Biodiesel & Thermal Management - Two Research Projects at the University of Birmingham

The University of Birmingham & Jaguar Research

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Wendesday, 13 September 2006

Controlled Homogenous Auto-ignition Supercharged Engine

CHASE Thermal Management

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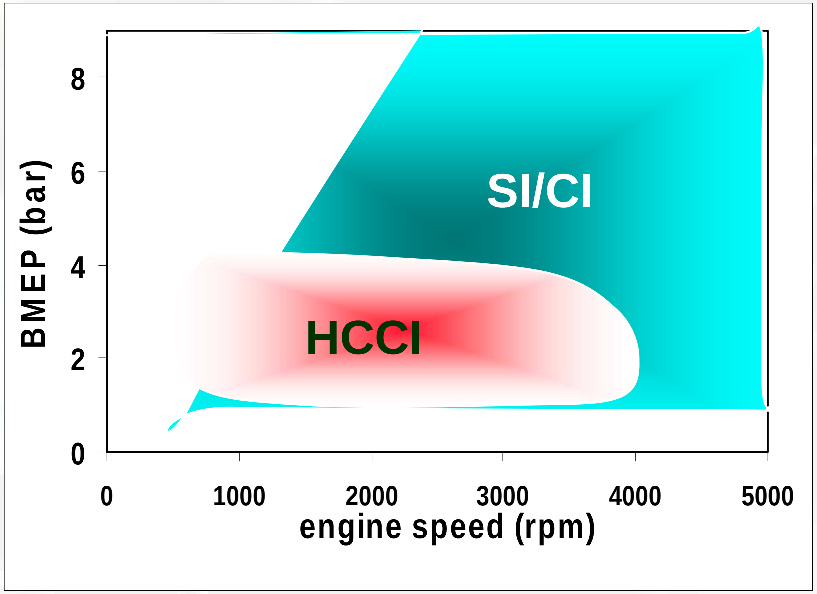
Implementation of HCCI

What are the outstanding issues?

- Size of HCCI operation envelopes
- Fuel economy at vehicle level
- Driver transparent transitions between HCCI and SI
- NVH and robustness (Customer interest)



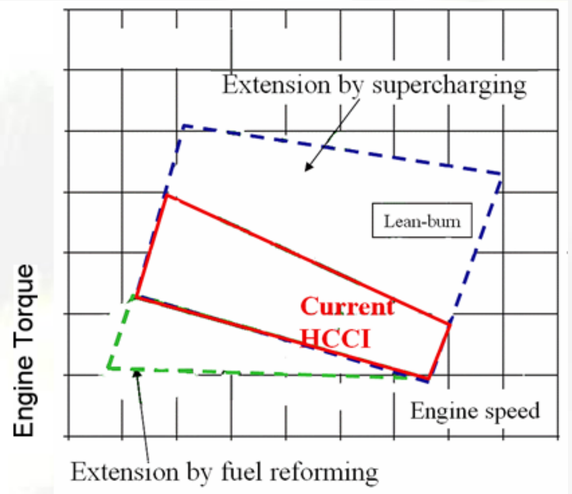
Schematic illustration of HCCI envelope for a vehicle application

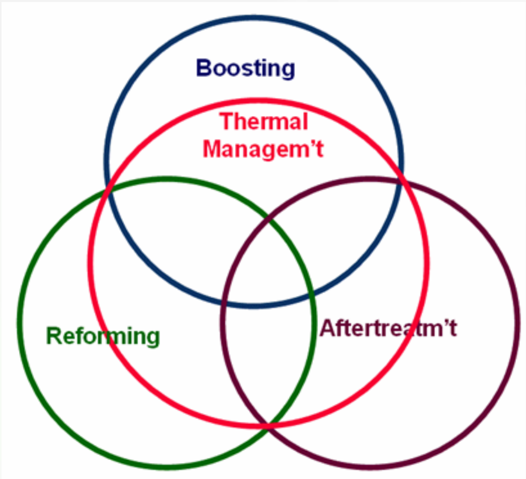
- Cost - engineering (engine upgrade)
  materials (e.g. special valve-train and control)
  manufacturing & special components

Project Objectives

Extending the HCCI Operating Window

- **Effect of charge boosting** to extend the size of the HCCI operation load/speed window upwards by increasing air delivery while retaining EGR.
- Exhaust-gas fuel-reforming technology to extend the size of HCCI operation window downwards by **chemically improving the ignitability** of the residual gas/air diluted charge.
- Develop **lower temperature gasoline reformers**, and **new catalytic converters** for HCCI engines.
- Achieve controlled auto-ignition across a wide range of vehicle conditions by **total thermal management** of the heat distribution inside the powertrain unit.





Introduction

Aim: Complete Thermal Management Study

The Thermal study investigates the gas thermodynamics and control of HCCI Jaguar Supercharged V6 engine and auxiliary components.

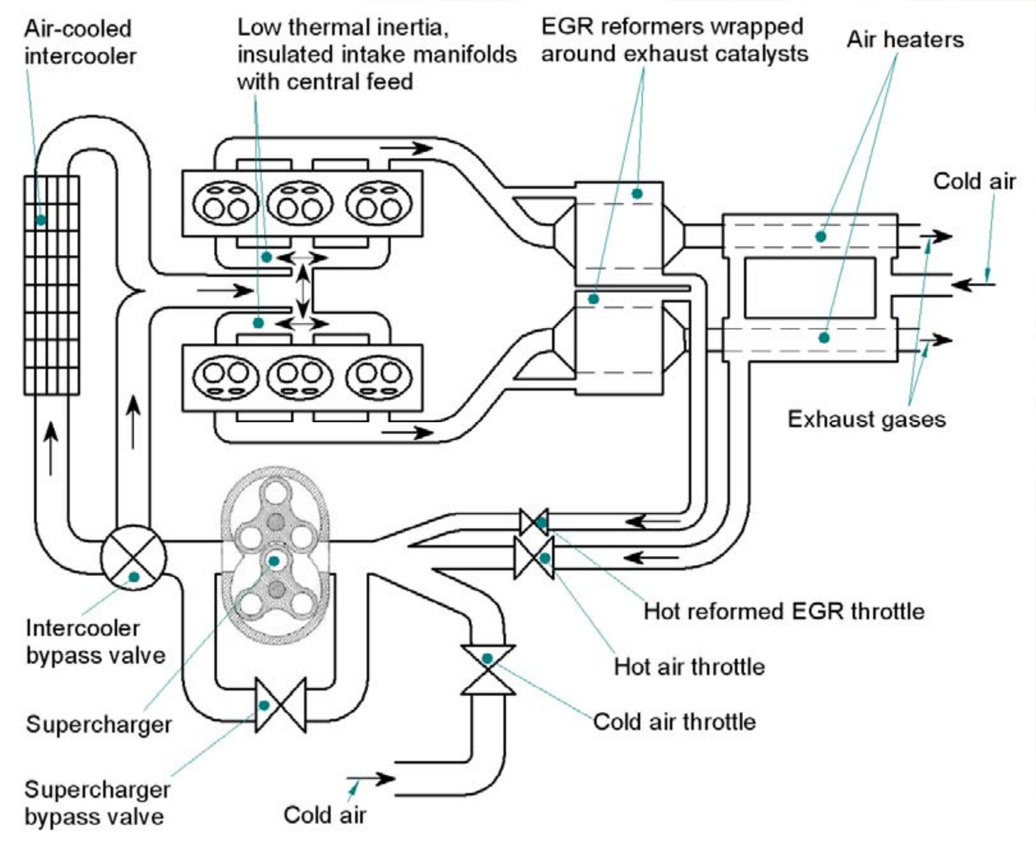
The thermodynamic work includes:

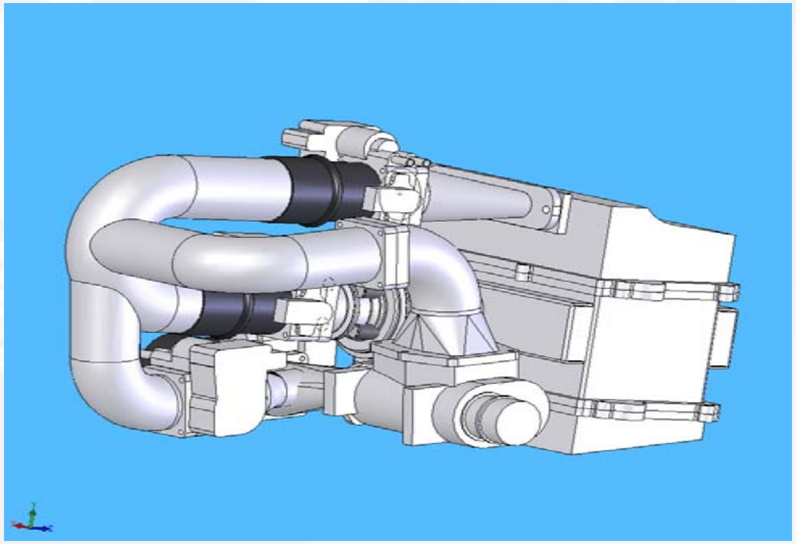
- System Modelling with respect to HCCI control.
- Model validation and adjustment regarding to components physical behaviour.
- Experimental work aiming for the extension of the operation envelope of HCCI.

Future aim is to include:

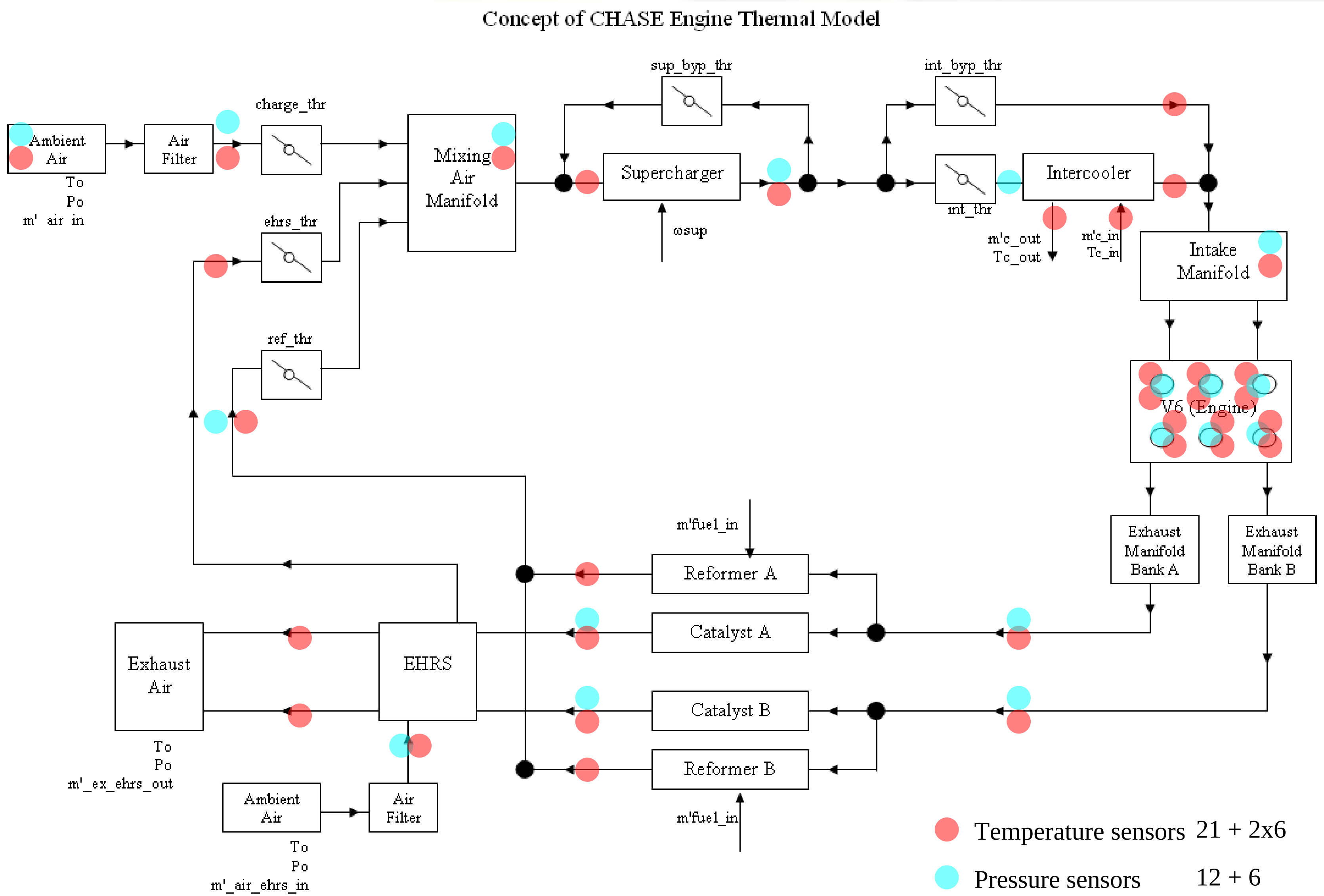
- Combination of heat flux availability from EGR, fuel reforming & exhaust after-treatment research work, done at Birmingham University.
- Include an HCCI heat release model (macro scale)

Thermal System





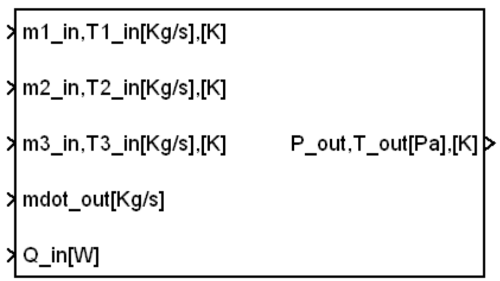
Experimental Layout



Modelling

Filling and Emptying Methods

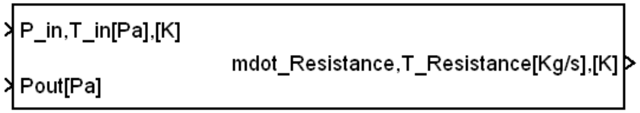
- In filling and emptying models the manifold (or sections of piping) are represented by finite volumes where the mass of gas can increase or decrease with time. Each volume is treated as an open system control volume which contains gas at a uniform state. To solve the problem the energy and mass conservation equations are applied..



Junction - Control Volume (P,T)

$$\frac{dT}{dt}=\frac{T\cdot R}{P\cdot V\cdot c_v}\left[\sum \dot{m}_{in}\cdot c_p\cdot T_{in}-\sum \dot{m}_{out}\cdot c_p\cdot T_{out}-c_v\cdot T\cdot\left(\sum \dot{m}_{in}-\sum \dot{m}_{out}\right)+\dot{Q}\right]$$

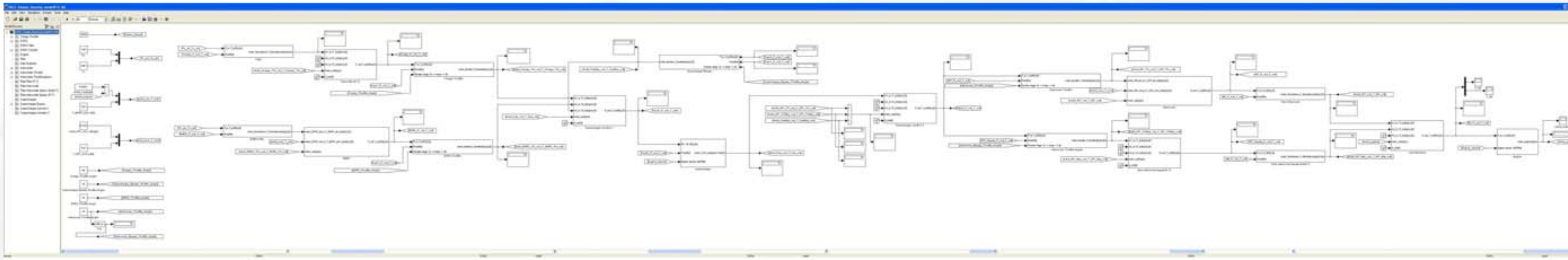
$$\frac{dP}{dt}=\frac{R}{V}\left[\left(\sum \dot{m}_{in}-\sum \dot{m}_{out}\right)\cdot T+\left(\frac{P\cdot V}{RT}\right)\cdot\frac{dT}{dt}\right]$$

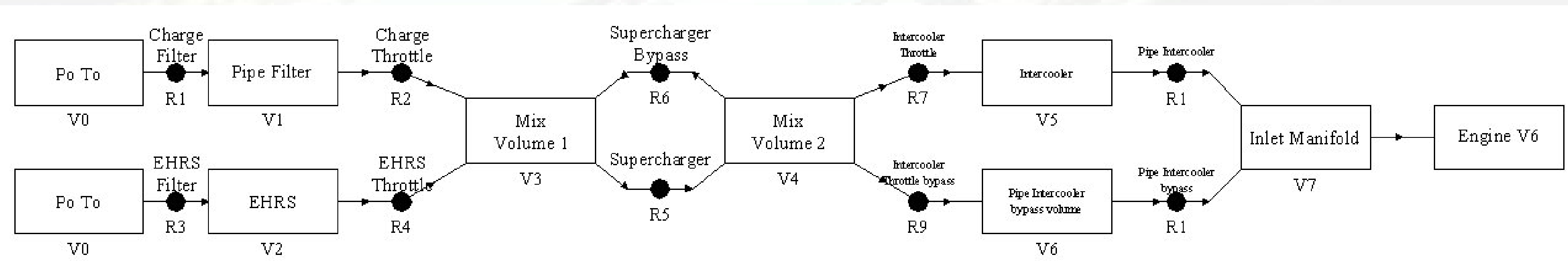


Filter - Restriction (mdot)

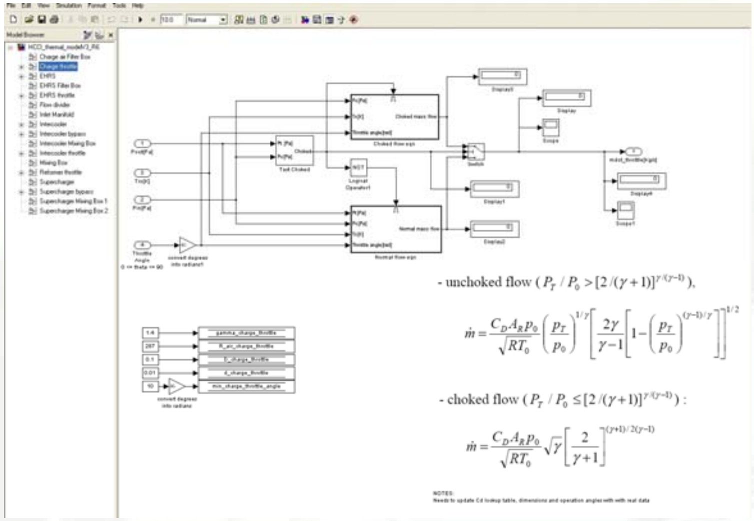
$$\Delta P=\frac{1}{2}\left(\frac{R\cdot T_{in}}{P_{in}}\right)\cdot\left(\frac{\lambda}{A_{in}^{2}}\right)_{const}\cdot\dot{m}^{2}$$

Simulink Model

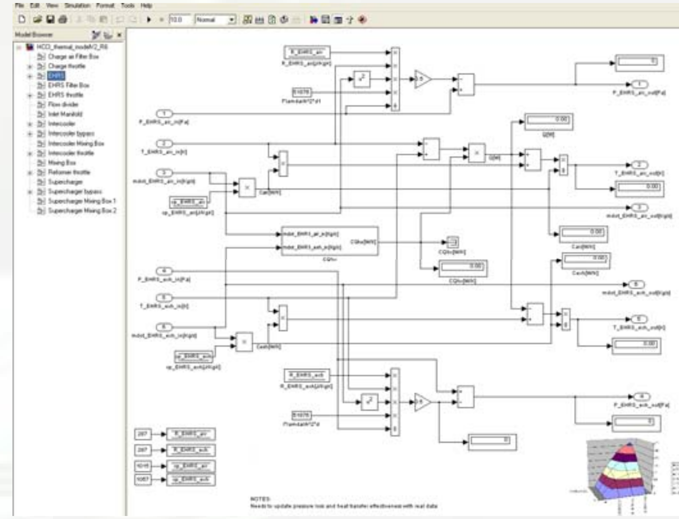




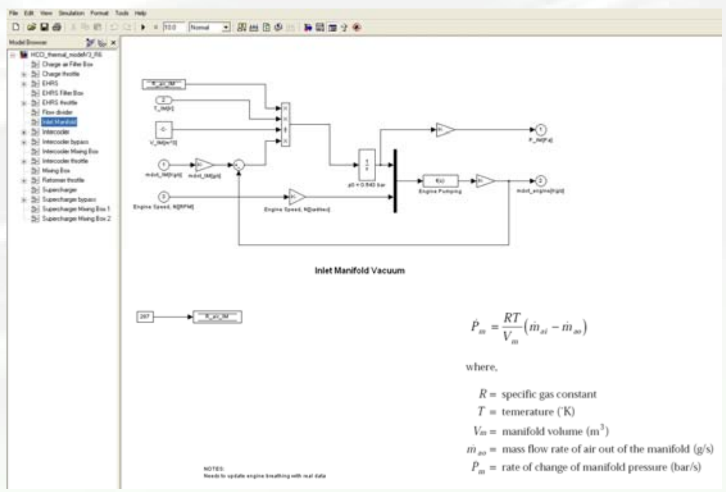
Subsystems



Throttle Model

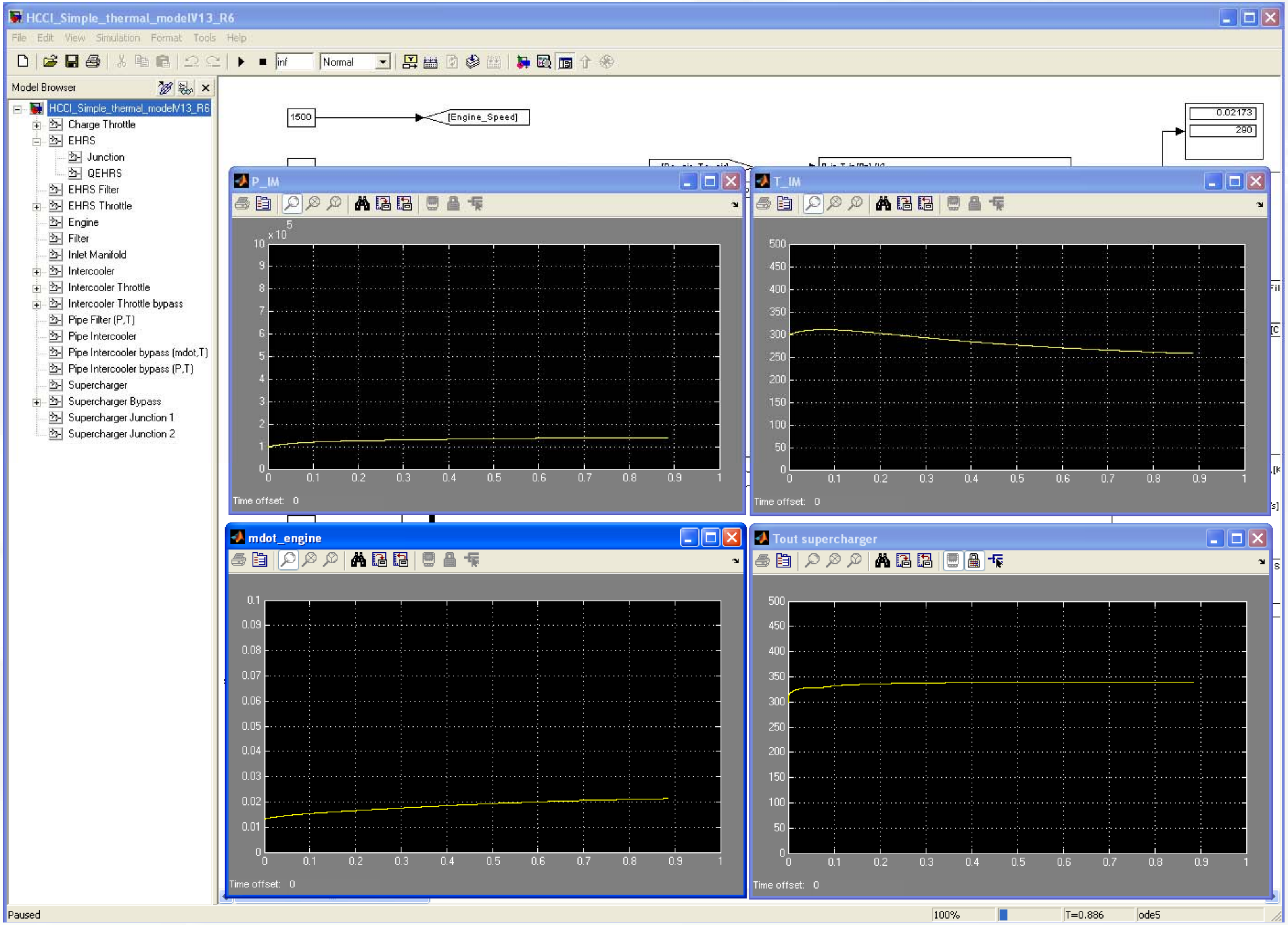


EHRS Model



Inlet Manifold Model

Preliminary Results



Tasks

- Modelling → Improve and validate
- Proceed with experiments ASAP

Acknowledgement

- Jaguar Cars
- Foresight Vehicle
- Johnson Matthey
- National Engineering Laboratories
- Race Technology
- Mass Spectrometry Instruments

Using Biodiesel in IC Engines

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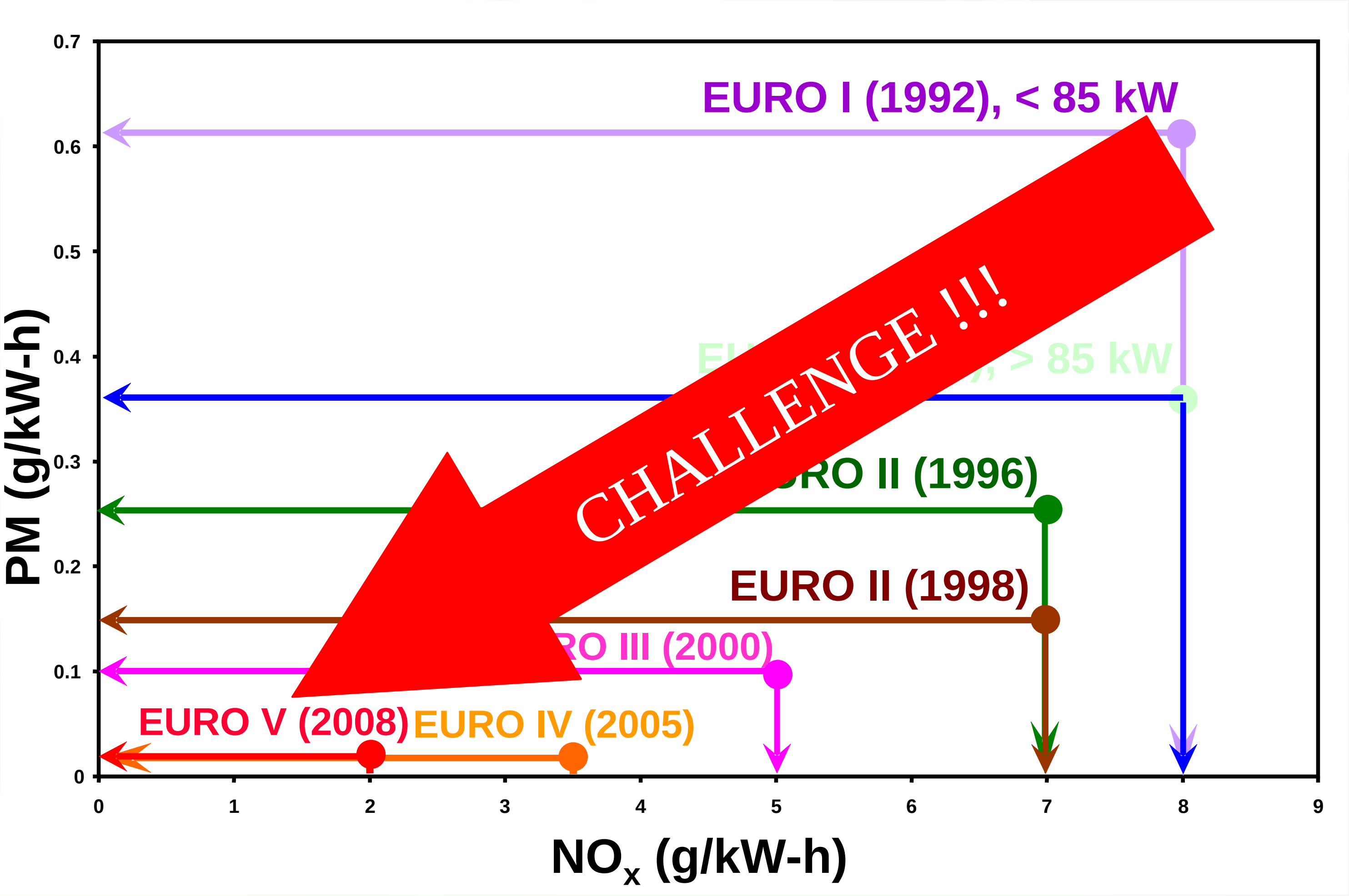
Motivation

- Recent interest in the use of biodiesel as a part-substitute for diesel fuel.
- There is a need to extend research on engine performance and emission effects of such fuels.
- To obtain the data required by motor industry.

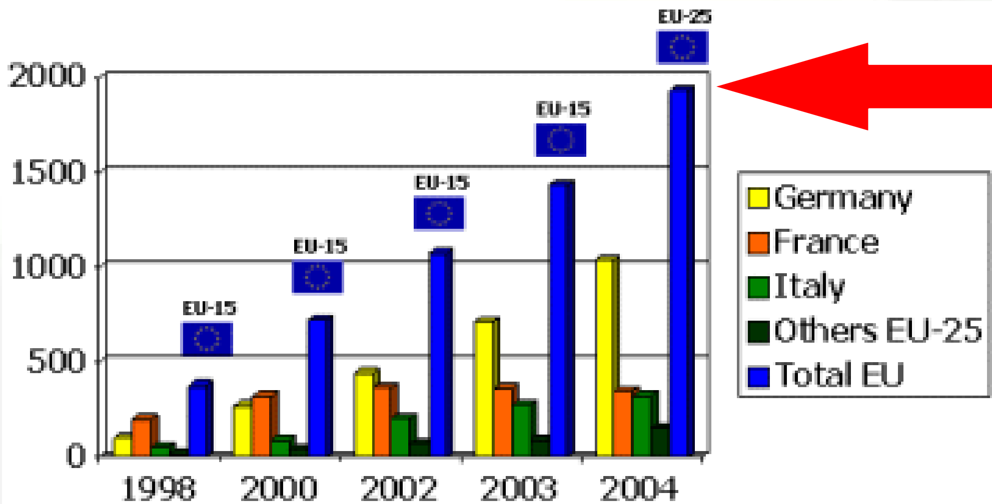
Why biodiesel?

- Environmental concerns on emissions from combustion of fossil fuel particularly in diesel-powered vehicles.
- Using biodiesel leads to lower net emission levels of greenhouse gases being released into the atmosphere.
- Continuous diminution of fossil fuel and fuel price crisis in the world.
- Abundance of raw materials for biodiesel production in the world, commonly rapeseed oil in Europe, soybean oil in North America, and palm oil in Southeast Asia.

The EU emission standards



EU biodiesel production capacity



Source: European Biodiesel Board www.ebb-eu.org

Close to 2 million tonnes were produced in 2004

The UK biofuels sales by month

Source: European Biodiesel Board www.ebb-eu.org

Month	Quantity (litres)
August – 2002	157,000
September	468,000
October	684,000
November	499,000
December	910,000
January - 2003	560,000
February	755,000
March	814,000
April	825,000
May	1,214,000
June	1,651,000
July	2,067,000
August	2,712,000
September	1,823,000
October	2,666,000
November	2,224,000
December	2,135,000
January -2004	1,037,000
February	1,893,000
March	1,308,000
April	1,441,000

Goals

To determine engine performance and exhaust gas emissions from the combustion of high proportion blends of biodiesel (i.e. RME) in conventional diesel fuel.

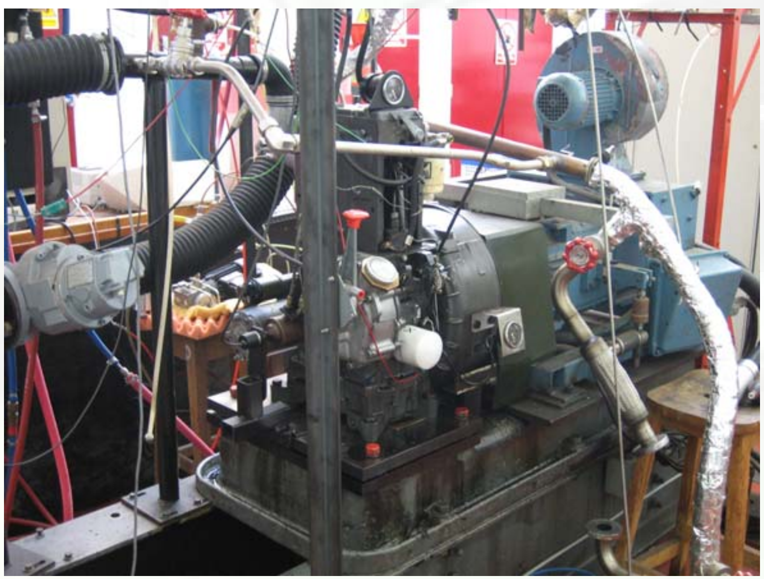
- Single- cylinder engine
- Multi- cylinder engine

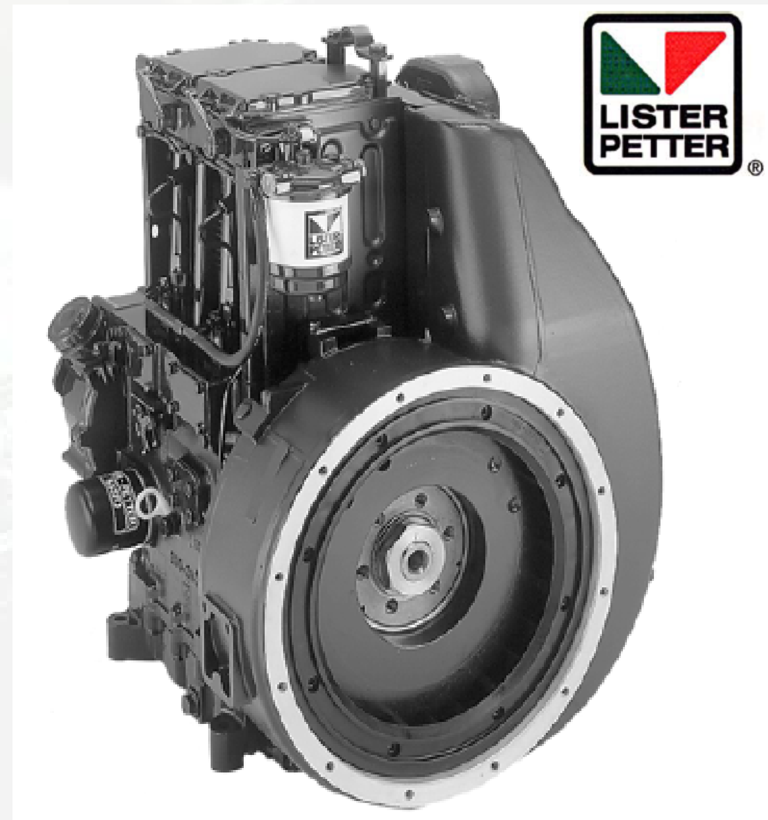
To investigate the injection strategies such as high pressure late fuel injection and controlled timing/quantity fuel injection for high proportion biodiesel blends.

To introduce the use of exhaust gas-assisted fuel reformer as an auxiliary emission control device for high proportion biodiesel blends.

Test engine

Engine: **Lister-Petter TR1**
Bore × stroke: **98.4mm × 101.6 mm**
Max. torque: **39.2 Nm @ 1800 rpm**
Max. power: **8.6 kW @ 2500 rpm**
Compression ratio: **15.5**



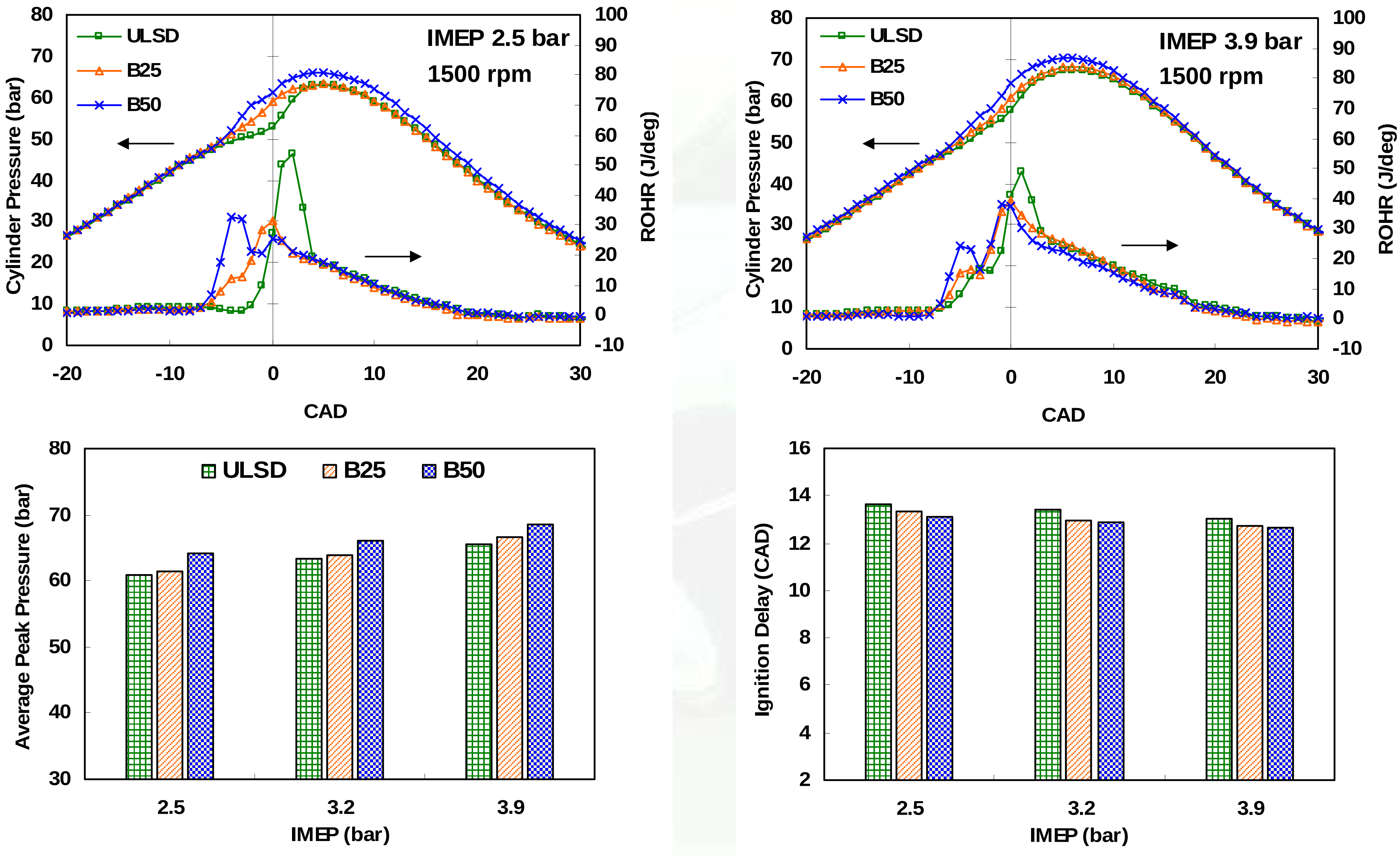


Fuel properties

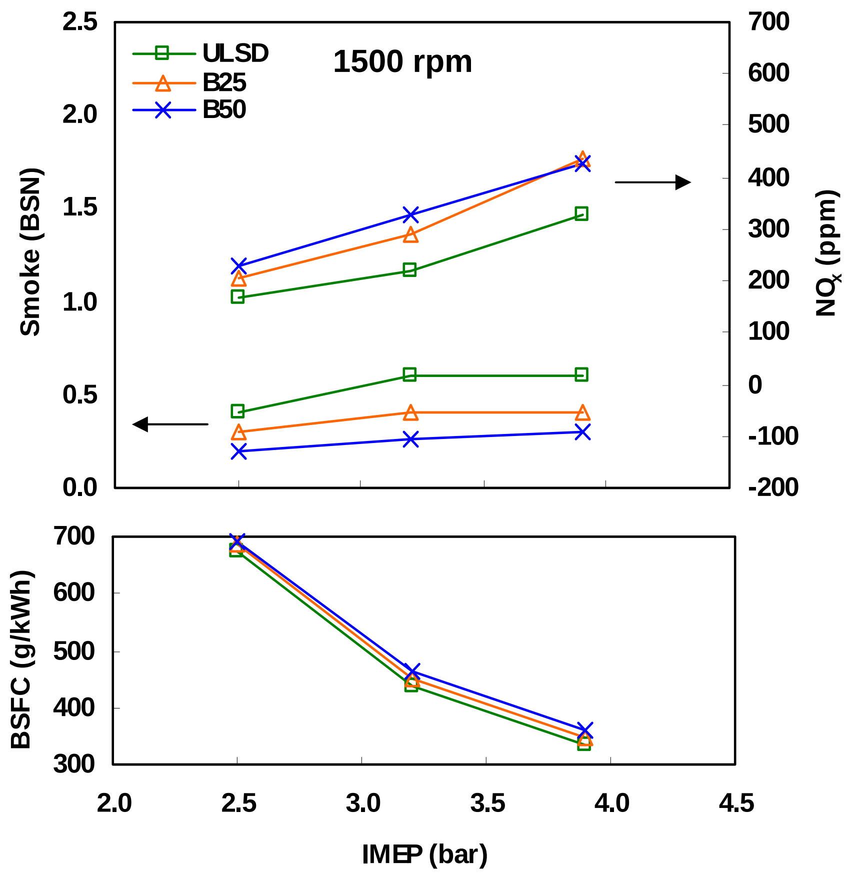
Fuel analysis	Method	ULSD*	RME*
Cetane number	ASTM D613	53.9	54.7
Density@15^{o}C (kg/m^{3})	ASTM D4052	827.1	883.7
Viscosity@40^{o}C (cSt)	ASTM D445	2.467	4.478
LCV (MJ/kg)		42.7	39
Sulphur (mg/kg)	ASTM D2622	46	5
Total aromatic (wt%)		24.4	32.1
Molecular weight		209	296
C (wt%)		86.5	77.2
H (wt%)		13.5	12.0
O (wt%)		-	10.8
Fuel standard		EN590	EN14214

(*) A.Tsolakis and A.Megaritis, ***Biomass and Bioenergy***, 2004, 27: p.493-505.

Results from 1- cylinder engine



Chuepeng et al, SAE 2007-01-0072



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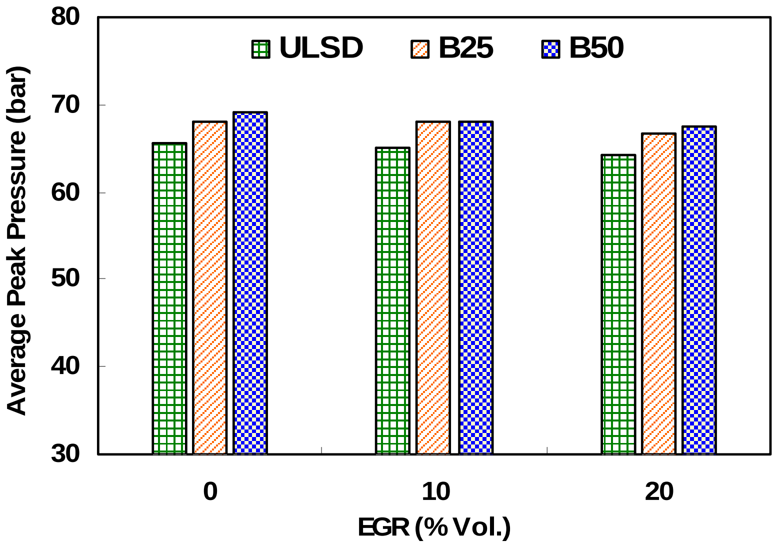
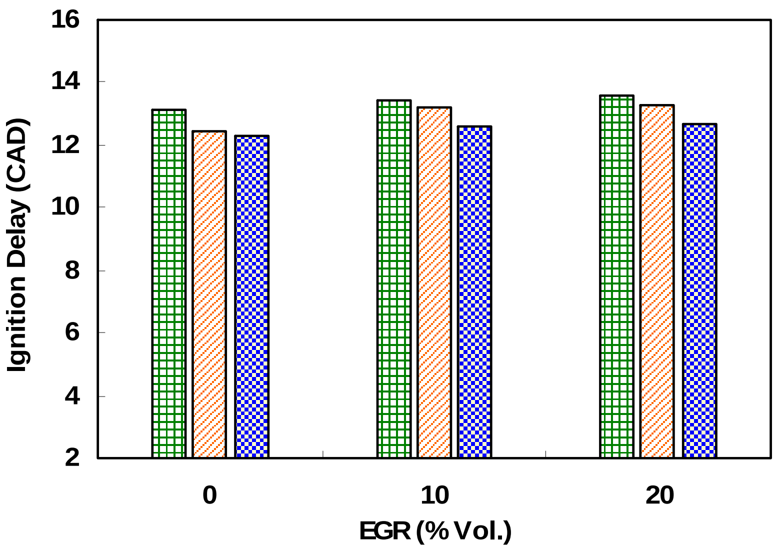
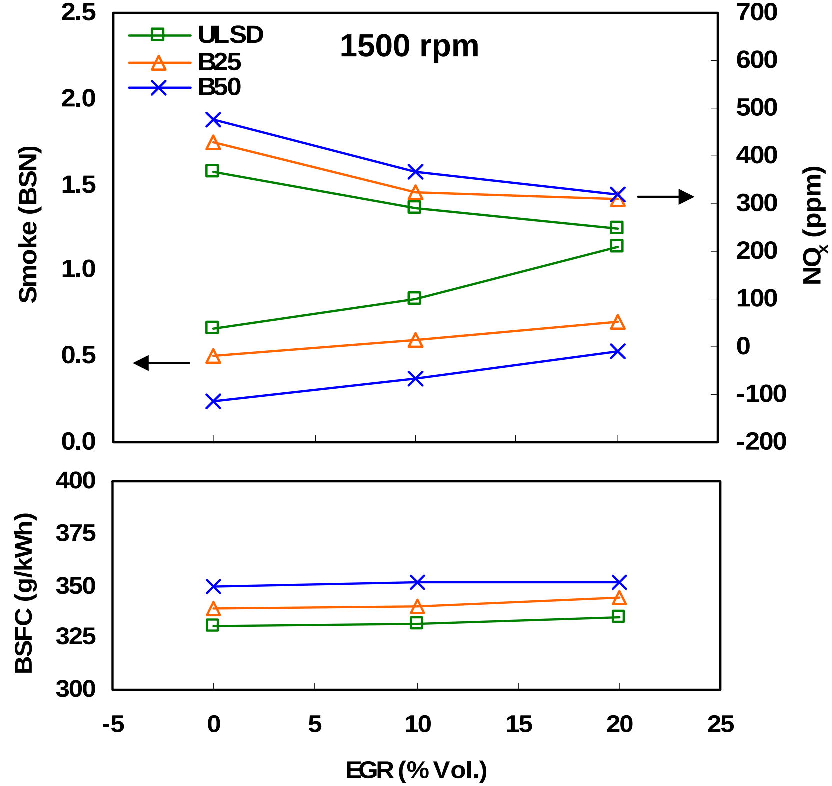
Effects of EGR







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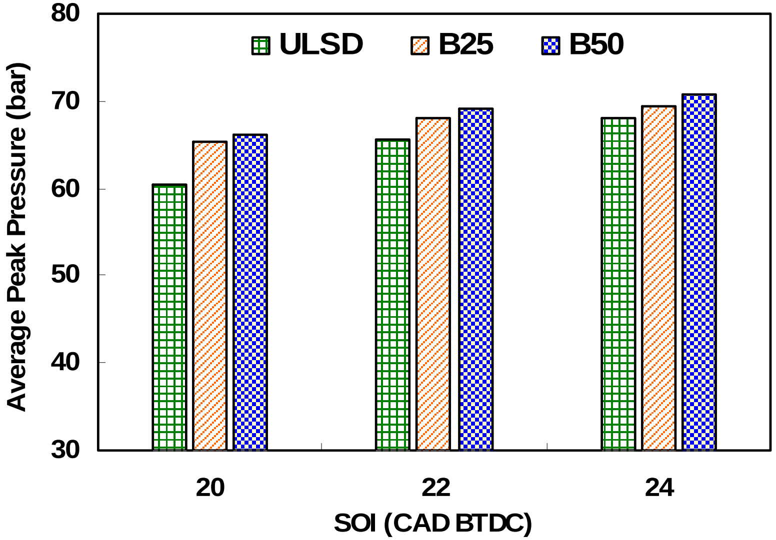
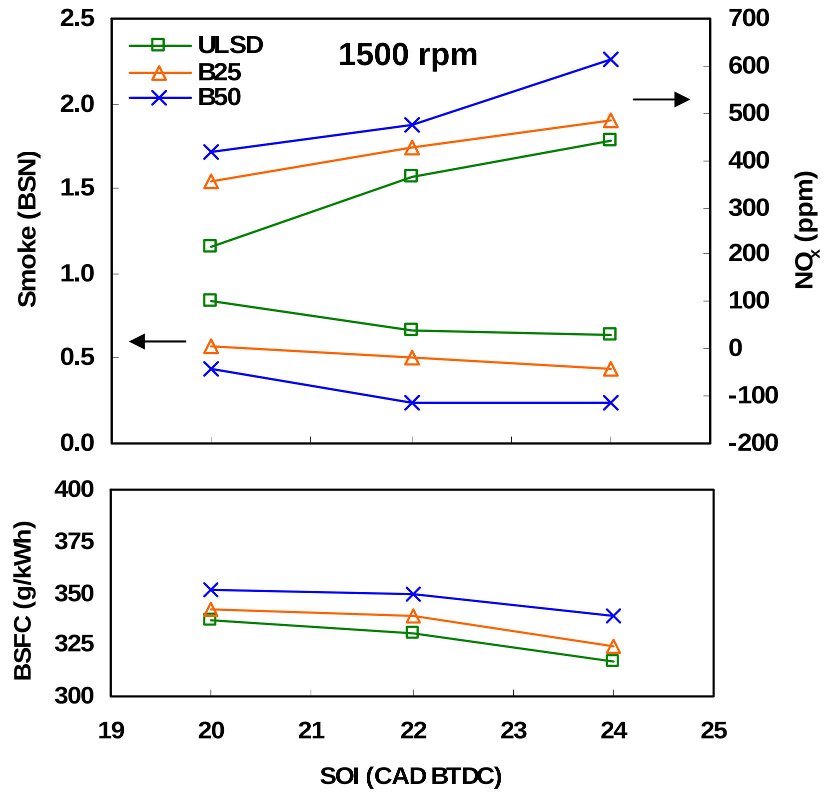
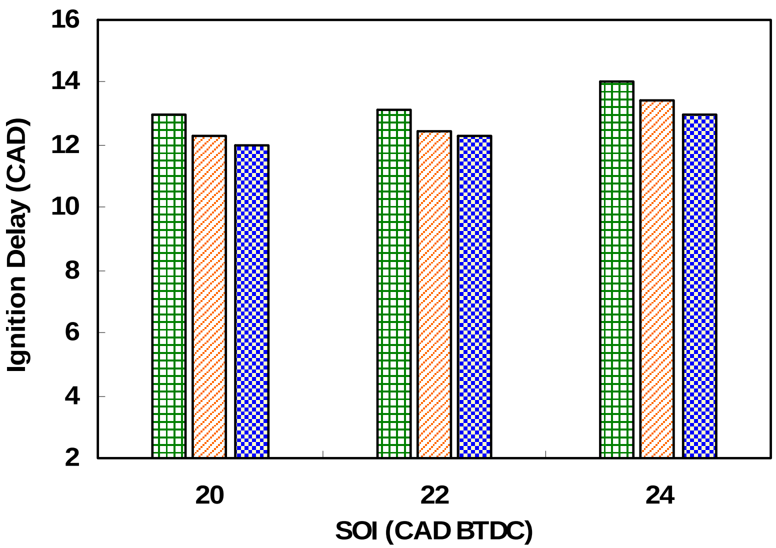
Effects of injection timing







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Summary

- Basically, in unmodified diesel engine equipped with pump-line-nozzle fuel injection system, the use of high proportion RME blends is shown to increase NO_x emissions, reduce smoke, and consume larger amount of fuel.

- For the same engine load, the higher proportion RME blends resulted in an increased proportion of the fuel burnt in premixed phase while combustion is advanced to earlier crank angle positions, with shortened ignition delay and increased peak cylinder pressure. These can also be observed with different load conditions.

- Increasing the EGR rate appeared to reduce peak pressure slightly and increase ignition delay. Similar trends can also be observed with all tested fuels.

- The application of higher EGR rate resulted in lower NO_x emissions, increased smoke, and slightly increased fuel consumption with all tested fuel blends.

- When running the engine with the same blended fuel, the retarded SOI resulted in lower peak pressure and shorter ignition delay for all tested fuels, and the adversed effects were observed with advanced SOI.

- The retarded SOI yielded a reduction in NO_x emissions but increase of smoke and fuel consumption.

Acknowledgement

- **The Royal Thai Government (full scholarship)**
- **Shell Global Solutions (UK)**

Discussion

- **Comments & suggestions?**

Thank you for attention