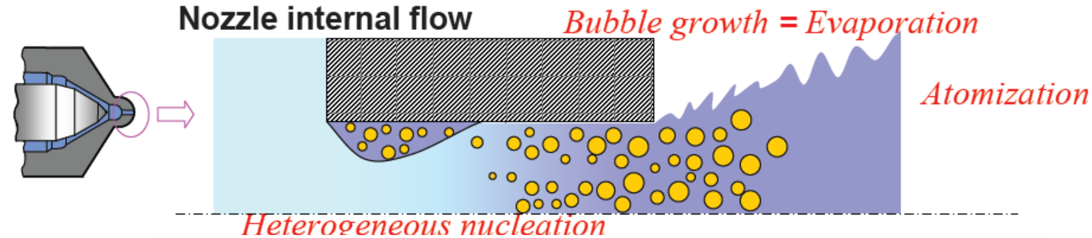
Summary of the HCCI-Fuel Collaborative Task

1. Hadjime Fujimoto (Japan), ”Fuel Design Approch for Low Emission in Engine Systems- Application of Flash Boiling Spray into HCCI”
2. Bengt Johansson (Sweden), ”The HCCI Fuel Activities at Lund University”
3. Gautam Kalgatgi (UK), ”Fuel Effects in Engines Using Premixed and Partially Premixed Compression Ignition”
4. Eiji Tomita (Japan), ”Dual Fuel HCCI Combustion – High Octane and Cetane Number Fuels”
5. Hongming Xu (UK), ”Dieseline for HCCI engines”

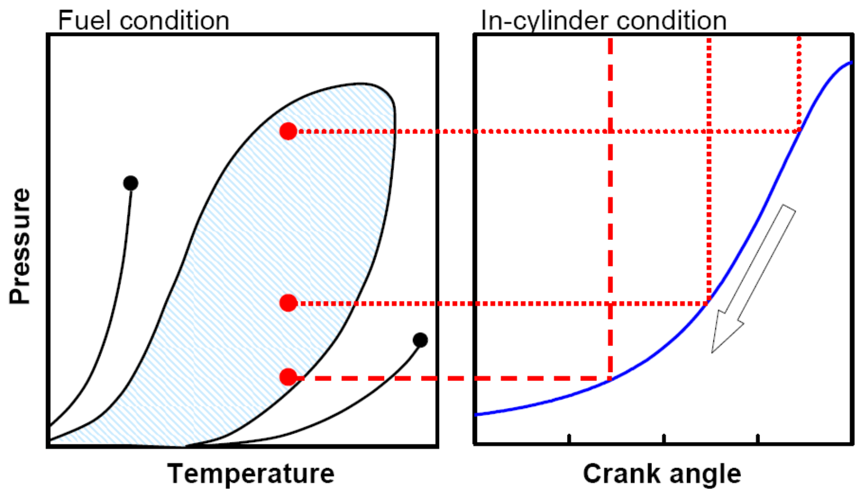
Lacking at this meeting but will go in the task later:

1. Tom Ryan, SwRI, (US) ”Diesel like fuel ratings using dedicated hardware”
2. Marie Bysvenn (Norway), ”HCCI Fuel Diagnostics in Rapid Compression Machine”

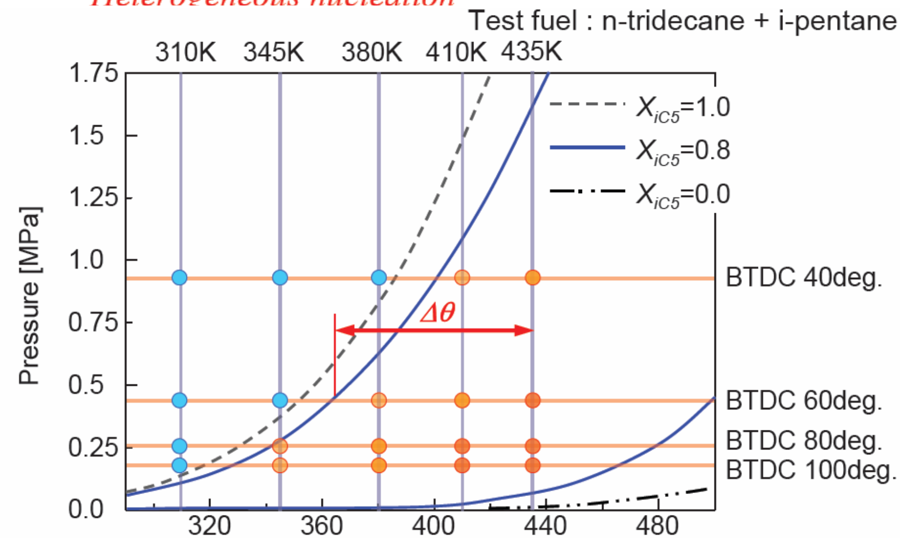
Fujimoto



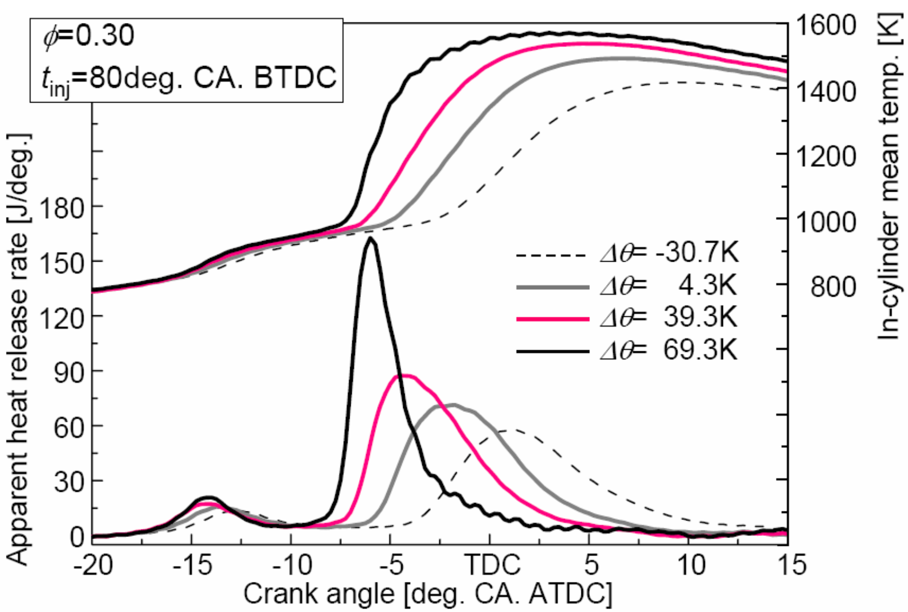
Nozzle internal flow
Bubble growth = Evaporation
Atomization
Heterogeneous nucleation



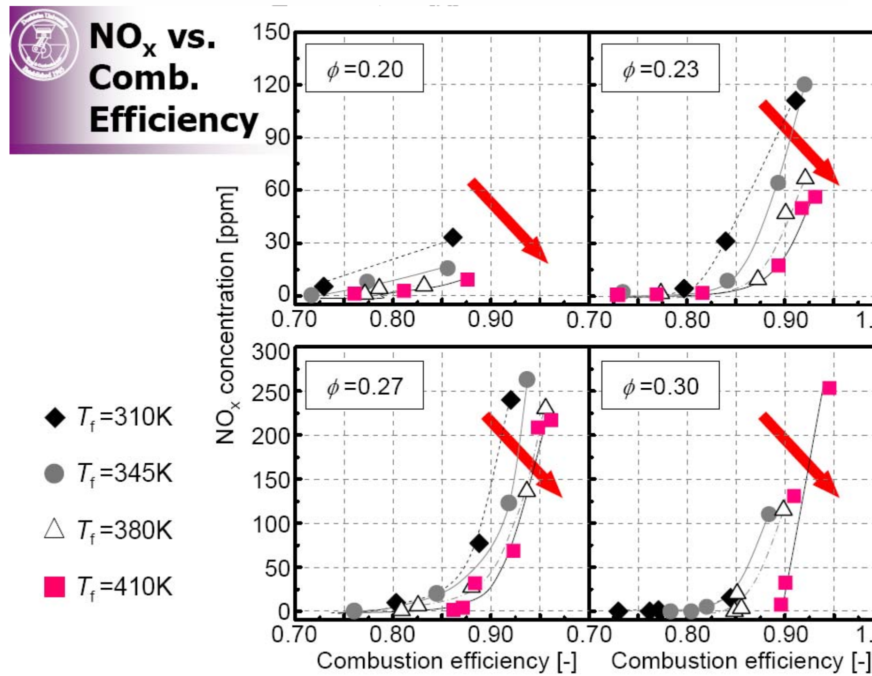
Fuel condition
In-cylinder condition
Pressure
Temperature
Crank angle



Test fuel : n-tridecane + i-pentane
310K 345K 380K 410K 435K
X_{iC5}=1.0
X_{iC5}=0.8
X_{iC5}=0.0
$\Delta\theta$
BTDC 40deg.
BTDC 60deg.
BTDC 80deg.
BTDC 100deg.
Pressure [MPa]
1.75
1.5
1.25
1.0
0.75
0.5
0.25
0.0
320
360
400
440
480



ϕ=0.30
t_{inj}=80deg. CA. BTDC
$\Delta\theta$= -30.7K
$\Delta\theta$= 4.3K
$\Delta\theta$= 39.3K
$\Delta\theta$= 69.3K
Apparent heat release rate [J/deg.]
In-cylinder mean temp. [K]
Crank angle [deg. CA. ATDC]
1600
1400
1200
1000
800
180
150
120
90
60
30
0
-20
-15
-10
-5
TDC
5
10
15



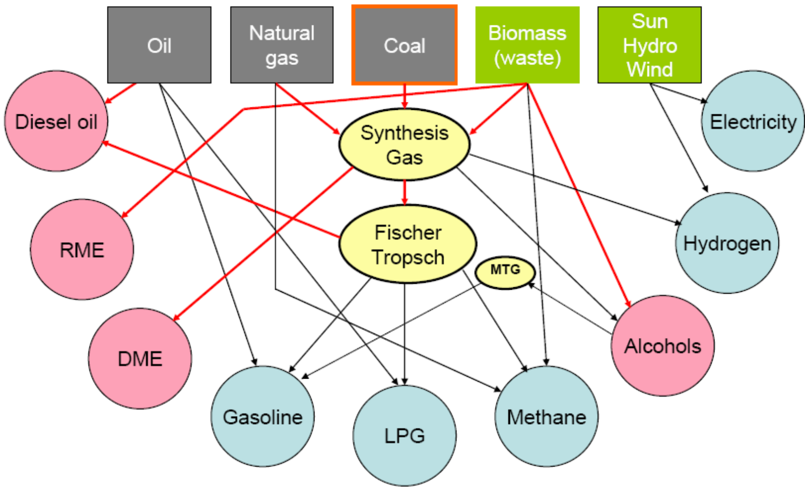
NOx vs. Comb. Efficiency
ϕ=0.20
ϕ=0.23
ϕ=0.27
ϕ=0.30
T_f=310K
T_f=345K
T_f=380K
T_f=410K
NOx concentration [ppm]
Combustion efficiency [-]
Combustion efficiency [-]
150
120
90
60
30
0
300
250
200
150
100
50
0
0.70
0.80
0.90
1.0

Johansson

HCCI, CAI, PCCI, pHCCI, PPC, LTC…?

- HCCI is normally a concept with port fuel injection and high compression ratio.
- CAI is normally a concept with low compression ratio and high residual gas concentration with negative valve overlap
- PCCI is normally a concept with early direct injection forming a rather homogeneous charge
- pHCCI=PCCI
- PPC, partially premixed charge is an bit less homogeneous than PCCI i.e. later injection
- LTC is any combustion process giving low NOx due to low temperature combustion.

Production of fuels from different feedstock



HCCI fuel index to be developed

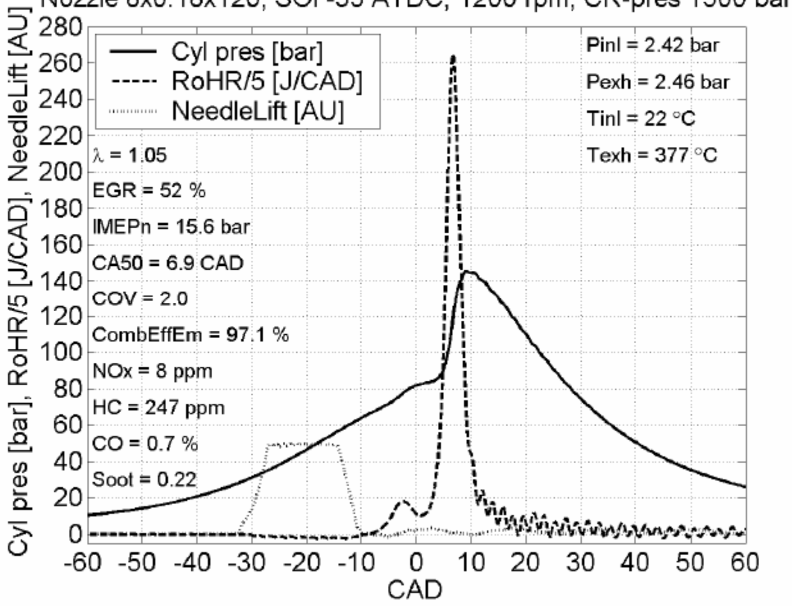
– Diesel engine has cetane number CN

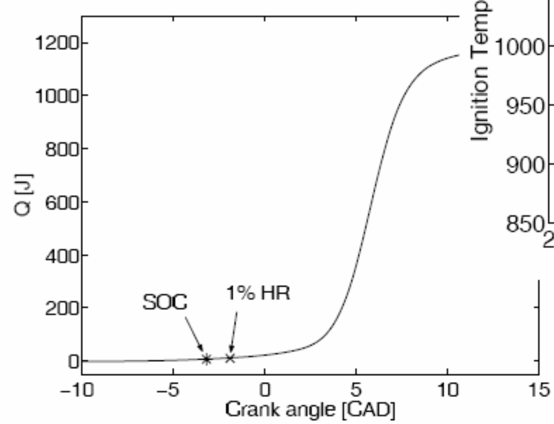
– SI engine has octane number, RON and MON

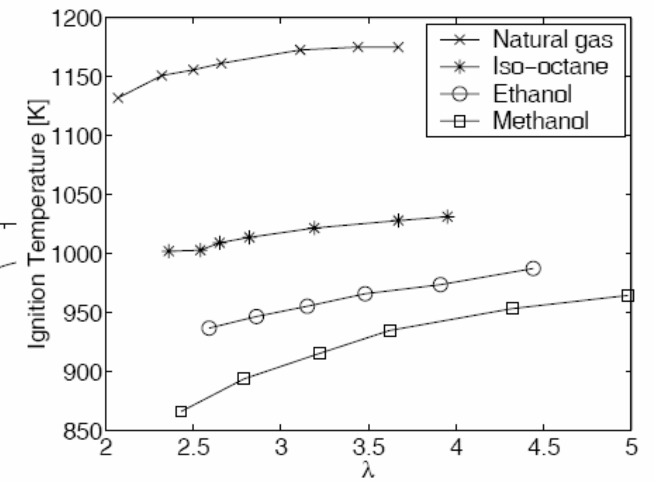
– But HCCI is a different process

PPC potential

Nozzle 8x0.18x120, SOI -33 ATDC, 1200 rpm, CR-pres 1500 bar



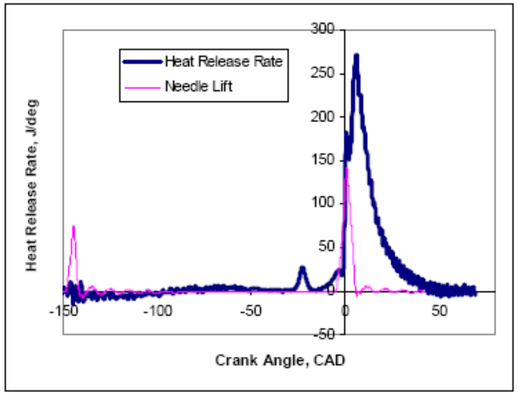




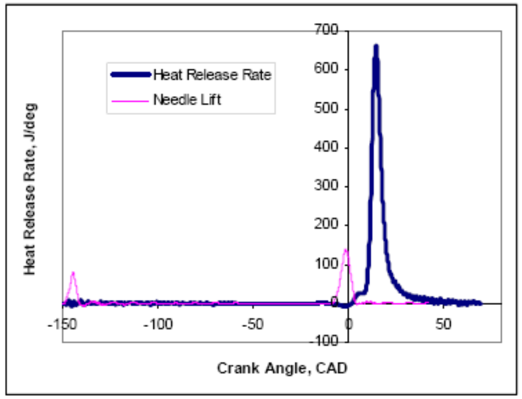
Kalgatgi

Comparison between diesel and gasoline

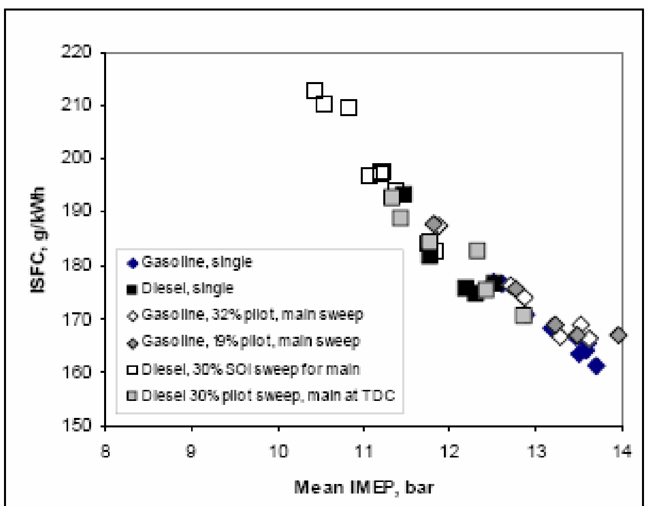
Total fuel rate 1.2 g/s, 70% in main injection. Lowest possible smoke with diesel was 7.8%

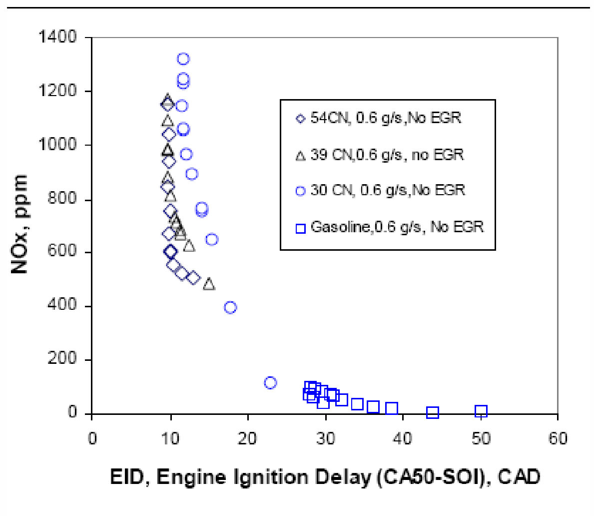


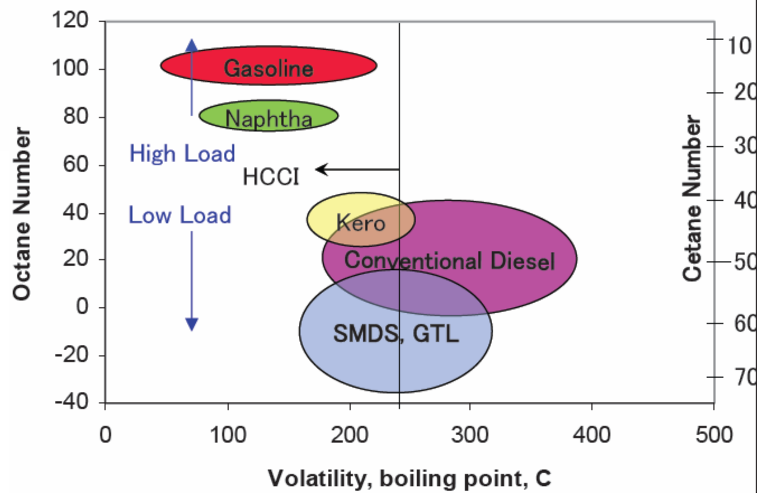
Swedish MK1 diesel. Main injection SOI at – 6 CAD. Mean IMEP 11.84 (std 0.115 bar) bar. AVL smoke opacity 8.7%. In g/kWh, ISFC= 183, ISNOx = 0.3, ISHC = 11.3, ISCO = 10



Gasoline. Main injection SOI at – 9 CAD. Mean IMEP 12.86 (std 0.108 bar) bar. AVL smoke opacity 0.9%. In g/kWh, ISFC= 174, ISNOx = 0.39, ISHC = 6.8, ISCO = 9



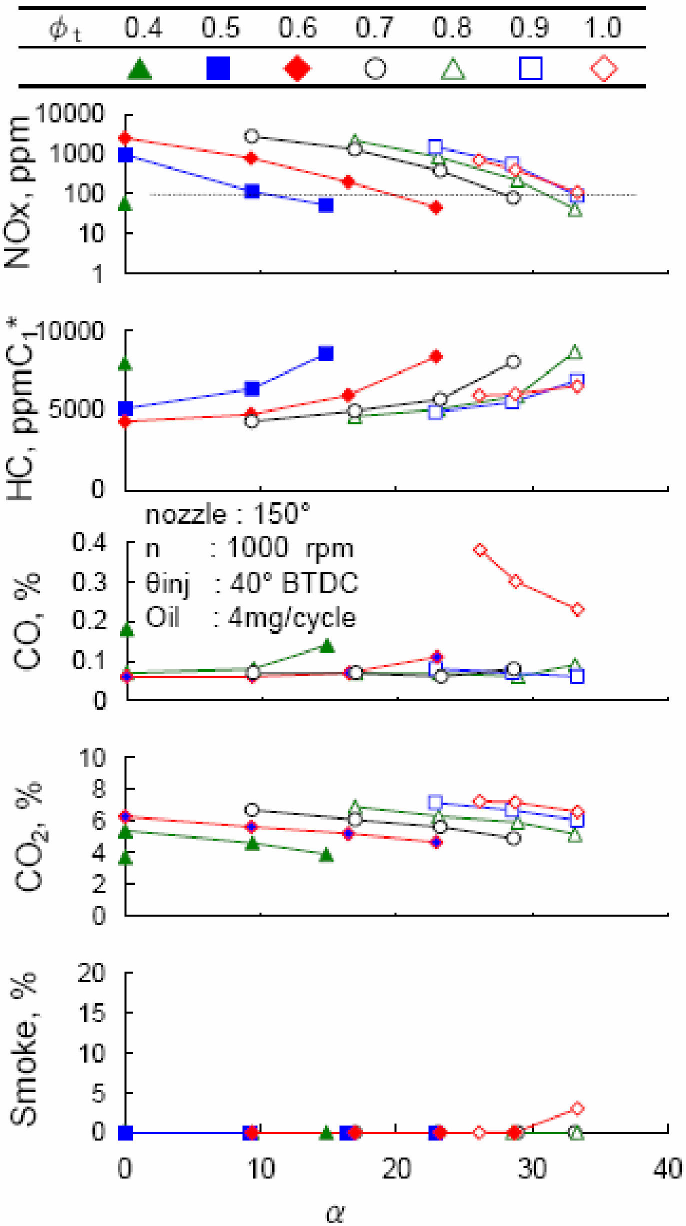


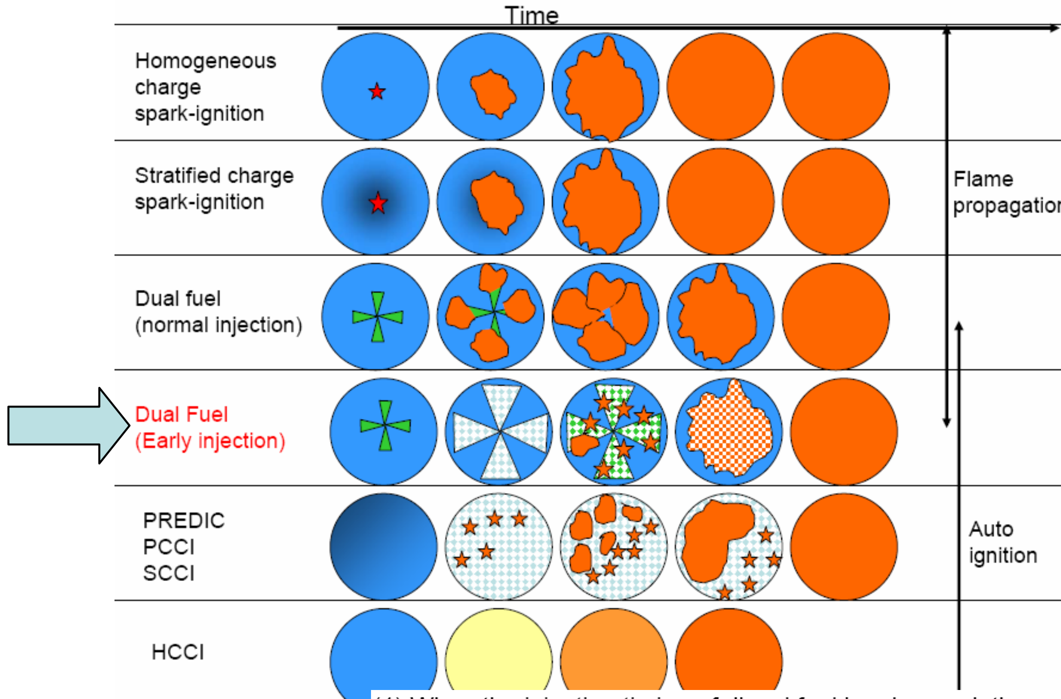


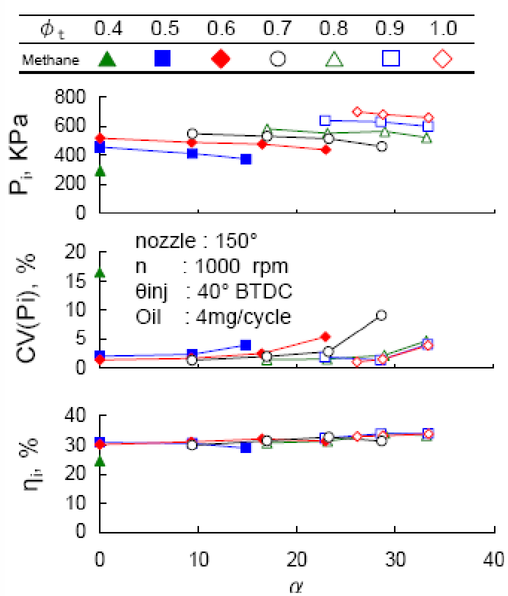
Conclusions

- The engine can be run on gasoline in partially pre-mixed mode even when it cannot be run in HCCI mode.
- Much higher ignition delay for gasoline compared to diesel at a given set of operating conditions and hence lower smoke (and lower NOx).
- Double injection helps reduce maximum heat release rate while maintaining IMEP,low emissions and fuel consumption for gasoline
- Much higher IMEP possible with gasoline compared to diesel for low smoke and NOx
- IMEP = 15.95 bar, smoke < 0.07 FSN, ISNOx, ISCO, ISHC and ISFC of ~ 0.6, 6.8, 2.9, 179 g/kWh. This was with 23% pilot, 2 bar abs. Pin and 35% EGR (actual).
- Highest IMEP possible with diesel fuel for this low smoke < 6.5 bar
- Further improvements should be possible with optimisation of injection and mixture preparation (multiple injections, more injector holes....)

Tomita







(1) When the injection timing of diesel fuel is advanced, the range of equivalence ratio for the engine operation becomes narrow.

However, the engine can operates even in stoichiometric mixture owing to N_2-dilution.

Under the condition of stoichiometric mixture, smoke can be seen when the injection timing is 20 degrees BTDC though smoke is not seen when the injection timing is 40 and 50 degrees BTDC.

This is because there is no rich region of fuel due to the diffusion of the diesel fuel in the early injection.

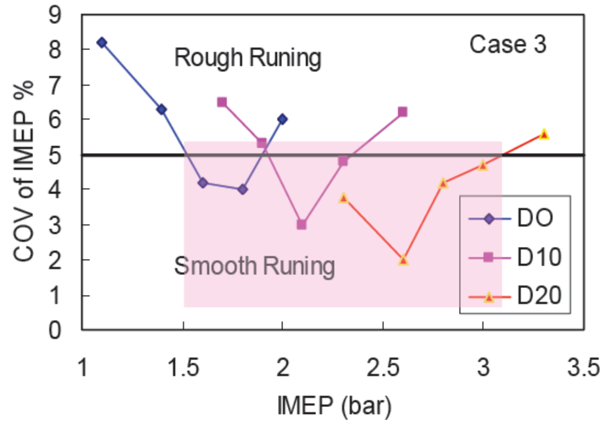
(2) The peak of the rate of heat release is retarded in the early injection timing. The exhaust emissions of NOx are very low and HC and CO are almost the same while thermal efficiency increases slightly.

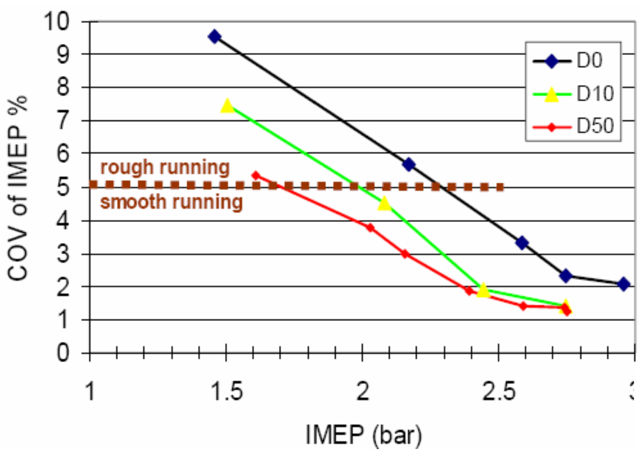
(3) In the early injection timing without N_2-dilution, when the equivalence ratio increases, the effective work decreases because the maximum value of the heat release is advanced and thermal efficiency decreases.

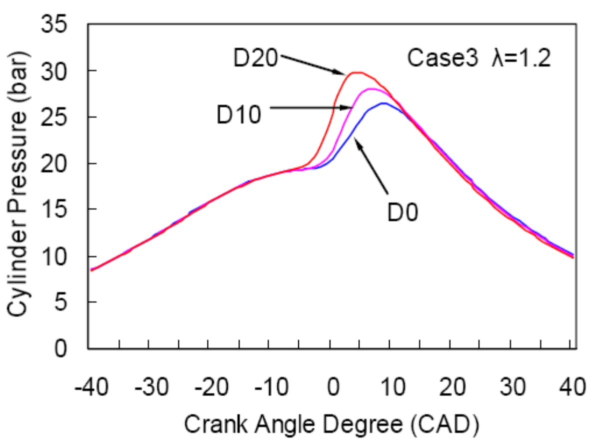
(4) The value of the hydrocarbons in the early injection is smaller than those in the normal injection timing though the absolute value seems to be large.

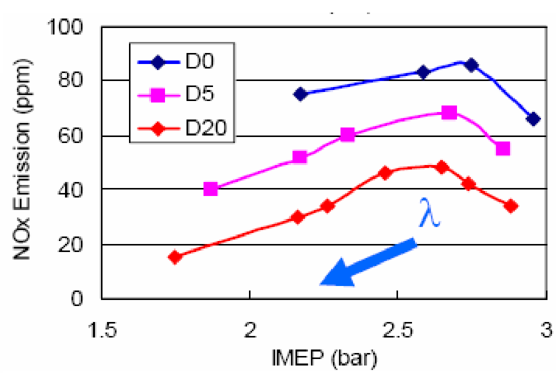
Xu

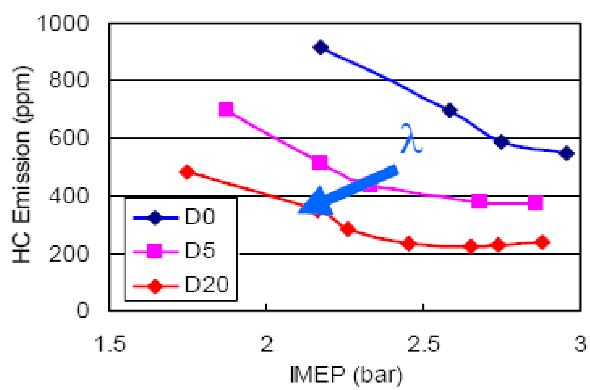
Fuel Designation	D0	D5	D10	D20	D50
Fuel Composition Gasoline : Diesel (by mass)	100:0	95:5	90:10	80:20	50:50
Intake heating (CR=15.0)			√	√	√
NVO (CR=10.4)	√	√	√	√	√











- The blended fuel namely 'dieseline' makes compromised and optimal offer to the desired ignition quality, which reduces the dependence of HCCI on EGR trapping or intake heating.
- For 'dieseline' HCCI, the required intake temperature heating can be lowered by at least 10 degrees compared with pure gasoline operation. With diesel addition, appropriate engine conditions can be achieved for gasoline HCCI with EGR trapping for a wide range of CR.
- The HCCI operating region for the unheated NVO can be significantly extended into lower IMEP values and the audible knocking is restrained to the highest values of λ at high load boundary for the highest mixture temperatures. The resulting effects make it possible to reduce the NVO interval required for stable combustion.
- The possible scale of NVO was extended by up to 40 CAD, the lean limit of lambda can almost reach up to 2.0 when engine is operated with a moderate compression ratio (10.4). However this might cause a CO emission penalty at the leanest limit due to lower combustion temperature.
- The indicated specific fuel consumption and CO emissions decrease due to decreased pumping losses of recompression and higher combustion efficiency.
- Emissions of HC and NOx show an interesting improvement compared with gasoline HCCI with optimized engine operating conditions.
- A substantial increase in the upper limit of load range will be achieved without intake heating because of higher volumetric efficiency resulting from smaller NVO and the presence of less residual gases in cylinder. However this can result in potentially higher NOx emissions due to the lower dilution amount present and higher combustion temperature.

Summary

- This is the first meeting of the collaborative task on HCCI fuels. It was formed after the assignment given in Sarasota, February 2006.
- The formation of a joint task is not that clear at this first meeting. It is now more of presenting results not linked together. Better synconization should be done in the future.
- Much results are on mixing different fuels to achieve HCCI combustion over a wider range of loads.
- Diesel for SI engine configuration (Xu) and Gasoline for CI engine configuration (Kalgatgi) is the best choice (!)