Optical Rapid Compression Machine Test Facilities at Advanced Engineering Centre, University of Brighton

Vikas Sharma, Guillaume de Sercey, Angad Panesar and Steven Begg

MariNH3 Clean, green ammonia engines for maritime

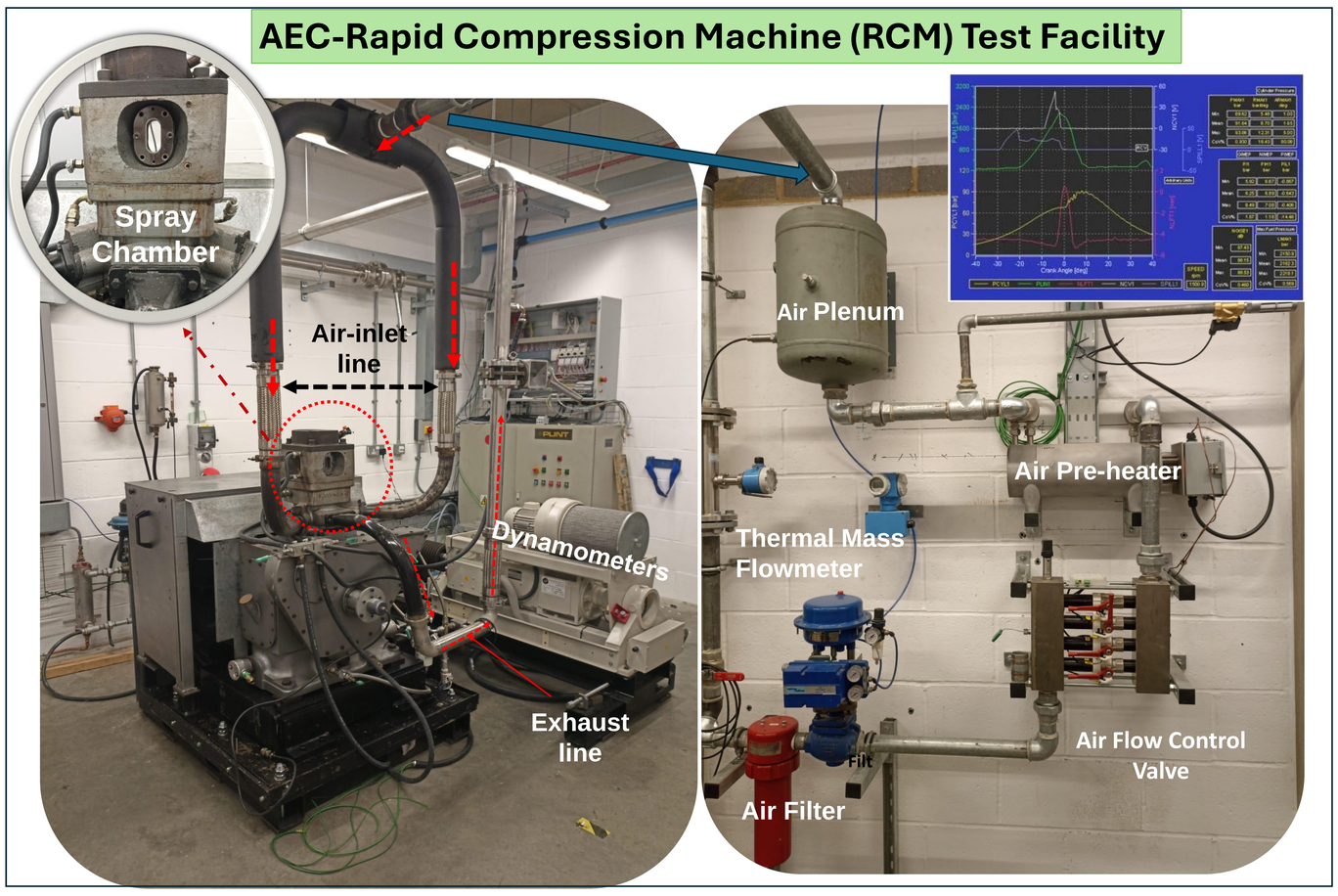
University of Brighton

Advanced Engineering Centre

Summary:

- Rapid Compression Machines (RCMs) widely used to study engine sprays and combustion under controlled, repeatable thermodynamic conditions.
- Application of optical diagnostics enables investigations of spray characteristics, fuel-air mixing, ignition, flame and formation of emissions.
- Research focussed on the investigation of zero and low carbon fuel sprays and combustion such as methanol, ammonia and hydrogen.
- The RCM is a flexible tool for the development and validation of computational models essential in advancing cleaner combustion technologies.
- **The AEC-RCM at Brighton is a highly configurable, 2-stroke single cylinder, loop scavenged design based upon the Ricardo Proteus engine platform.**

AEC-Rapid Compression Machine (RCM) Test Facility



AEC-RCM Specifications

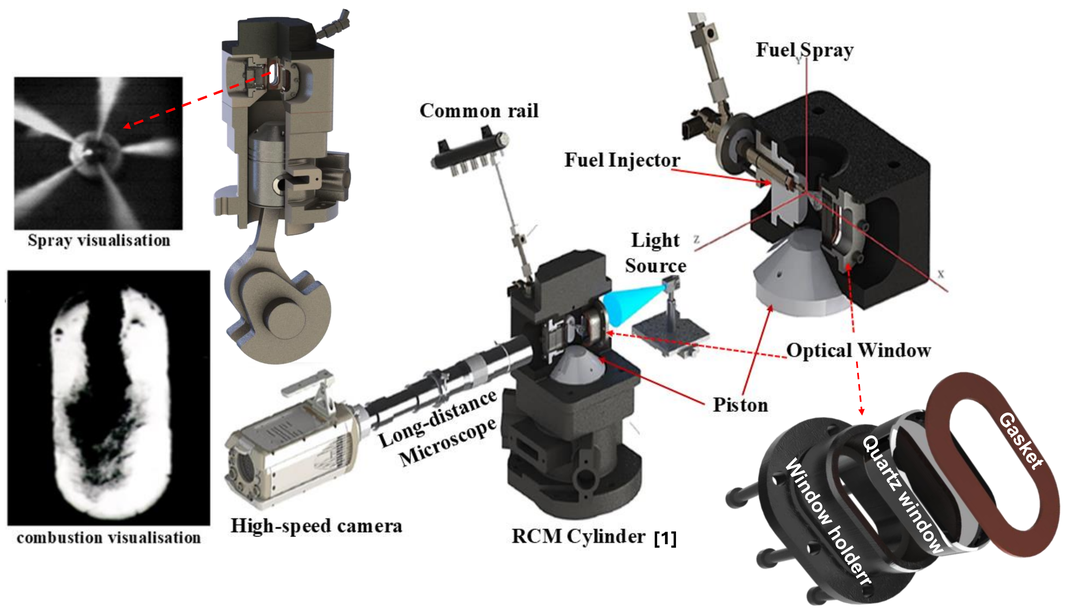
Parameter	Value	Unit
Cylinder	1	
Cycle/Strokes	2	
Bore	13.5	cm
Stroke	15	cm
Compression ratio	9:1	
Engine displacement volume	220	cm^3
Engine speed	500	rpm
Intake boost pressure	1-10	bar

- Provides fundamental data for light-duty scale engines
- Equipped with industry standard instrumentation for control and data acquisition for combustion system analysis.

- **<u>In-cylinder conditions</u>**
  - Maximum intake air temperature 373 K
  - Maximum 120 bar peak pressure at TDC
  - 540-850 K estimated temperature range at TDC
  - Quiescent air motion at start of injection (no swirl)
  - Variable back pressure can retain residuals

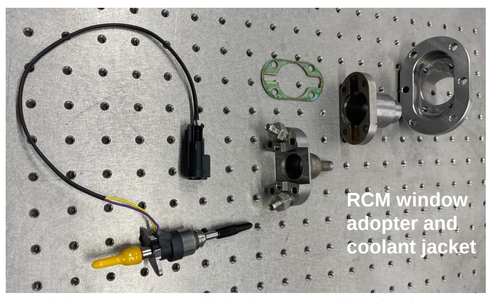
- Independent control of the operating parameters of the RCM such as boost and back pressure and temperature, engine speed, fuel injection and ignition equipment etc. remove the complexities of full engine systems. Several designs are available for both DI and PFI operation along with flexibility for modifications.
- The combustion chamber comprises a top-hat design with 4 optical access quartz and sapphire windows (51 mm H x 23 mm W) suitable for experimental observations at AEC, Brighton including high-speed shadowgraphy, and Schlieren, Mie scattering, TR-PIV (50 kHz), LIP, LDA, PDA, TR-PLIF (10kHz, fuel, NO, OH), LII, chemiluminescence, high speed thermal imaging (580 kHz).

Examples of Setups for Optical Diagnostics

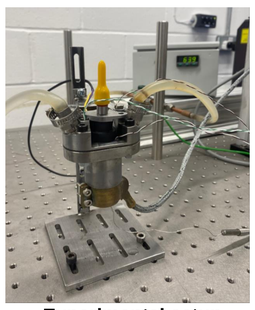


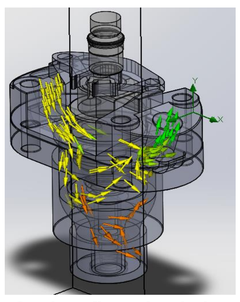
Injector Tip Temperature Control

- Injector controlled temperature bath
  - Investigate injector tip temperature effects on spray breakup
  - Low Pressure Chamber to induce flashing (<500 mbarA)
  - Thermal imaging study of tip temperature (Telops IR FAST M1k)
  - RCM window adapter incorporates coolant jacket
  - Experiments confirm design fit for purpose

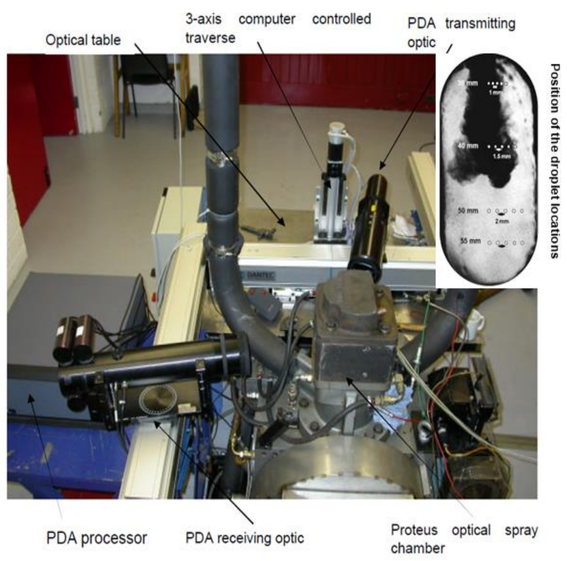


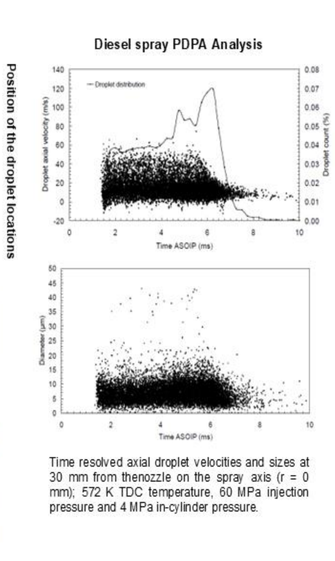
ECN spray G multi hole DI gasoline (M8)


Experimental setup


Coolant flow simulation

Example of Phase Doppler Anemometry Set-up



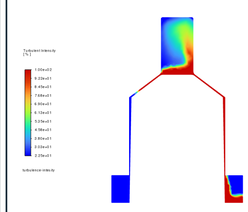


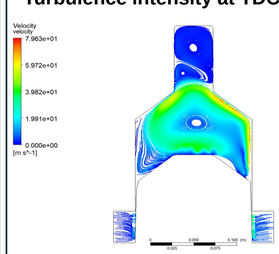
Time resolved axial droplet velocities and sizes at 30 mm from thenozzle on the spray axis (r = 0 mm); 572 K TDC temperature, 60 MPa injection pressure and 4 MPa in-cylinder pressure.

RCM with Traversing PDA Setup using Brewster's Angle Cylinder Head [2]

RCM CFD

- 2D modelling for investigation of liquid and gas injection and mixing.
- Investigation of geometries to augment air turbulence for enhanced mixing.


Turbulence intensity at TDC


Velocity streamline

Conclusion

- The Advanced Engineering Centre RCM (AEC-RCM) at the University of Brighton has over 30 years' experience conducting experiments in optical engines with a wide-range of academic and industrial collaborators.
- The AEC-RCM is a tool for evaluating teh performance of alternative fuels such as hydrogen, ammonia, or bio-derived fuels, that exhibit different spray and combustion properties compared to conventional hydrocarbons.
- Operating conditions at end of compression mimic typical engine operating cycles.
- Optical access in the RCM allows for the study of the following:
  - Fuel atomisation and spray penetration.
  - Droplet diameter and vaporisation rate.
  - In-cylinder gas dynamics and turbulence effects.
  - Ignition delay, flame development, propagation & combustion.
  - Emissions formation & combustion products.
- The insights gained from these measurements support R&D of fuel injection strategies, combustion modelling, and emission reduction technologies for next generation fuels.

<u>References</u>
[1] Ref: Viacheslav Stetsyuk et al., 2015 presentation
[2] Ref: LACOSTE Julien PhD Thesis 2006

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Dr Vikas Sharma, PhD, AMCI, AMEI
Research Fellow
Advanced Engineering centre
University of Brighton
Email: v.sharma2@brighton.ac.uk

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