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Combustion Characteristics of HCCI Engine Fuels

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Presentation outline

- Background and objectives
- Experimental Systems
- Results and discussion
- Conclusions

Acknowledgement

- The experiment work was carried out by PhD student Pawel Luszcz, with contributions to the setup of experimental engine systems from Rob Stevens and Trevor Wilsons of Jaguar Cars

Nature of HCCI

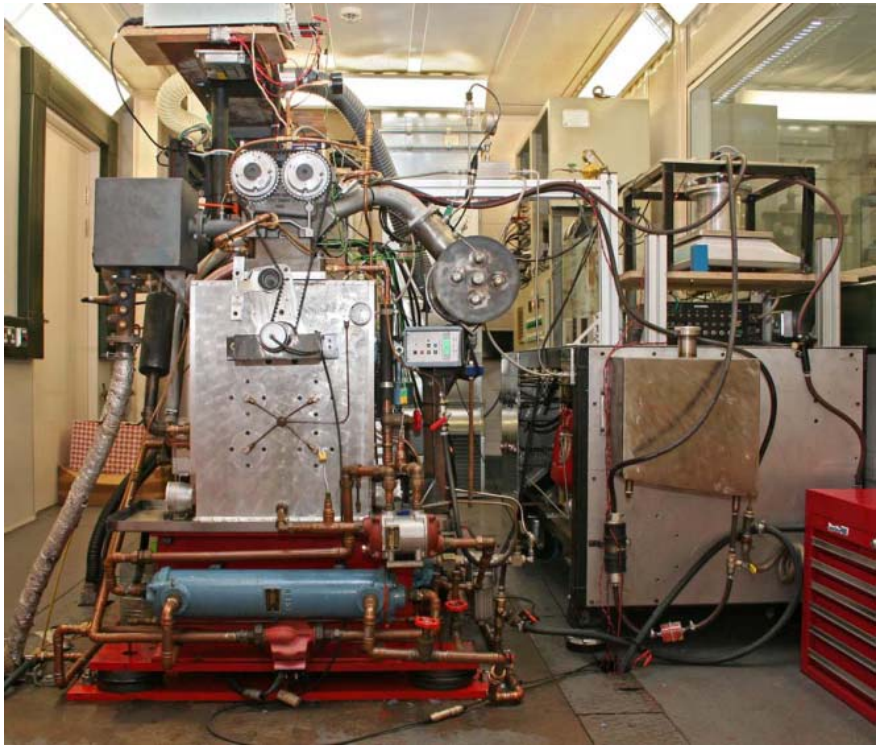
- Kinetically controlled auto ignition
  - ❖Can be either 1 stage or 2 stages
- A 2 stage autoignition claims potential benefits over 1 stage autoignition
  - ❖Lower CBC variations under certain conditions
  - ❖Lower intake air temperature is required
- Factors of influence
  - ❖Fuel molecule types
  - ❖Engine operating conditions
- Autoignition quality designators
  - ❖RON, MON, OI, K.....

Objective of present study

To investigate the factors which influence the pattern of heat release:

- Engine speed
- Residual burned gas
- Fuel quantity
- Air-fuel ratio
- Representatives of fuel type

Single cylinder thermal engine



- **GDI (SG)**
- **Dual VCT**
- **Intake air heating 25- 250^{o}C**
- **Fuels - PRF40 and PRF80**

Bore x Stroke (mm)	90.0 x 88.9	
Swept. Volume (cm^3)	565.6	
Compression Ratio (Geometric)	11.5:1	
Fuel Delivery	Direct Injection	
Valves	**Intake**	**Exhaust**
Lift (mm)	2.65	2.10
Duration (CAD)	130	110

Test condition (1) - valve strategy, thermal engine

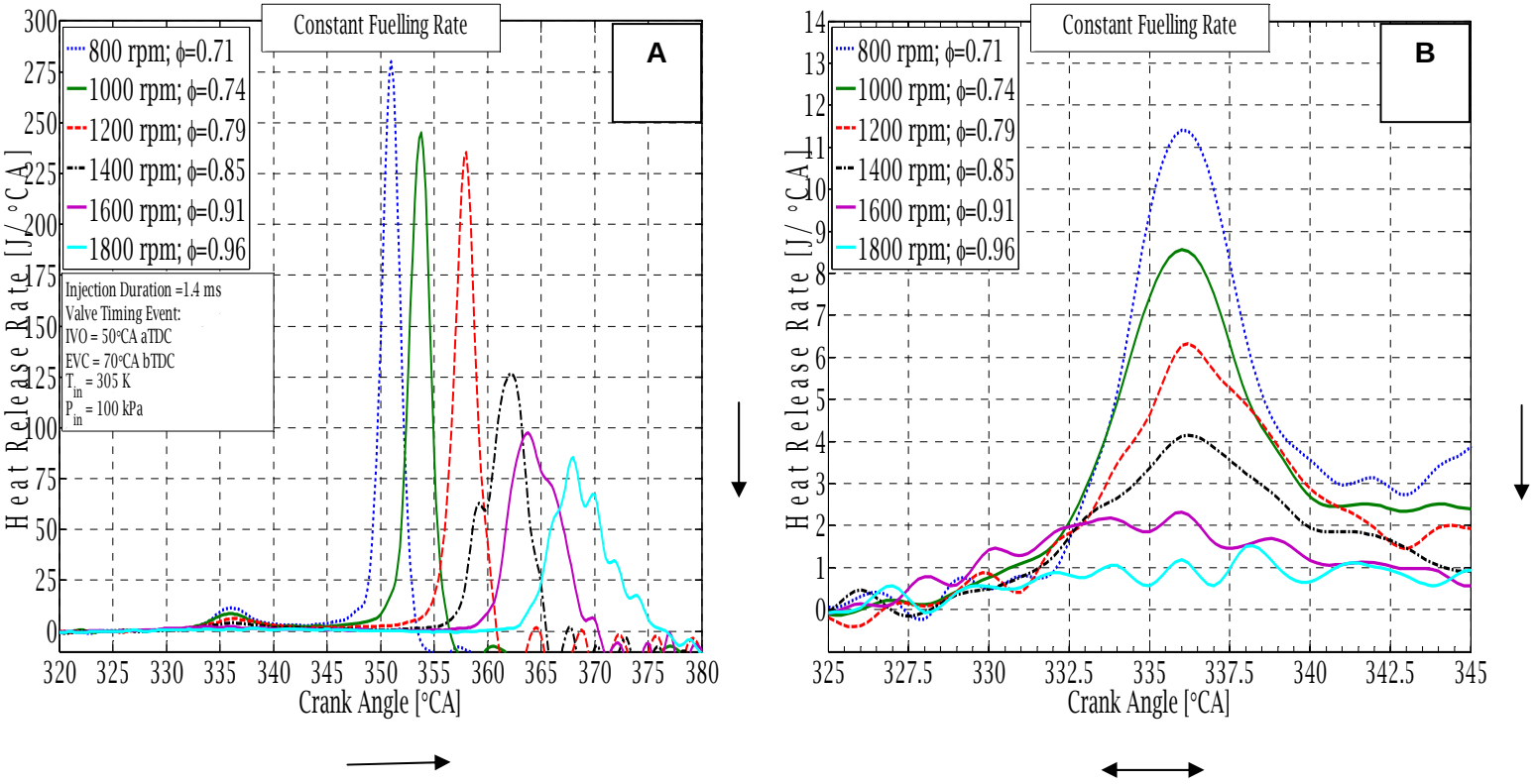
Valve Timing (VTE)	*Intake Valve Timing*		*Exhaust Valve Timing*		*Estimated iEGR Rate*	
	IVO °CA aTDC	IVC °CA aTDC	EVO °CA bTDC	EVC °CA bTDC	Constant Fuelling %	Constant AF %
VTE-1	50	180	170	60	≈ 36.7	≈ 36.5
VTE-2			175	65	≈ 40	-
VTE-3			180	70	≈ 44.2	≈ 45.7
VTE-4			185	75	≈ 47.6	-
VTE-5			190	80	≈ 51.2	≈ 51
VTE-6			195	85	≈ 54.8	-
VTE-7			200	90	≈ 57.5	≈ 57.4
VTE-8			205	95	≈ 59.6	-
VTE-9			210	100	≈ 60.4	≈ 59.8

Test conditions (2) - thermal engine

Experiments	Engine Speed Influence	Fueling and EGR Influence
Intake Air Temperature	305 K	305 K
Intake Air Pressure	100 kPa	100 kPa
Coolant Temperature	363 K	363 K
Injection Timing	110° CA aTDC	110° CA aTDC
Injection Pressure	100 bar	100 bar
Engine Speed	Variable (800 – 1800 rpm)	1000 rpm
Valve Timing Event	Corresponding to VTE#3	Variable

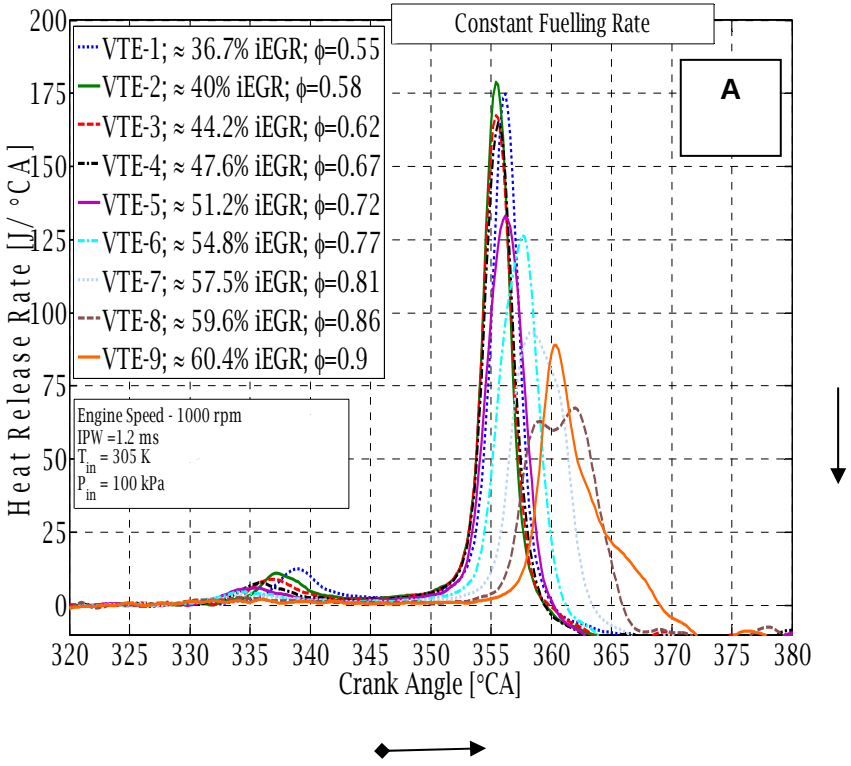
Fuel: PRF 40

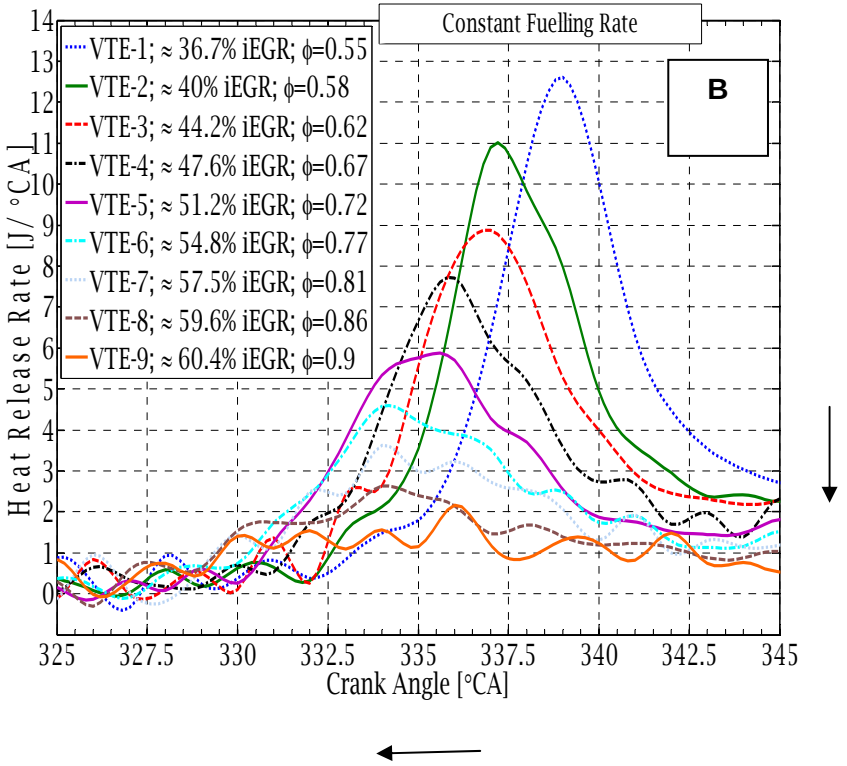
Effect of engine speed (with constant fuelling quantity)



(A) Total heat release profiles
(B) Low temperature heat release profiles

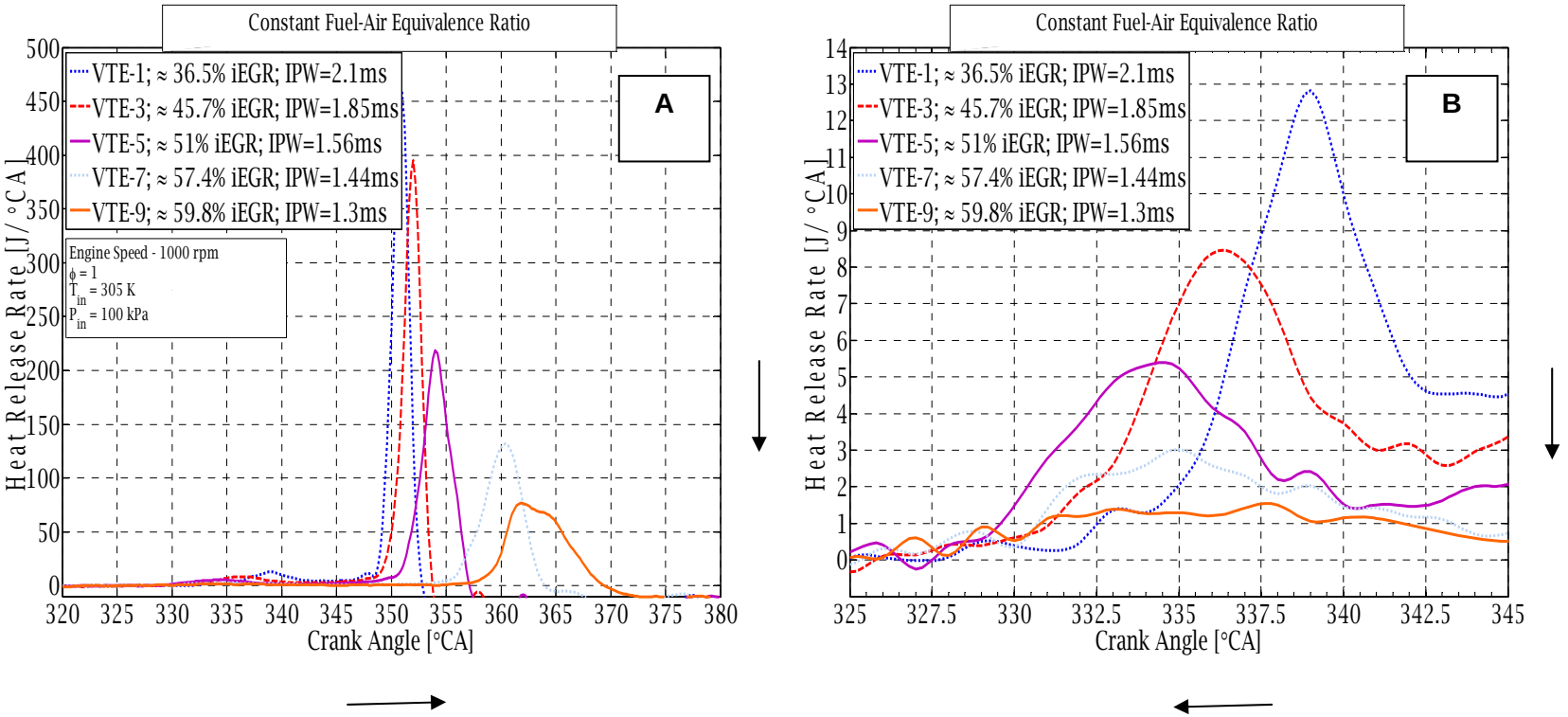
Effect of residual exhaust gas (with constant fuelling quantity)





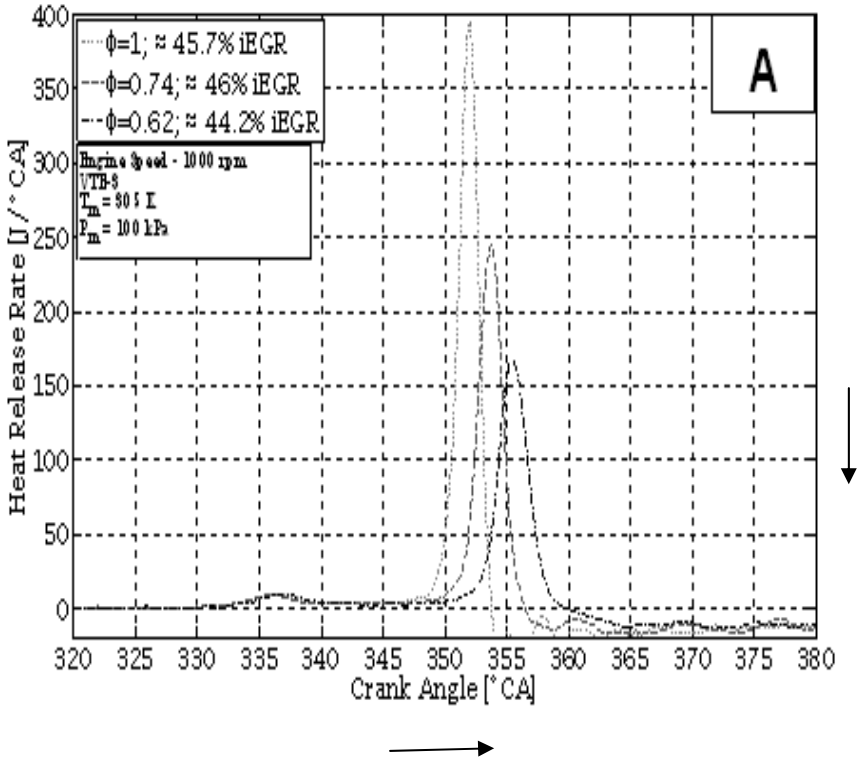
(A) Total heat release profiles
(B) Low temperature heat release profiles

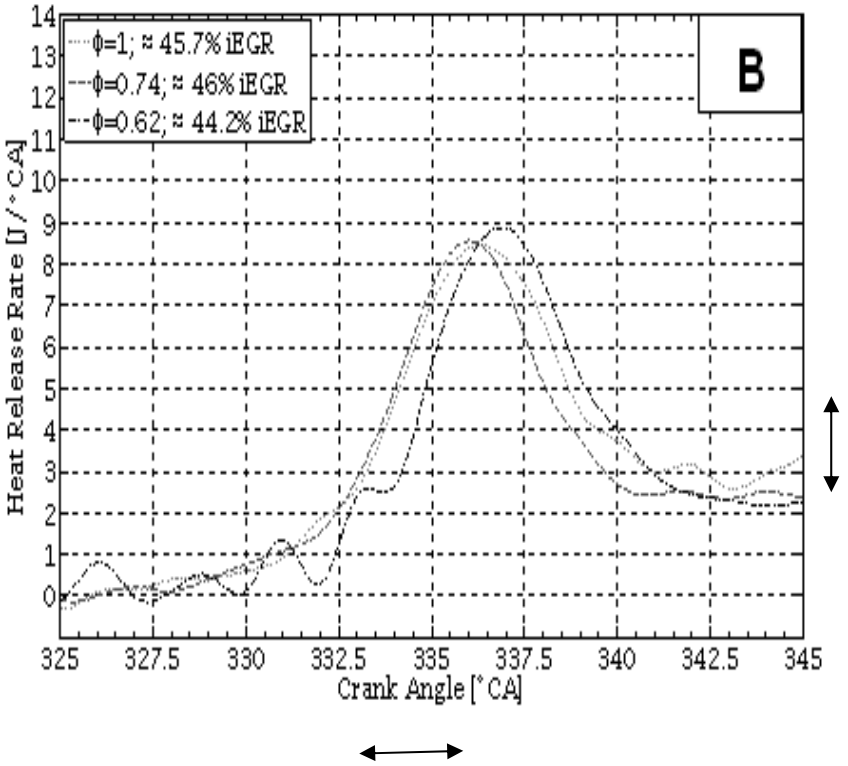
Effect of residual exhaust gas (with constant AF ratio)



(A) Total heat release profiles
(B) Low temperature heat release profiles

Effect of fuel quantity





(A) Total heat release profiles
(B) Low temperature heat release profiles

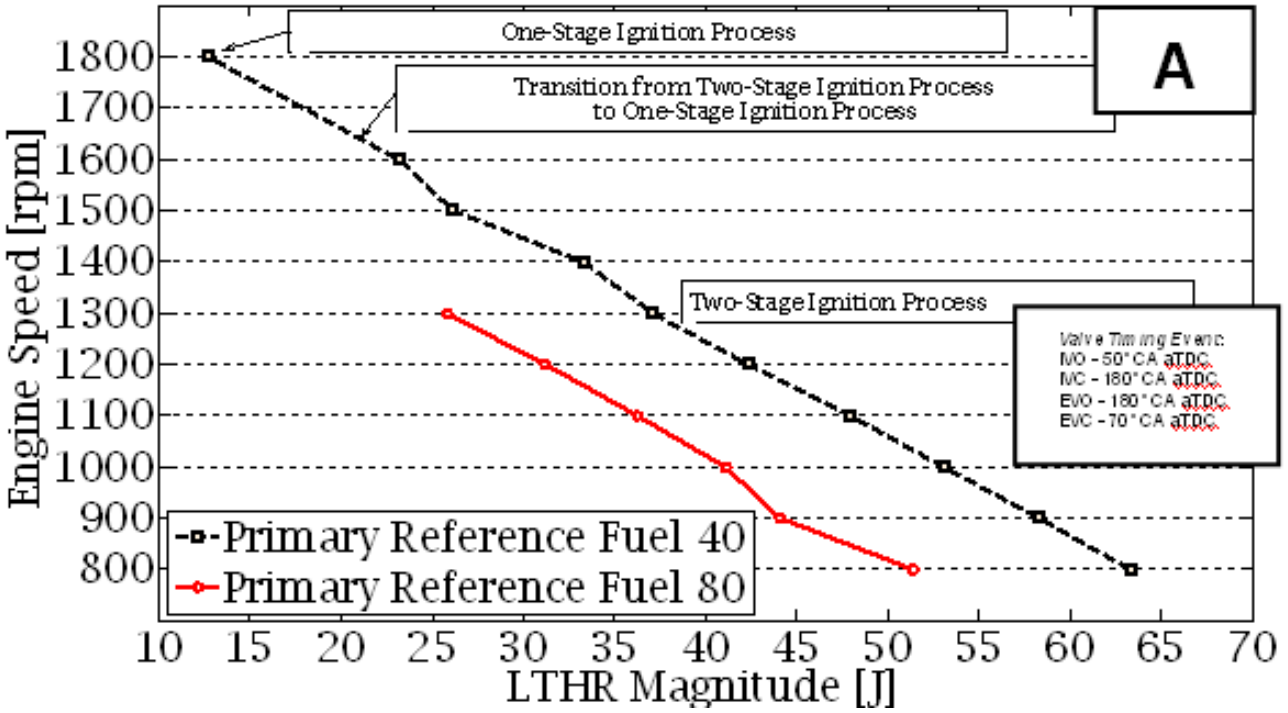
Test conditions (thermal engine)

Engine parameters	PRF40 & PRF80
Intake Temperature	Variable
Intake Pressure	100 kPa
Coolant Temperature	363 K
Injection Timing	110° CA aTDC
Injection Pressure	100 bar
Engine Speed	600 rpm
Valve Timing Event	
Intake Valves Opening	50° CA aTDC
Intake Valves Closing	180° CA aTDC
Exhaust Valves Opening	180° CA bTDC
Exhaust Valves Closing	70° CA bTDC

Special test fuels

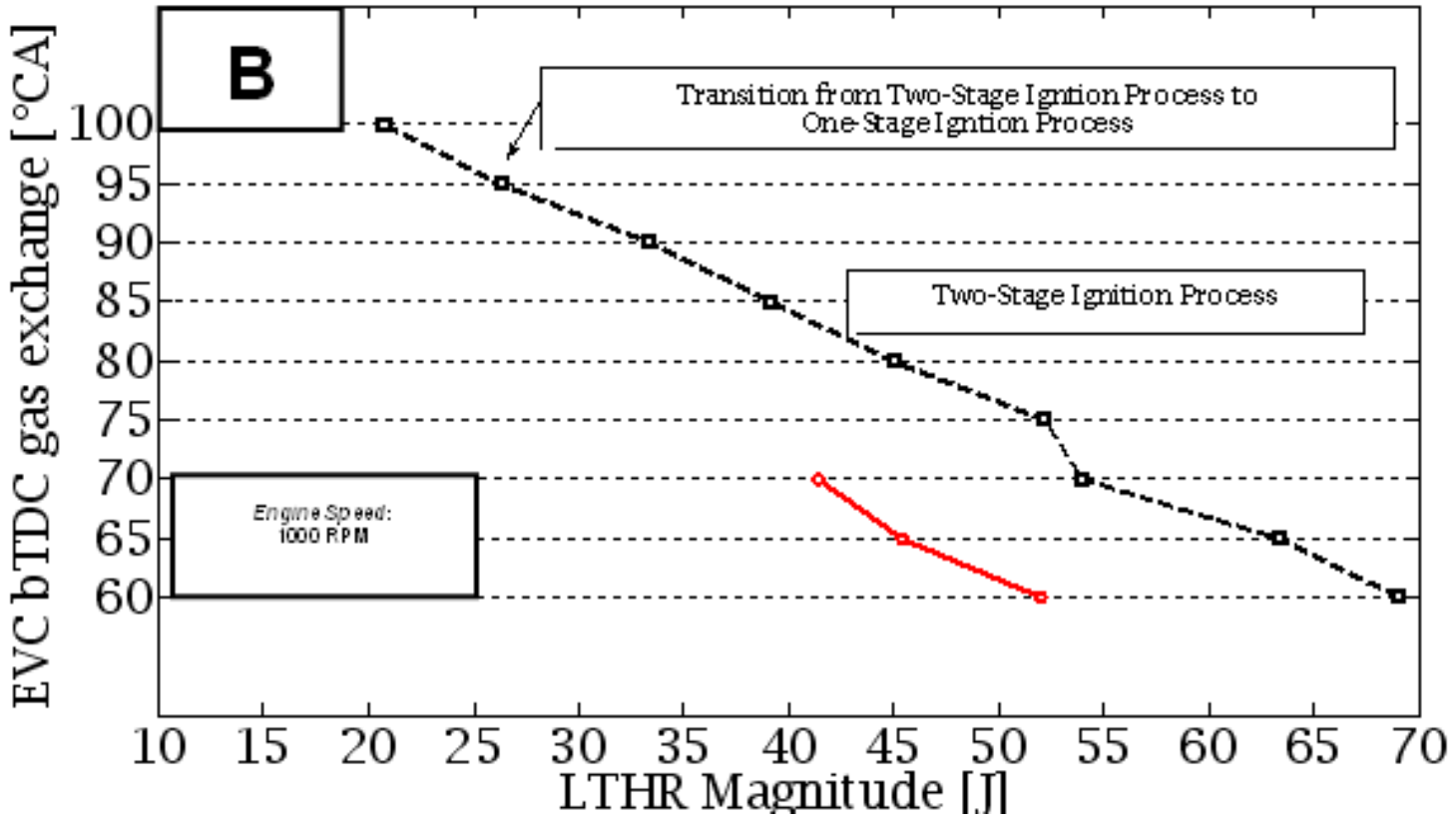
Fuel	PRF756	TSF756
Iso-Octane %vol.	75.6	0
n-Heptane %vol.	24.4	48
Toluene %vol.	0	52
RON	75.6	75.6
MON	75.6	66.9
Antiknock index	75.6	71.25
Fuel sensitivity	0	8.7
C-atoms	7.76	7
H-atoms	17.51	11.36
Molecular weight	110.58	95.36
A/F Stoichiometric	15.12	14,21
LHV [kJ/kg]	44363	42263
HHV [kJ/kg]	47873	44839
Heat of vaporization [kJ/kg]	296	372

Magnitudes of cool flame activities



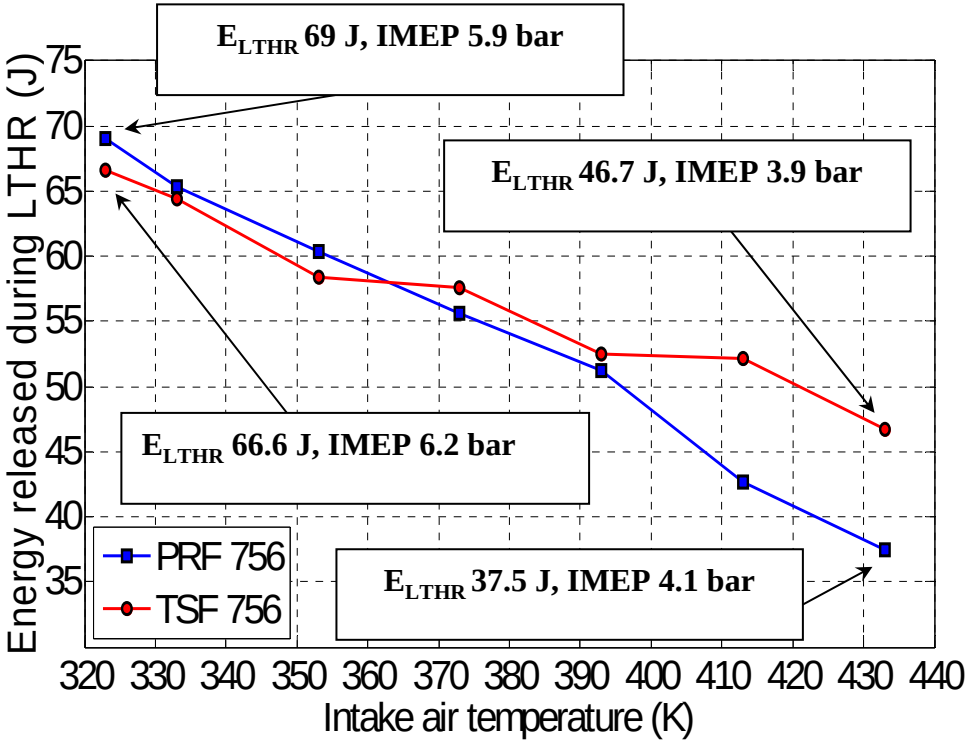
Effect of engine speed

Magnitudes of cool flame activities



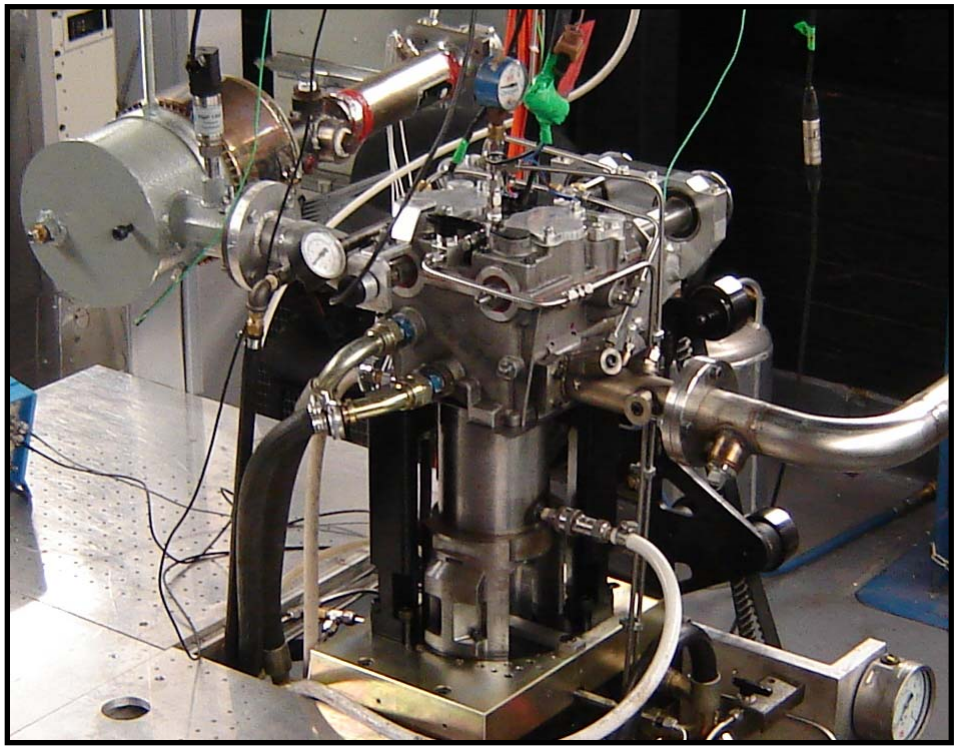
Effect of valve timing

Comparison of cool flame activities



Magnitudes for PRF75.6 and TSF75.6 blends at a range of intake air temperatures with constant valve timing, engine speed and stochiometric fuel-air ratio.

Single cylinder optical engine



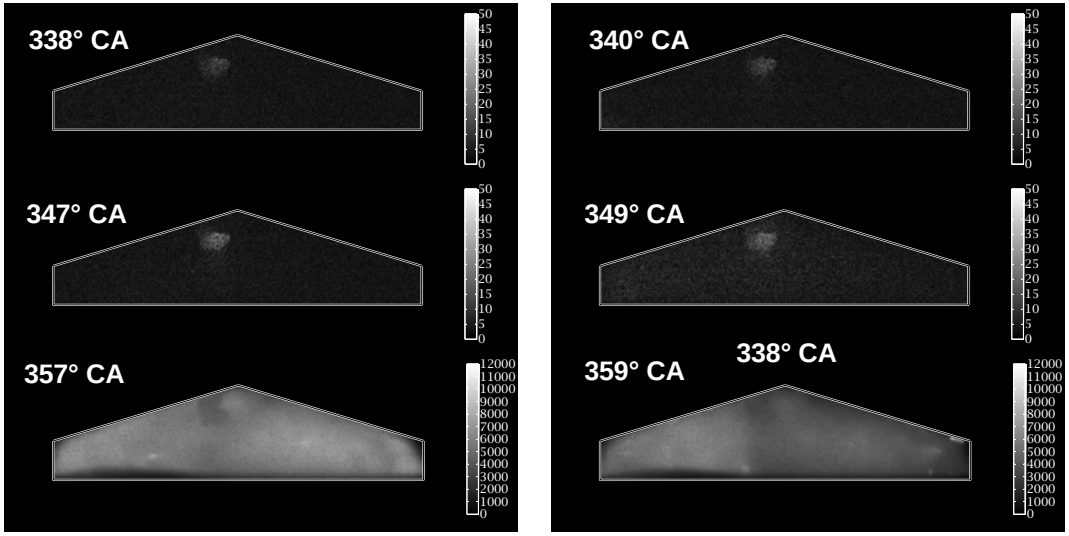
- **GDI (SG) or PFI**
- **Dual VCT**
- **Intake air heating 25- 250°C**

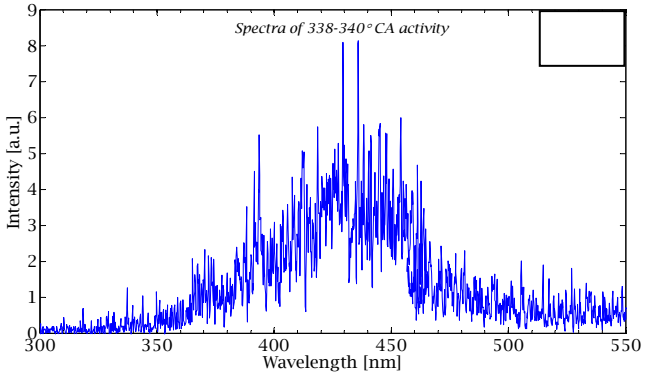
Parameter	Value
Engine Head Type	Jaguar AJ133 V8
Bore	89 mm
Stroke	90.3 mm
Displacement	0.562 L
Clearance Volume	0.0562 L
Compression Ratio	11:1
Connecting Rod Length	148.9 mm
Number of Intake Valves	2
Number of Exhaust Valves	2
Intake Valve Lift	2.5 mm
Exhaust Valve Lift	2.5 mm
Intake Camshaft Duration	150° CA
Exhaust Camshaft Duration	150° CA

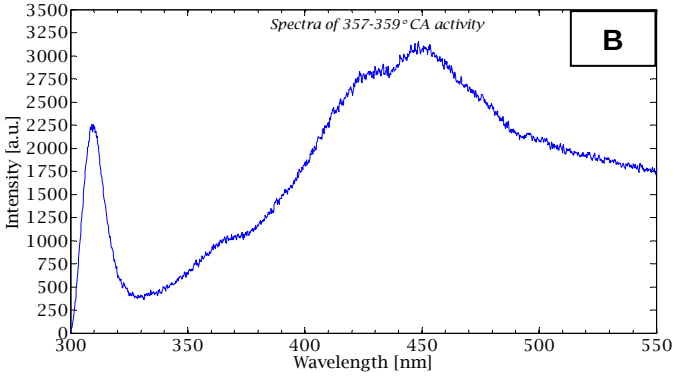
Test condition – optical engine

Engine Operating Variables	**Experiments**	
	One- and two-step ignition process – - physicochemical nature	
Intake Air Temperature	313 K	
Intake Air Pressure	100 kPa	
Coolant Temperature	363 K	
Injection Timing	140° CA aTDC	
Injection Pressure	100 bar	
Engine Speed	1000 rpm	
Valve Timing Event	***VTE#1***	***VTE#2***
Intake Valves Opening	55° CA aTDC	55° CA aTDC
Intake Valves Closing	205° CA aTDC	205° CA aTDC
Exhaust Valves Opening	220° CA bTDC	240° CA bTDC
Exhaust Valves Closing	70° CA bTDC	90° CA bTDC
Estimated iEGR Mass Fraction	≈ 42%	≈ 57%

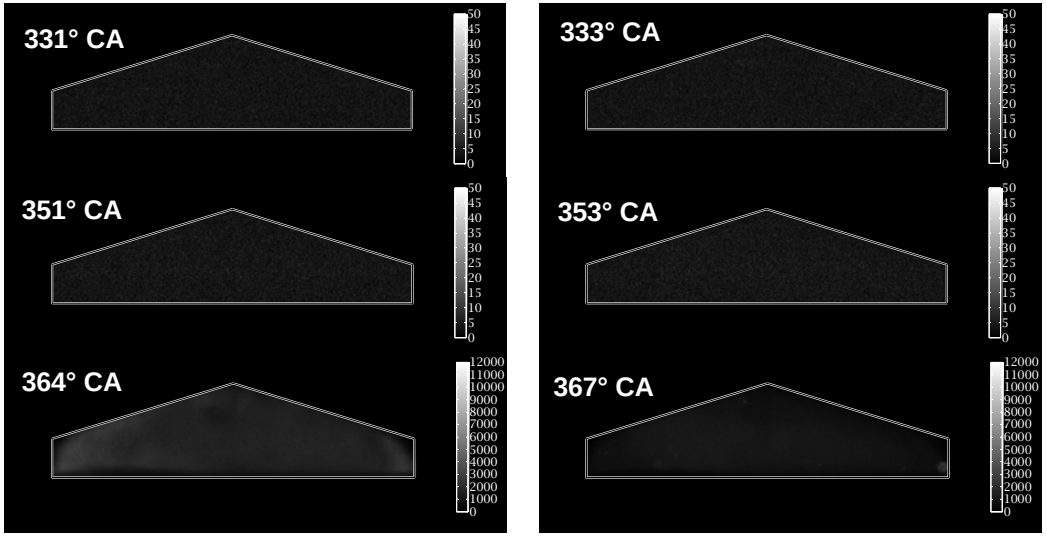
Optical characteristics (1) – VTE1

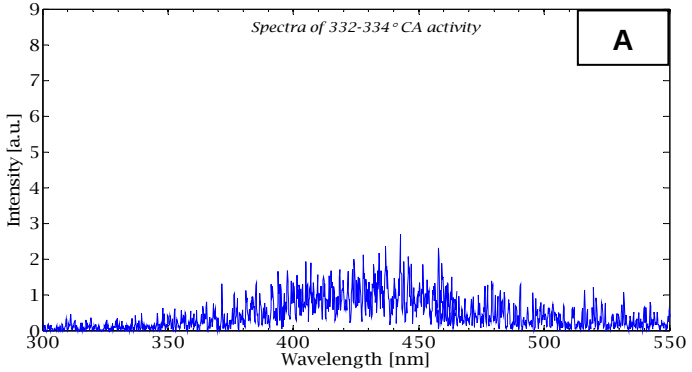


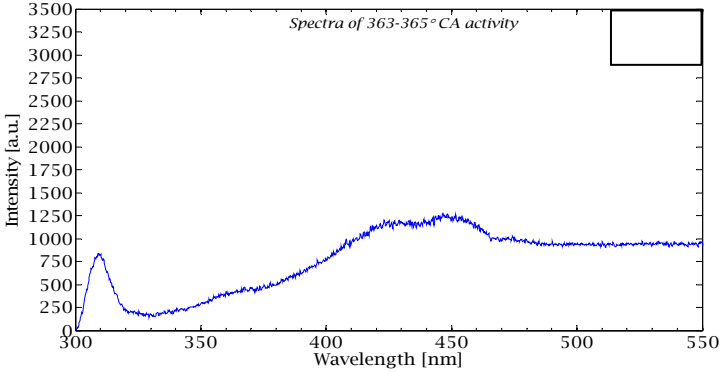




Optical characteristics (2) – VTE2







Development of 2 stage auto-ignition

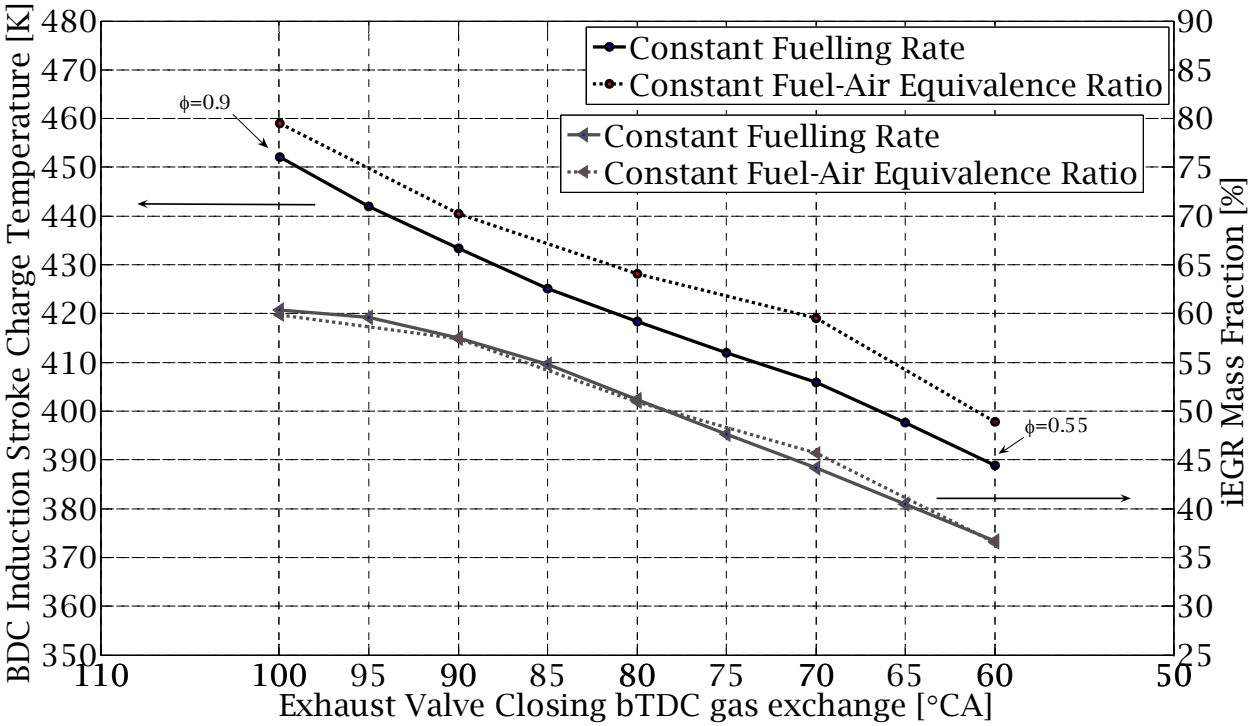
Conclusions

- In two stage autoignition combustion, each stage is influenced by engine operating conditions such as engine speed, residual gas ratio, air-fuel ratio and the effect is different to LTHR and HTLR.

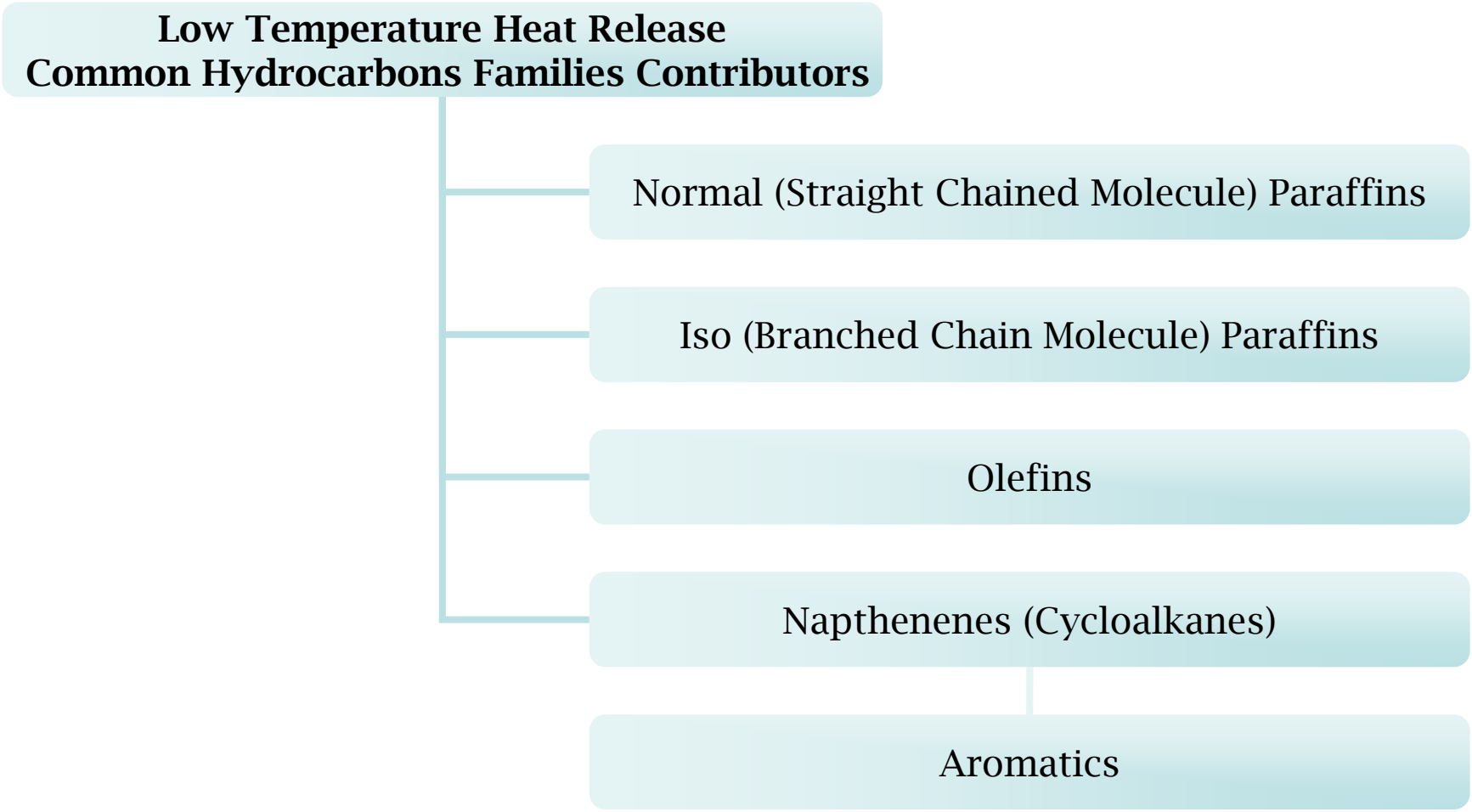
- The portion of low temperature heat release can become so small that can be omitted and thus the autoignition appears as a single stage process under certain engine conditions.

- At low intake temperature, the cool flame activities of the fuels with the same MON are similar but the differences increase temperature.

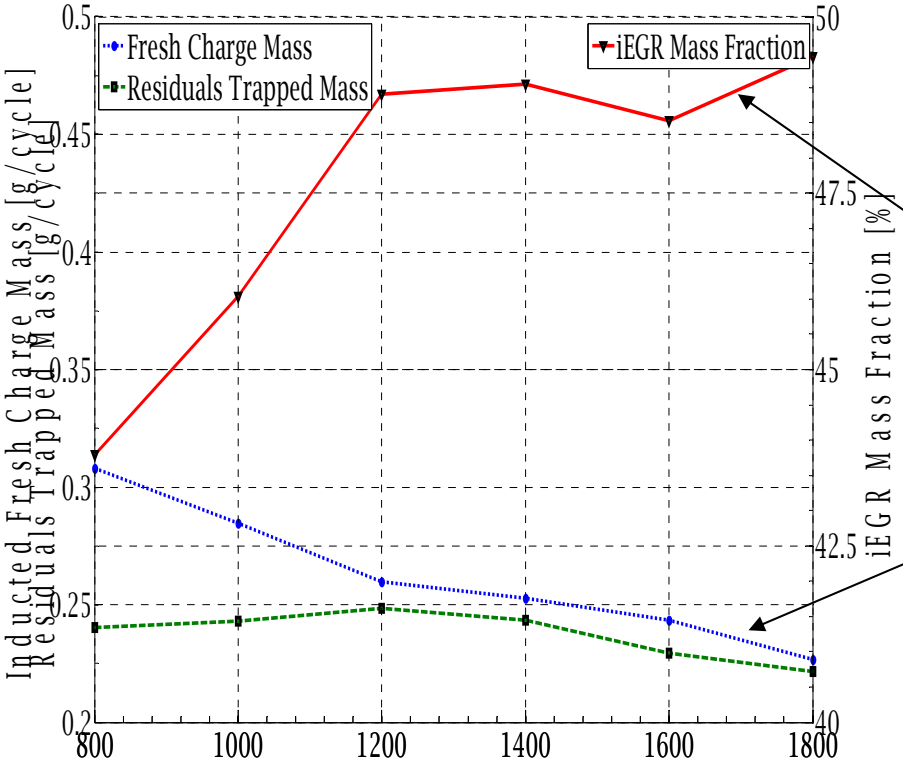
Temperature/EGR with varied valve timing

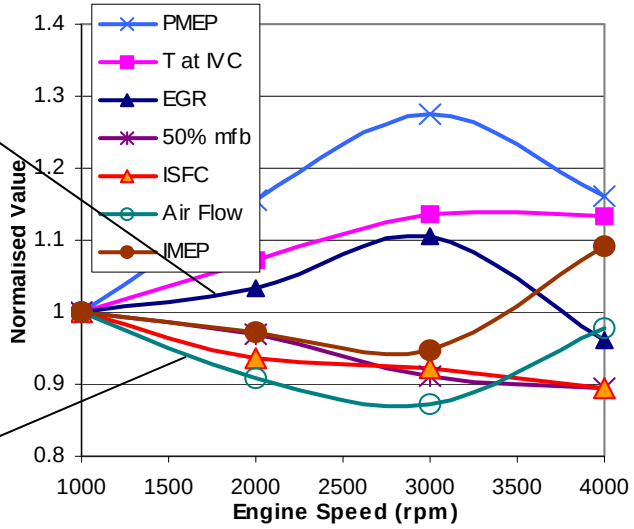


HCCI fuels


Low Temperature Heat Release
Common Hydrocarbons Families Contributors
Normal (Straight Chained Molecule) Paraffins
Iso (Branched Chain Molecule) Paraffins
Olefins
Napthenenes (Cycloalkanes)
Aromatics

Mass of fresh charge, residual gas





Modelling result SAE 2003-01-1859