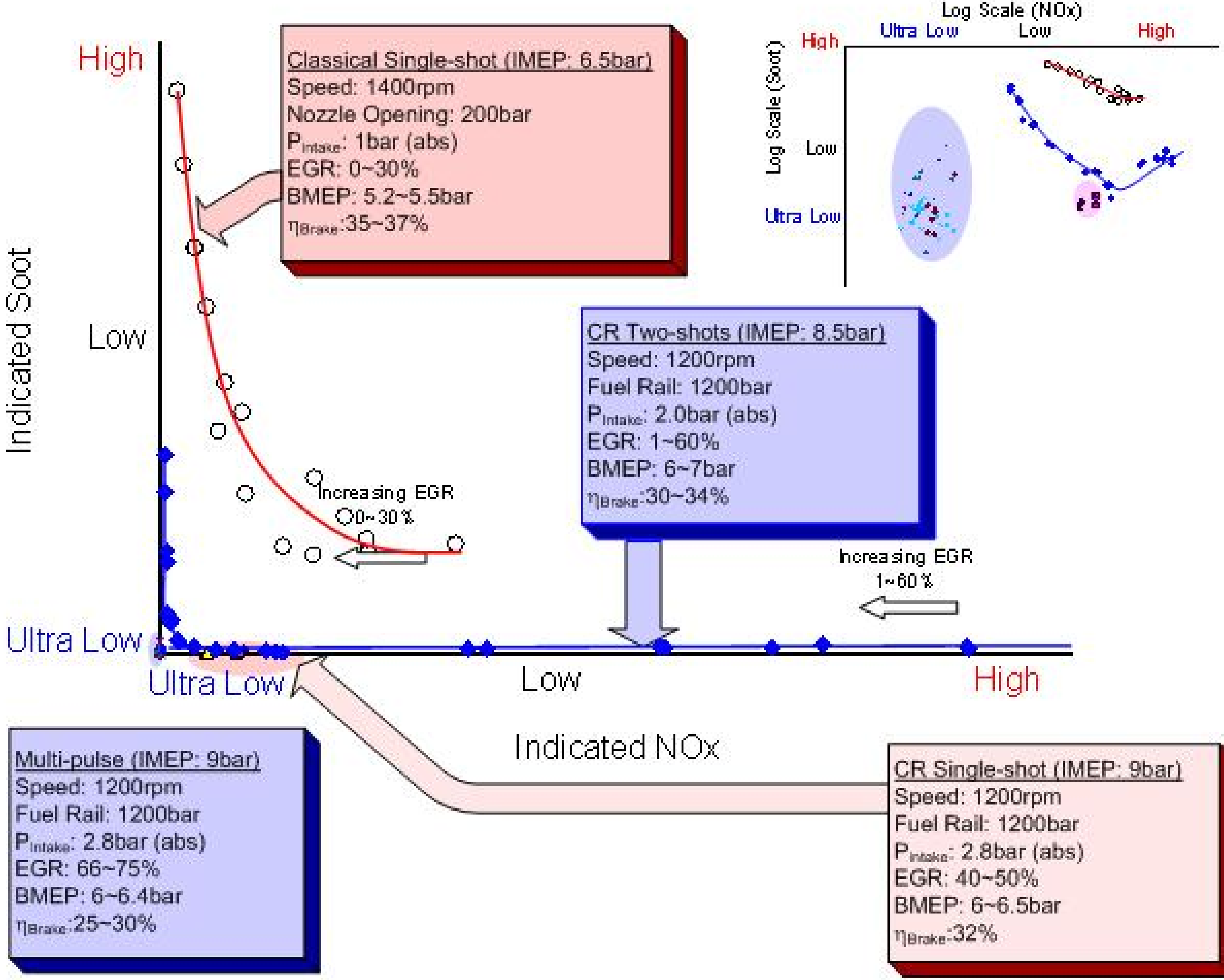
Mode Switch

Load	HCCI	Diesel
Idle		High EGR
Low	Low EGR	
High	Heavy EGR	
Full		High EGR

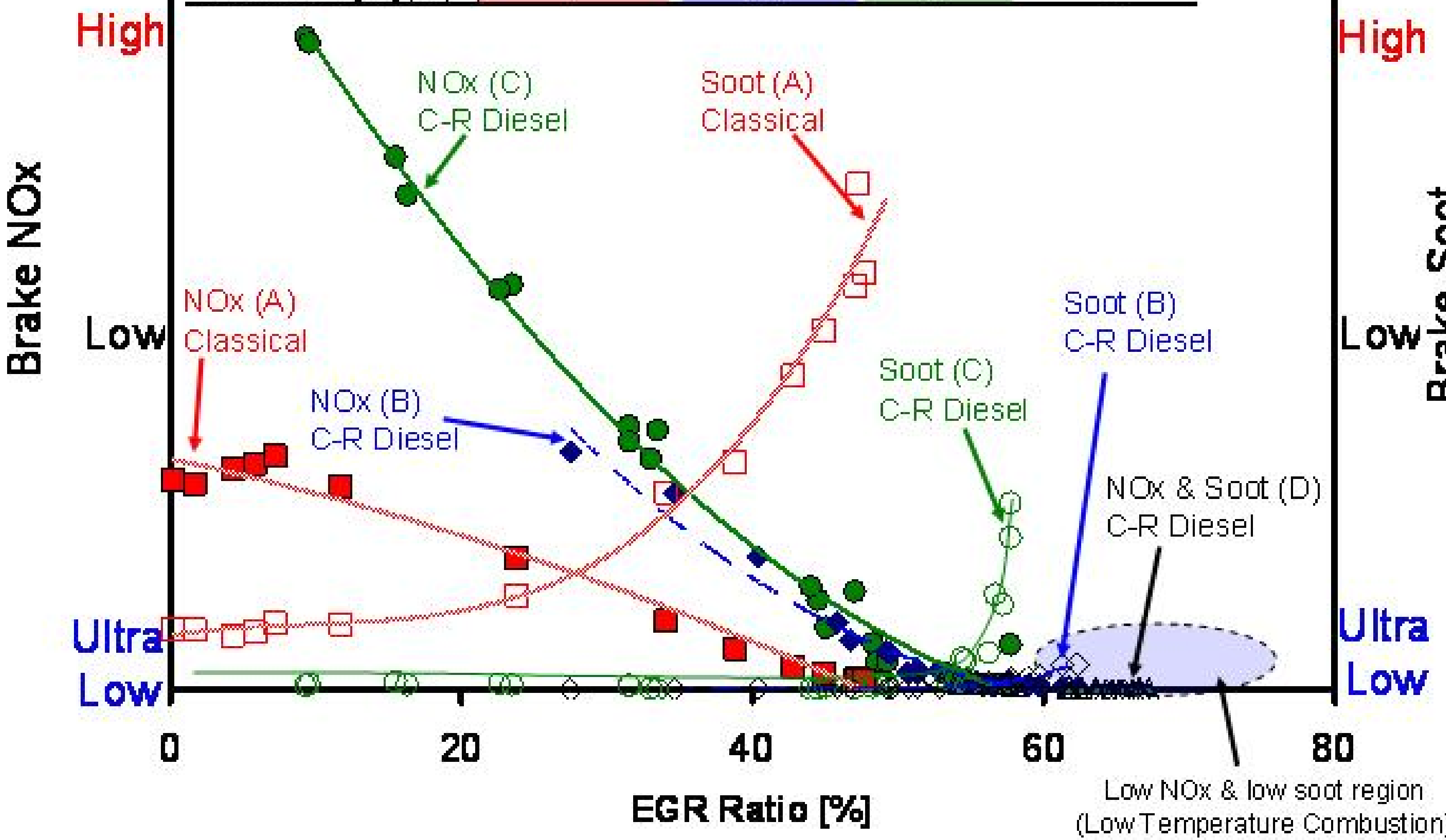
University of Windsor Engine Test System

Sync Manager | Online Data Processing | Online Analysis | Network Status |




Classical Single-shot (IMEP: 6.5bar)
Speed: 1400rpm
Nozzle Opening: 200bar
P_Intake: 1bar (abs)
EGR: 0~30%
BMEP: 5.2~5.5bar
η_Brake:35~37%
High
Low
Ultra Low
Indicated Soot
Increasing EGR
0~30%
CR Two-shots (IMEP: 8.5bar)
Speed: 1200rpm
Fuel Rail: 1200bar
P_Intake: 2.0bar (abs)
EGR: 1~60%
BMEP: 6~7bar
η_Brake:30~34%
Increasing EGR
1~60%
Ultra Low
Low
High
Indicated NOx
Multi-pulse (IMEP: 9bar)
Speed: 1200rpm
Fuel Rail: 1200bar
P_Intake: 2.8bar (abs)
EGR: 66~75%
BMEP: 6~6.4bar
η_Brake:25~30%
CR Single-shot (IMEP: 9bar)
Speed: 1200rpm
Fuel Rail: 1200bar
P_Intake: 2.8bar (abs)
EGR: 40~50%
BMEP: 6~6.5bar
η_Brake:32%
Log Scale (NOx)
Ultra Low
Low
High
Log Scale (Soot)
High
Low
Ultra Low

	A	B	C	D
Engine Type	Classical Diesel	Common-Rail	Common-Rail	Common-Rail
No. of Injections	1	1	2	6
BMEP [bar]	3.4	4.4	6.1	3.6
Fuel Pressure [bar]	NOP: 200	Rail: 1200	Rail: 1200	Rail: 1200
Intake Pressure [bar] (abs)	1	2.75	2.0	2.7



LOW TEMPERATURE COMBUSTION

Test Engine Condition

Intake Pressure: ~2bar (abs)

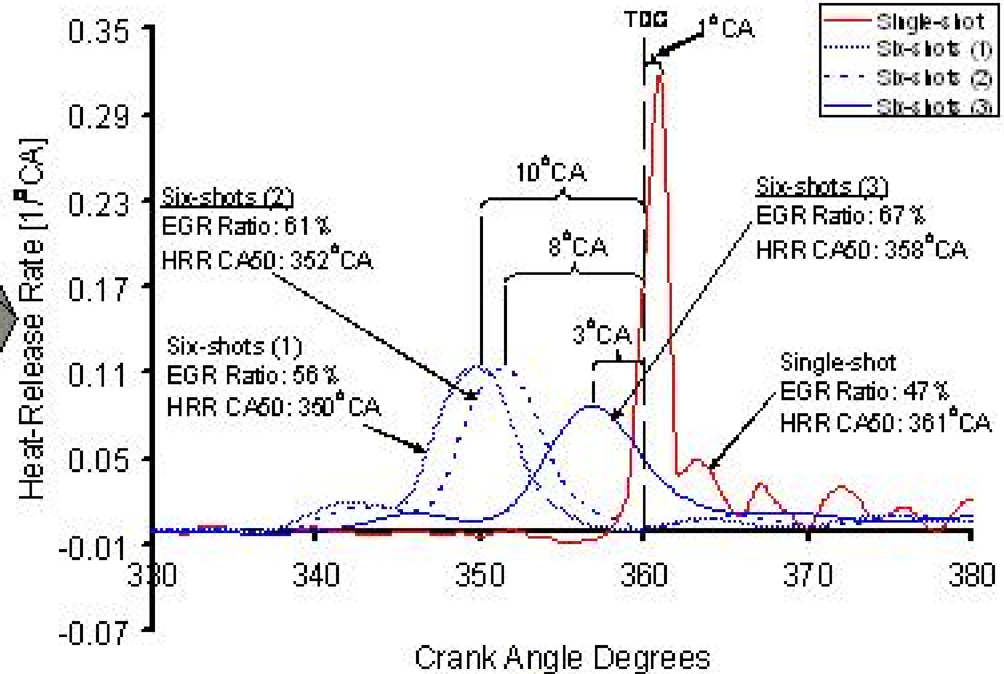
EGR Ratios: 50~68%

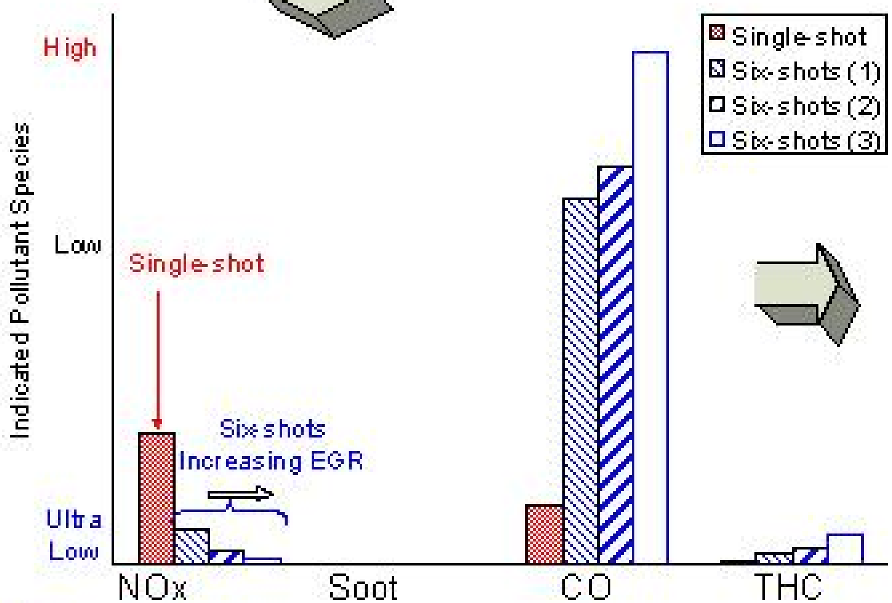
Fuel Rail Pressure: 1200bar

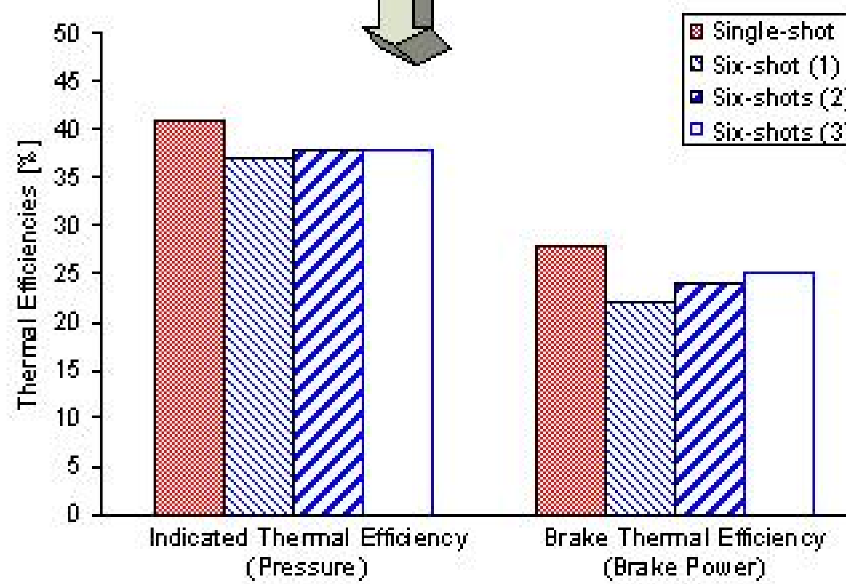
Engine Speed: 1200rpm

Injections

Single-shot vs multi-pulse







Soy Based Biodiesel LTC

Speed: 1400rpm

CR: 17.8

BMEP: 3bar

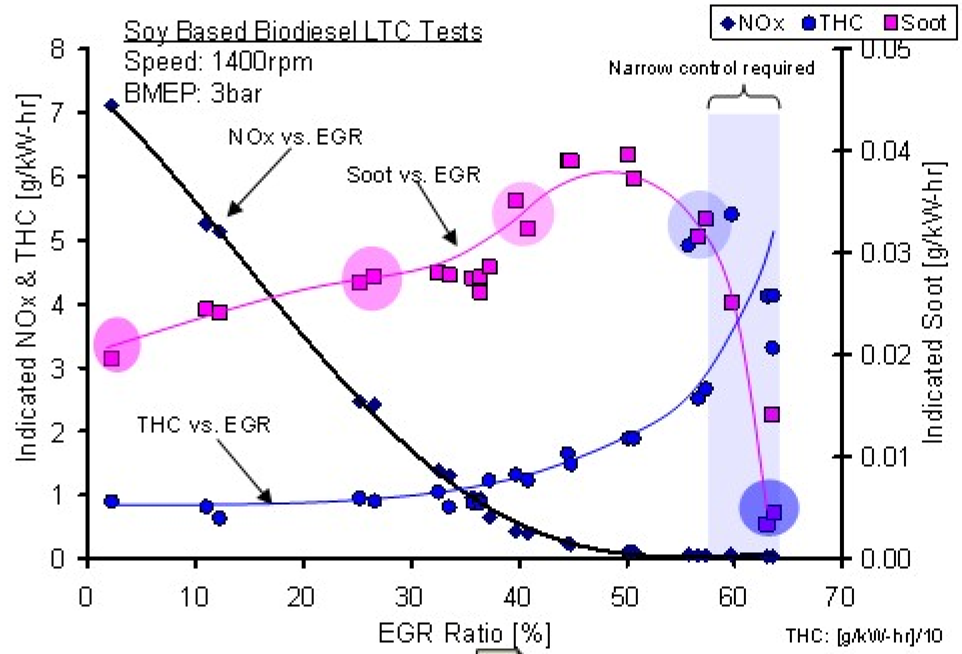
P_{Intake}: 1bar (abs)

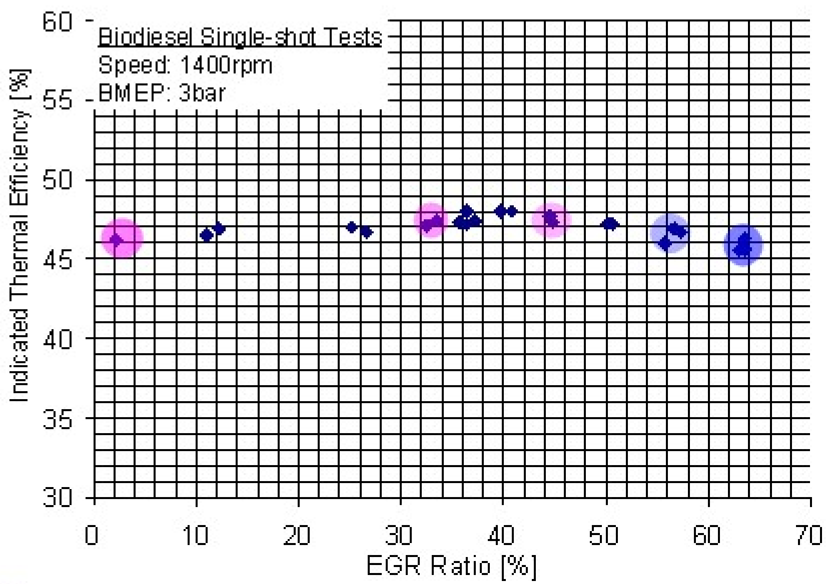
T_{Intake}: 30°C

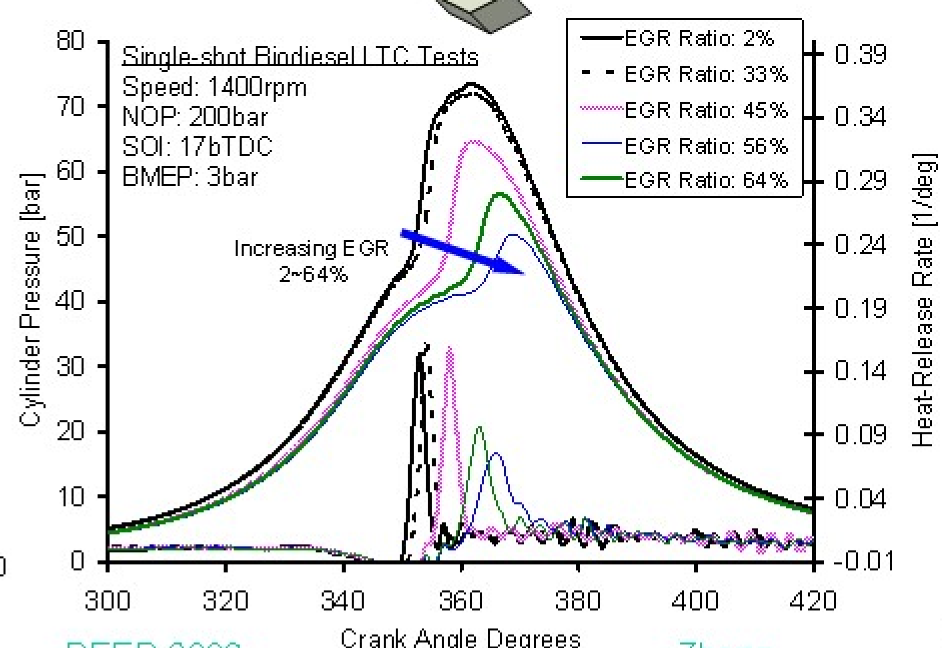
Nozzle Opening: 200bar

SOI: 17°CA bTDC

EGR: 2~64%

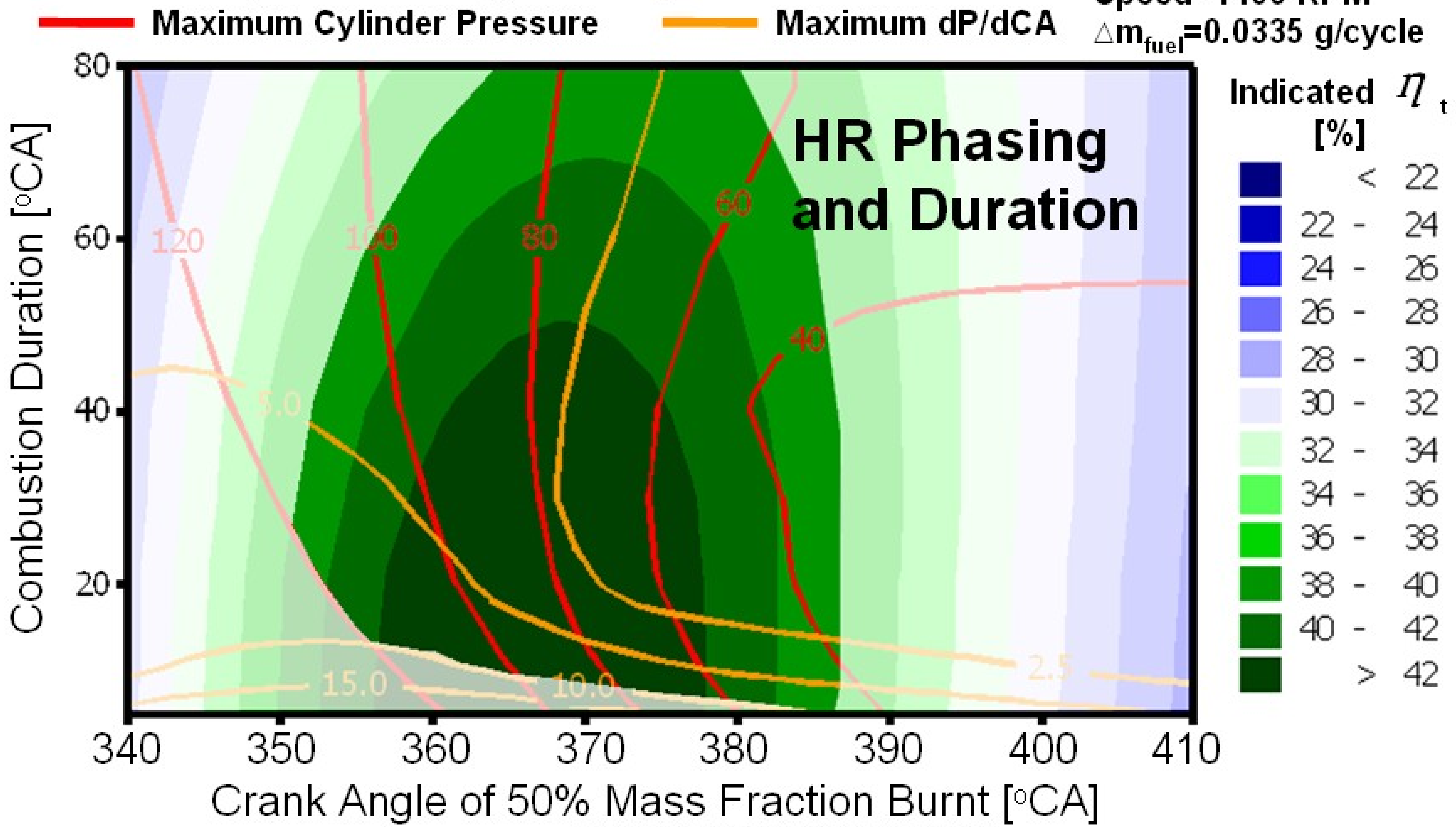


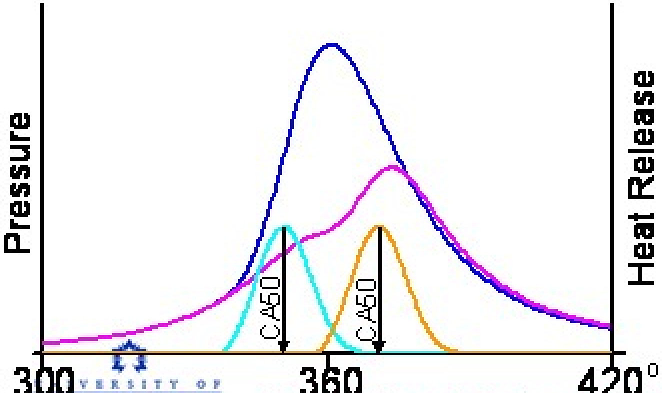


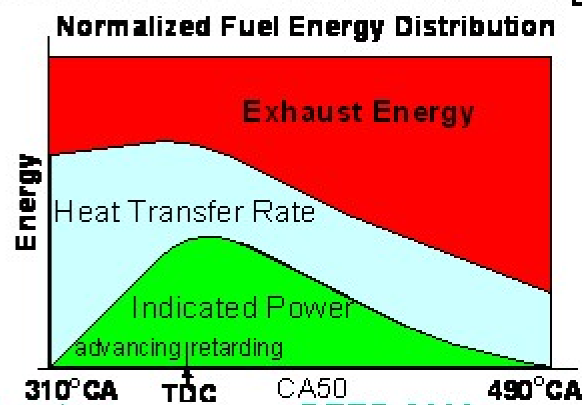


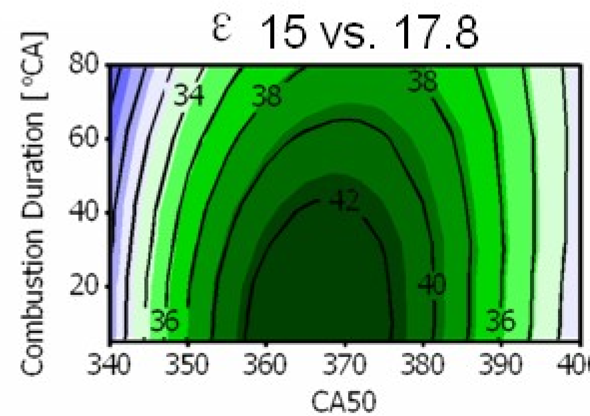
Indicated η_t from engine cycle simulation

P_{int}=1bar, T_{int}=300K, ε =17.8
Speed=1400 RPM
Δm_{fuel}=0.0335 g/cycle

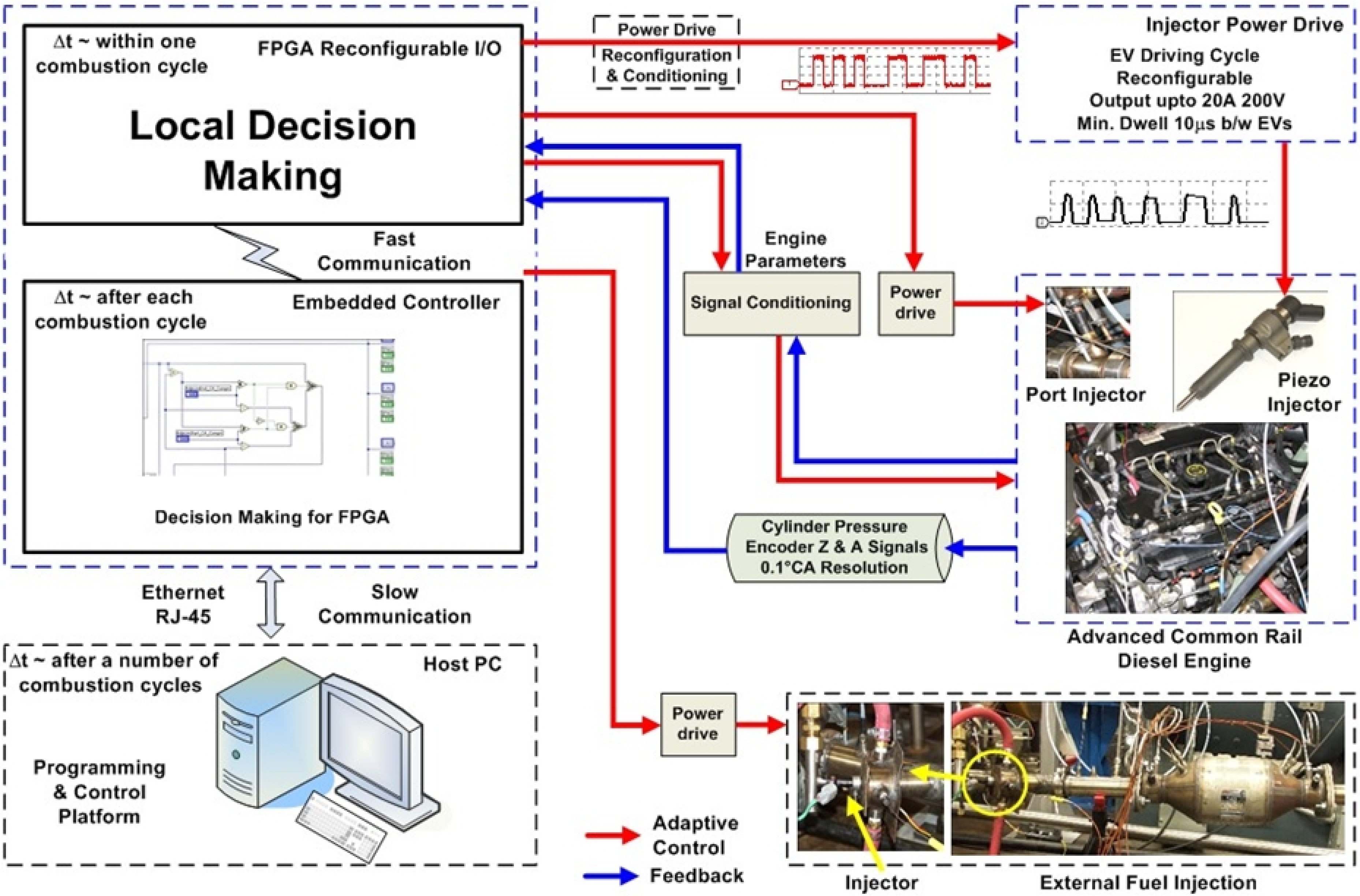


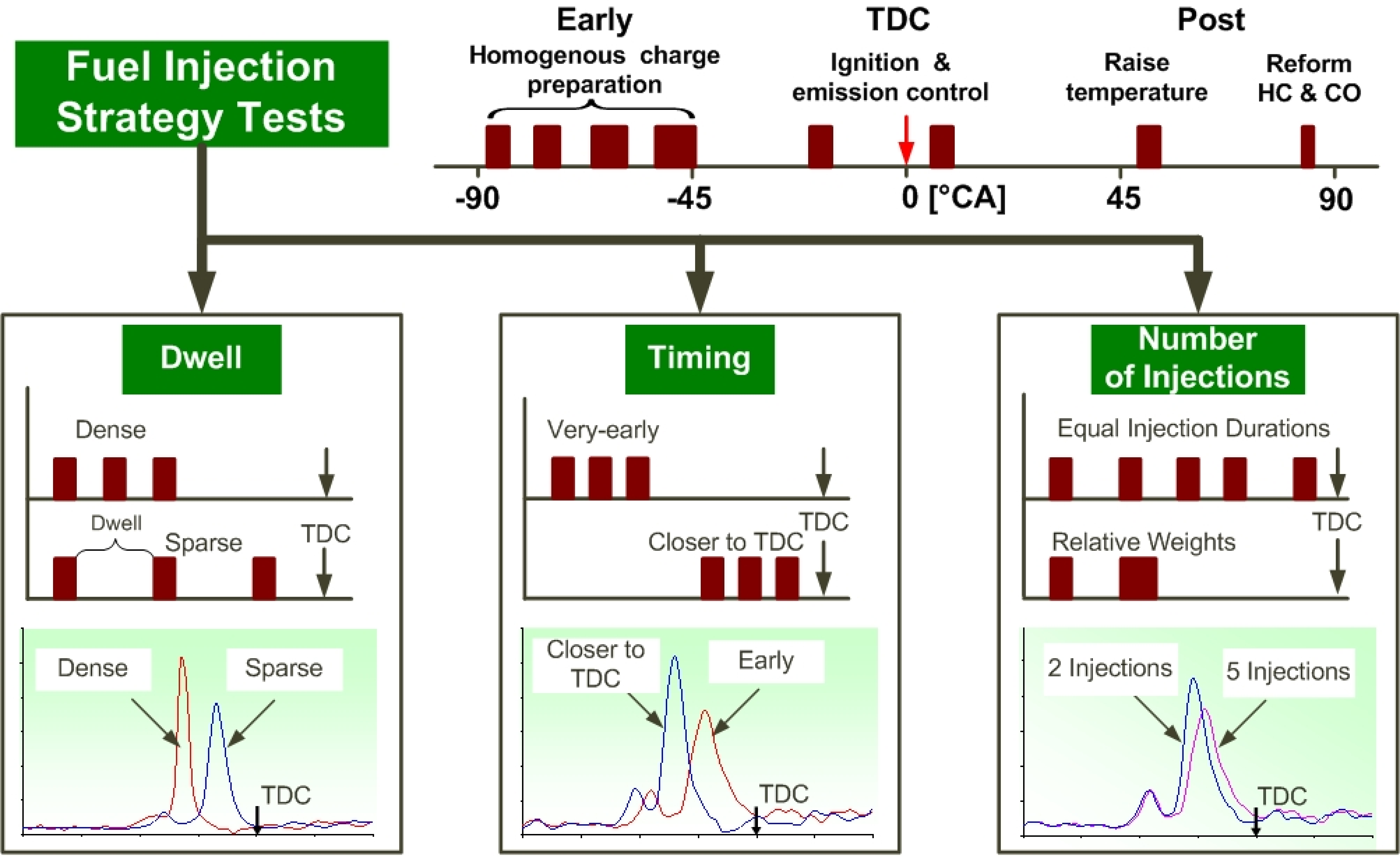




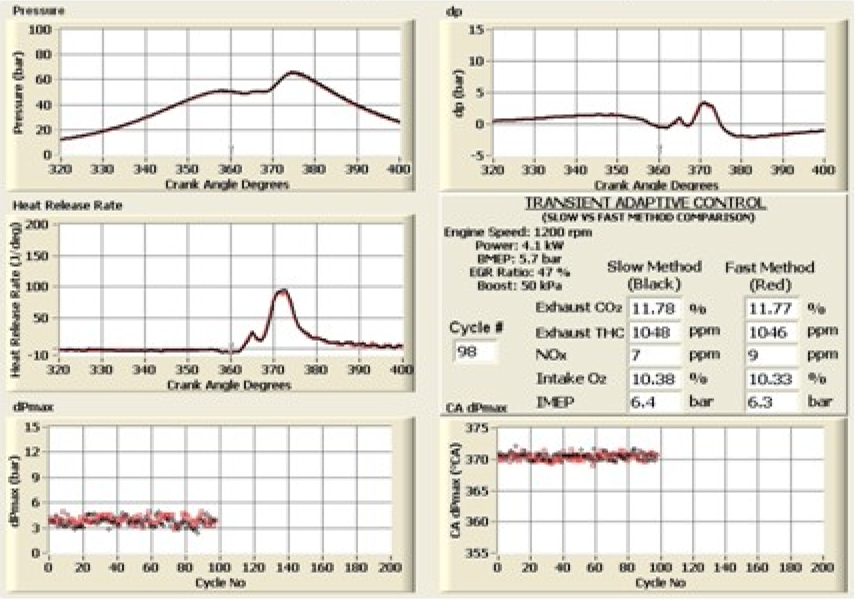


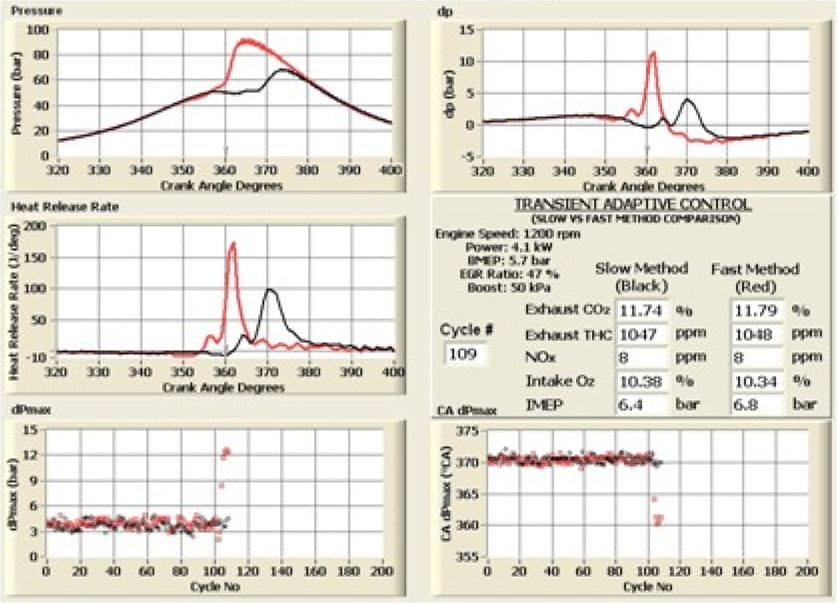
University of Windsor Adaptive Control System

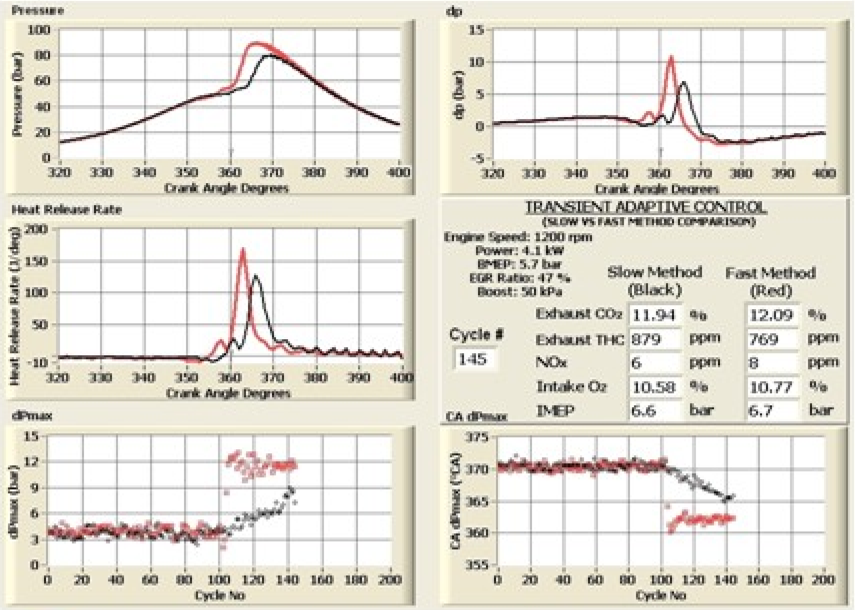


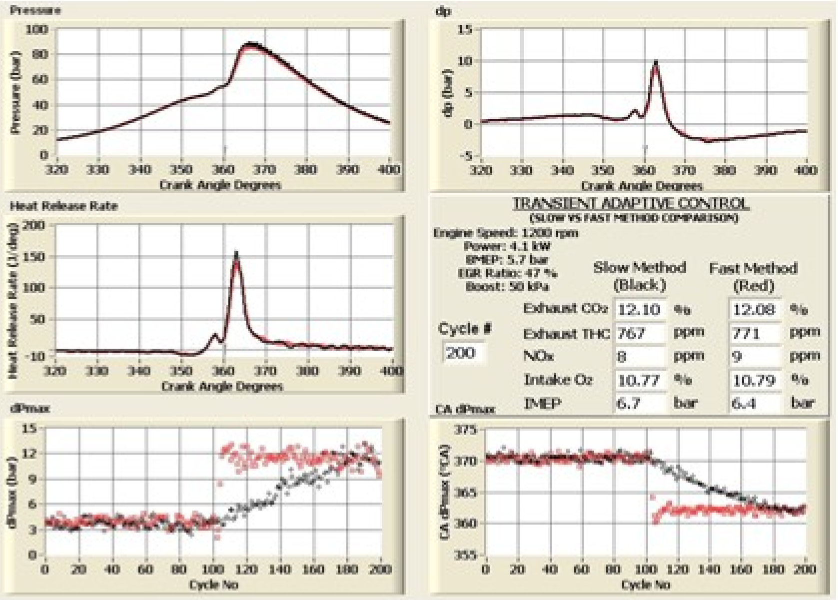

Fuel Injection Strategy Tests
Early
Homogenous charge preparation
TDC
Ignition & emission control
Post
Raise temperature
Reform HC & CO
-90
-45
0 [°CA]
45
90
Dwell
Dense
Dwell
Sparse
TDC
Dense
Sparse
TDC
Timing
Very-early
Closer to TDC
TDC
Closer to TDC
Early
TDC
Number of Injections
Equal Injection Durations
Relative Weights
TDC
2 Injections
5 Injections
TDC

Example-Adaptive Control Algorithm for Timing of $(dp/d\theta)_{max}$ Other Algorithms (P_{max}, CA50% HR etc) are Applicable









Conclusions:

1. Diesel HCCI Engine Fuel Energy Efficiency

< Conventional diesel (Diesel+ SCR)
≈ Conventional diesel + heavy emission control
> SI gasoline engine with emission control

2. Early Multi-event Injection

Away from TDC → Improve homogeneity ⇨ condensing rise
- Lower NOx
- Rise HC

Close to TDC → Homogeneity reduce
- HR advance, Rough P
- Lower HC

3. Minimum early injection for sufficient mixing but reduced condensing and adaptive combustion control is the key.

Thank you!