UNIVERSITY OF BIRMINGHAM

Future Engines & Fuels Laboratory

Ritchie Daniel, Chongming Wang, Prof Hongming Xu, Prof Miroslaw Wyszynski

Combustion and Emissions of bio-fuel in an SI Engine

Instrumentation

The Medusa Engine (Figure 1) is a single cylinder 4-stroke gasoline engine which was manufactured in-house. Currently using a Jaguar spray guided Direct Injection cylinder head from the AJ 133 production V8 engine. This thermal engine is used to examine combustion and emissions performance using a variety of instruments.

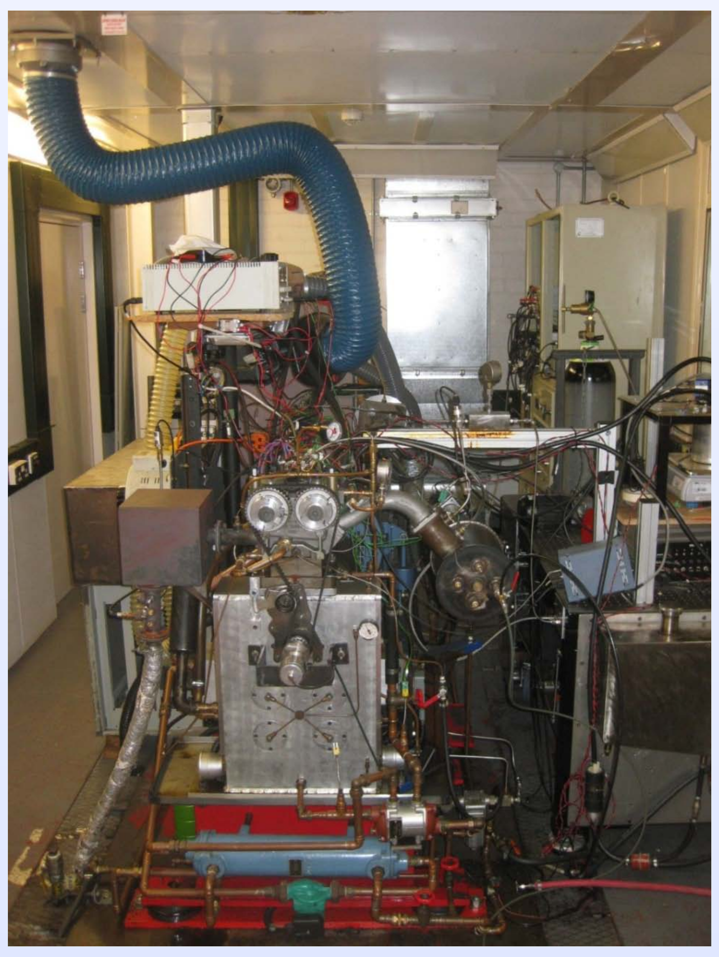

Figure 1

Single-cylinder Research Engine Facility

The key features of this engine include:

- Direct and Port fuel injection independently or simultaneously.
- Each injection system has its own fuel tank so that two different fuels can be run.
- Variable Valve Timing (VVT) technology is available on both camshafts.
- Adjustable compression ratio.
- Can be run in spark-ignition (SI) mode or homogenous charge compression ignition (HCCI) mode.

The Medusa engine benefits from advanced engine technology. The BOSCH spray guided injector (Figure 2) uses 6-holes with varying spray angle to disperse the fuel efficiently.

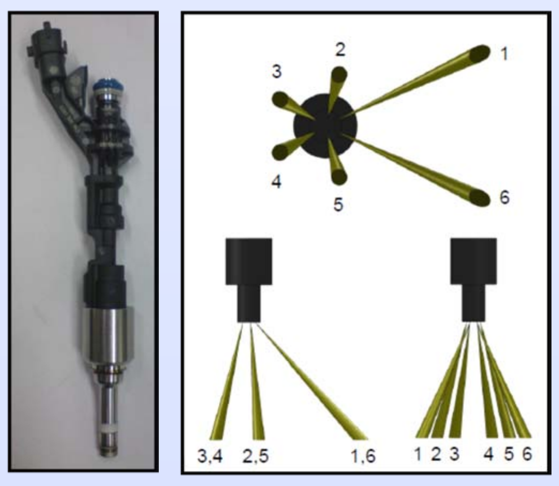

Figure 2

GDI Injector and Configuration

The injector is centrally mounted, with the spark hole being mounted beside the injector at 18° to the cylinder axis, as shown in Figure 3.

The spray plumes consist of two groups of three holes, with the line of symmetry coinciding with the crankshaft axis. Spray plumes 1 and 6 pass either side of the spark plug. The injector is purged using nitrogen each time the fuel is changed.

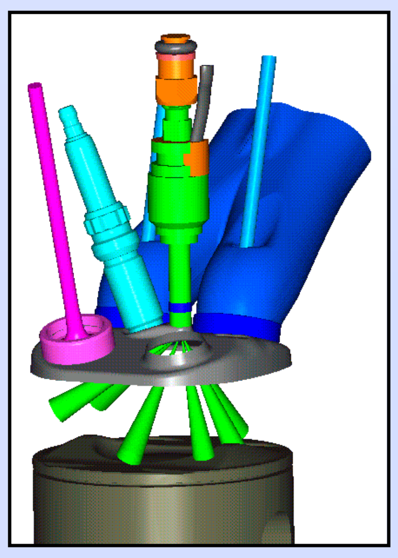

Figure 3

Layout of Combustion System

Table 1

Single-cylinder Engine Specification

Engine Type	4-Stroke, 4-Valve
Combustion System	Spray Guided DISI
Swept Volume	565.6cm^3
Bore x Stroke	90 x 88.9mm
Compression Ratio	11.5:1
Engine Speed	1500rpm
Injector	Multi-hole Nozzle
Fuel Pressure and Timing	150bar, 280º bTDC
Intake Valve Opening	16º bTDC
Exhaust Valve Closing	36º aTDC

Table 1 shows the standard operating conditions. The following parameters can be varied in real-time:

- Air mass flow, using the throttle
- Start of injection and ignition timing
- Valve opening timing (fixed duration)

Test Fuels

The single-cylinder gasoline engine is compatible with various biofuels, which help to understand the influence of blends and to reduce dependency on gasoline (ULG).

Short- to mid-term solution for solving the concerns of global warming. 2,5-dimethylfuran (DMF) is a promising biofuel.

Figure 4

Liquid Samples of DMF, Ethanol and Gasoline

Table 2

Physical and Chemical Properties of the three Fuels

	DMF	Ethanol	Gasoline
Chemical Formula	C_6H_8O	C_2H_6O	C_2-C_{14}
H/C Ratio	1.333	3	1.795
O/C Ratio	0.167	0.5	0
Gravimetric Oxygen Content (%)	16.67	34.78	0
Density @ 20ºC (kg/m3)	889.7*	790.9*	744.6
Research Octane Number (RON)	n/a	106	96.8
Stoichiometric Air-fuel Ratio	10.72	8.95	14.46
LHV (MJ/kg)	33.7*	26.9*	42.9
LHV (MJ/L)	30*	21.3*	31.9
Heat of Vaporization (kJ/kg)	332	840	373
Initial Boiling Point (ºC)	92	78.4	32.8

Engine Combustion and Emissions

The Medusa engine is used to study the combustion and emissions performance of any gasoline alternative fuel using the GDI or PFI injection system. After several hours of running components can be checked for deposit formation. Other areas of interest include:

Monitoring spark sweeps to find MBT

Emissions measurements to monitor HCs and NOx.

Particulate matter (PM) measurements.

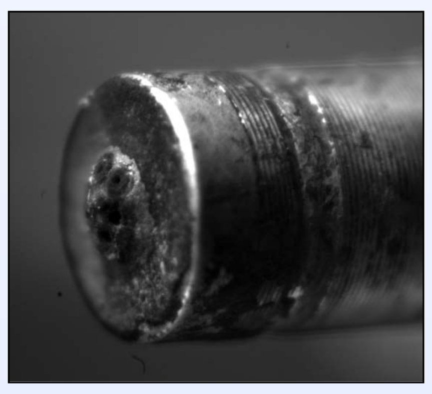

Figure 5

GDI Injector Tip Deposits

Using the raw signals from the in-house LABVIEW code, the combustion and emissions data is then interpreted using an in-house MATLAB script.

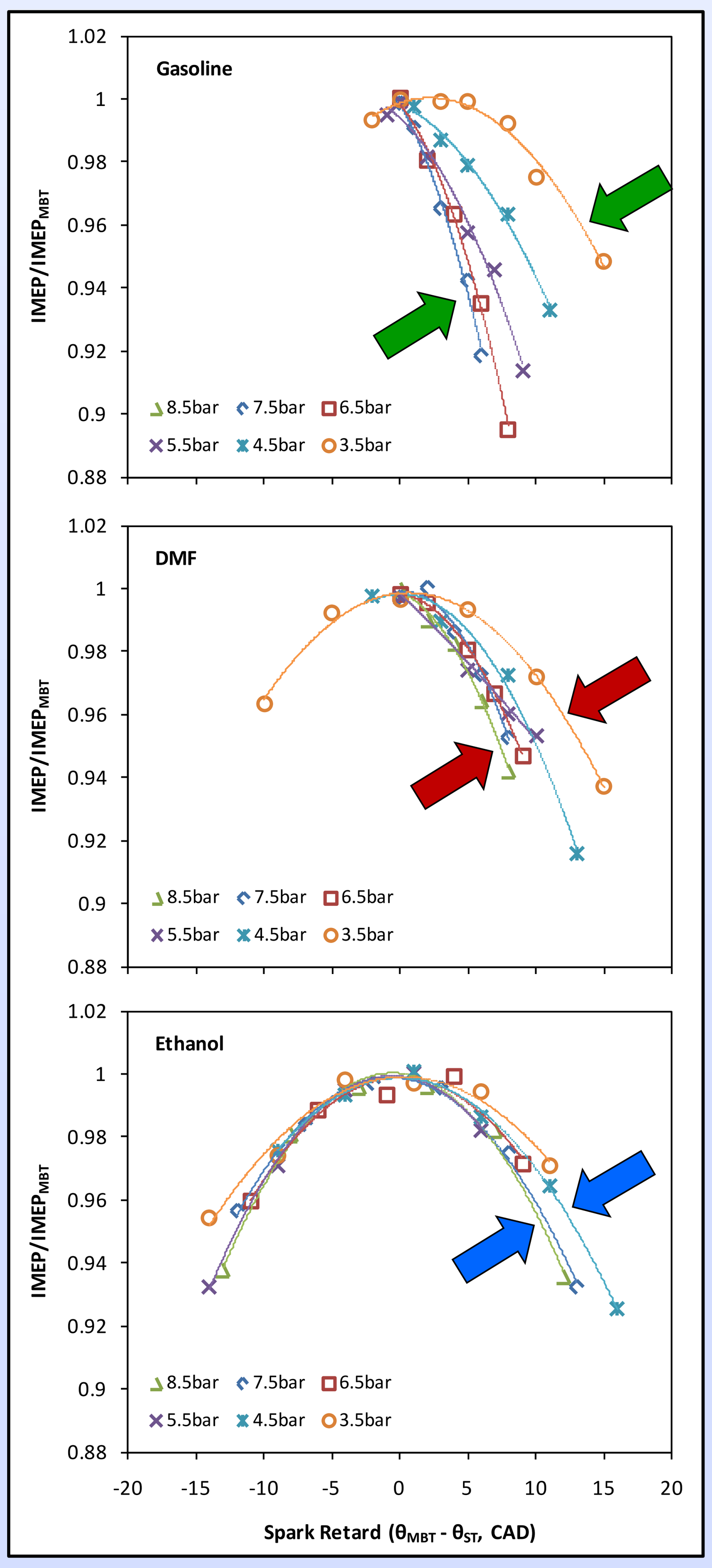

Figure 6

Effect of Spark Retard on Normalized IMEP at various Engine Loads

Reducing spark 'sensitivity'

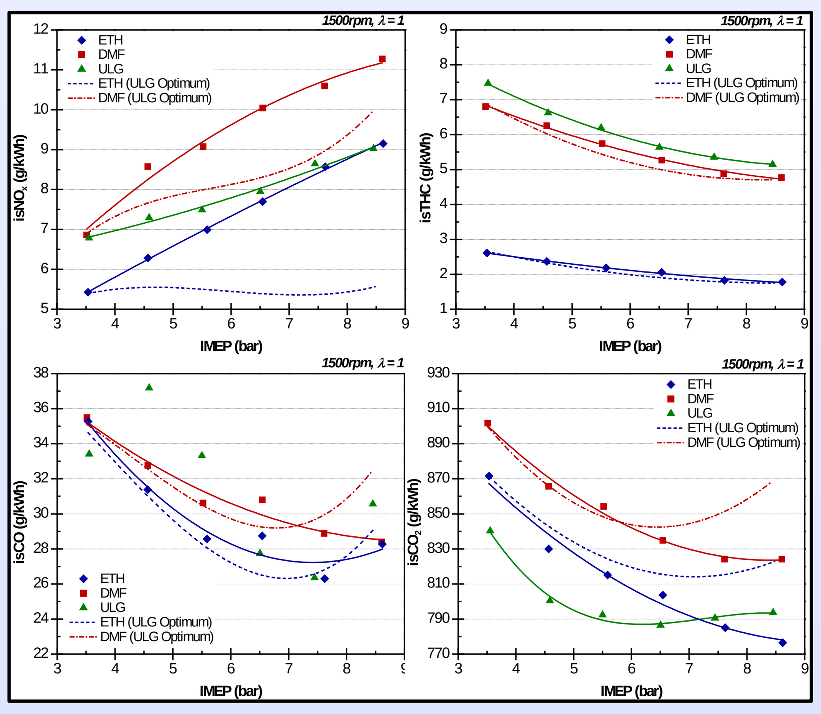

Figure 7

PM Distributions at 3.5bar IMEP and Gasoline Optimised Spark Timing

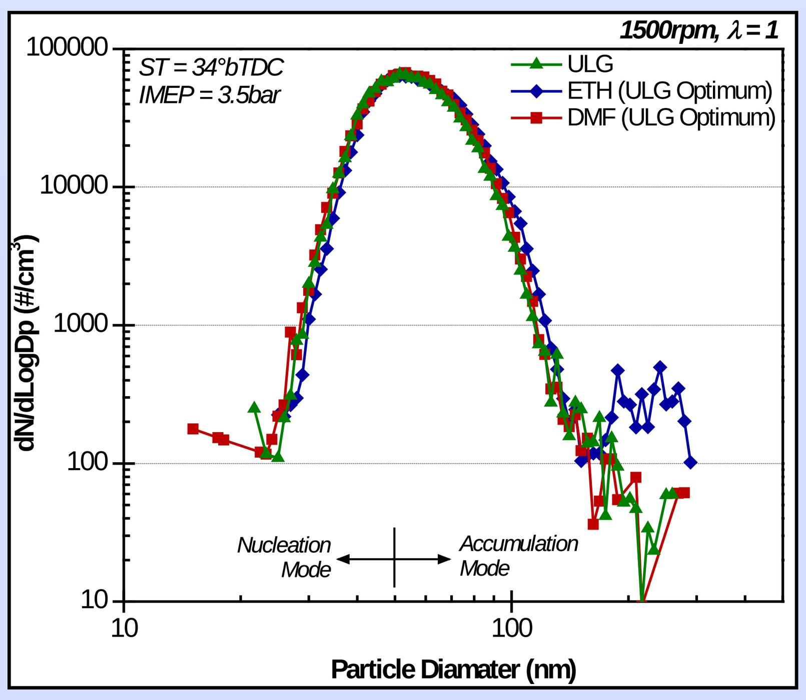

Figure 8

Effect of SR10 (10CAD Spark Retard) on Normalized IMEP at various Engine Loads

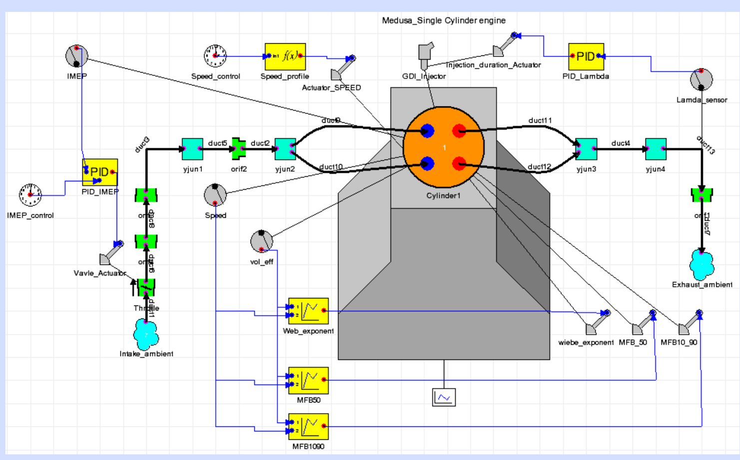

Figure 9

Ricardo Wave Simulation

Figure 10

Horiba-MEXA 7100DEGR and 1230

Publications

1. Combustion and Emissions of 2,5-Dimethylfuran in a Direct-Injection Spark-Ignition Engine Shaohua Zhong, Ritchie Daniel, Hongming Xu, Jun Zhang, Dale Turner, Miroslaw L. Wyszynski and Paul Richards. Energy and Fuels, 2010, 24(5), pp 2891-2899.
2. Laminar Burning Velocities of 2,5-Dimethylfuran Compared with Ethanol and Gasoline Guohong Tian, Ritchie Daniel, Haiying Li, Hongming Xu, Shijing Shuai and Paul Richards. Energy and Fuels, 2010, 24(7), pp 3898-3905.
3. Effect of Spark Timing and Load on a DISI Engine Fuelled with 2,5-Dimethylfuran Ritchie Daniel, Guohong Tian, Hongming Xu, Miroslaw L. Wyszynski, Xuesong Wu and Zuohua Huang. Fuel, 2011, 90(2), pp 449-458.
4. Spray Characteristics study of DMF Using Phase Doppler Particle Analyzer Guohong Tian, Haiying Li, Hongming Xu, Yanfei Li and Satish Mohan Raj. SAE Int. J. Passeng. Cars – Mech. Syst., 2010, 3(1), pp 948-958.
5. Dual-injection: The Flexible, Bi-fuel Concept for Spark-ignition Engines Fuelled with various Gasoline and Biofuel Blends Xuesong Wu, Ritchie Daniel, Guohong Tian, Hongming Xu, Zuohua Huang and Dave Richardson. Applied Energy, 2011, Article In Press.
6. DMF – a New Biofuel Candidate Guohong Tian, Ritchie Daniel and Hongming Xu, Biofuel, InTech, ISBN 978-953-307-178-7, Article In Press.