OPTICAL TECHNIQUES THAT CAN BE APPLIED TO INVESTIGATE GDI ENGINE COMBUSTION

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ICE 2017 – 13th International Conference on Engines & Vehicles
Overview

SAE 2009-01-1060
### Single Cylinder Engine with Optical Access

- **Bore**: 89 mm
- **Stroke**: 90 mm
- **Capacity**: 562 cc
- **Compression Ratio**: 11.1
- **Injection Pressure**: 150 bar

High Speed Imaging – Bowditch Piston

• Photron FASTCAM-1024PCI model

100K Colour Camera

• Resolution: 1024x1024 pixels
Selection of Spray Images at 20° C

- Variation of the spray area at 3° after SOI is due to shot-to-shot variations in injection;
- Spray area and evaporation duration increase as the ethanol content increases.
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Semi-Quantitative Data from Mie Scattering

- In general, warm fuel plumes exhibit smaller integrated pixel values than cold plumes;
- The evaporation duration of warm plumes is shorter than for cold plumes;
- The spray duration increases as the ethanol content increases;
- Standard deviations in the ‘plateau’ region are always smaller than at both ends.

Soot Pyrometry

\[ I_{\lambda b} = \frac{2C_1}{\lambda^5 \left[ \exp \left( \frac{C_2}{\lambda T} \right) - 1 \right]} \]

Black Body Radiation, \( C_1, C_2 \) are Planck’s constants

\[ \varepsilon_\lambda = 1 - \exp \left( -KL/\lambda^\alpha \right) \]

\( K \) is the absorption coefficient per unit flame thickness, and \( L \) is the geometric flame thickness along the optical path length of the detection system.

Hottel and Broughton: \( \alpha = 1.39 \).
Three-Colour Pyrometry

Bayer Colour Filter Array

Colour Filter Array Calibration Procedure

Colour Filter Array Calibration

Blue Filter

Integrate: $\int$Blue, $\int$Green, $\int$Red

Toluene, Lambda = 0.9
Fringe spacing: \( \Lambda = \frac{\lambda}{2 \sin(\theta/2)} \)

Bragg Angle: \( \theta_B = \sin^{-1}\left(\frac{\lambda_p}{2\Lambda}\right) \)

\( f_{osc} = \frac{c_S}{\Lambda} \quad c_s = \left(\frac{\gamma R_o T}{M}\right)^{1/2} \)

Spray Imaging

Calibration Loop

Sequence of PLIF images - evolution of the fuel distribution with crank angle and fuel fraction. The late injection timing for this sequence was 140 BTDC. Each image is an average of 32 single shots.

Two Colour PLIF (T-PLIF) Combined with LI(T)GS

T-PLIF:- Frequency quadrupled Nd:YAG 266 nm

Number of photons absorbed Optical efficiency Fluorescence quantum efficiency

$$S_1 = \frac{N(\gamma) \sigma_{abs} \eta_{opt1} \phi_1}{S_2} = \frac{N(\gamma) \sigma_{abs} \eta_{opt2} \phi_2}$$

Vertical distance, mm

(a) Horizontal distance, mm
Two Colour PLIF (T-PLIF)

20 sequential LIGS signals at crank angles between 90° and 50° BTDC at intervals of 10°
Conclusions

• High Speed Videoing
  o Cameras are becoming faster, more sensitive, with greater resolution and a larger dynamic range
  o LED illumination is readily controllable and low cost
  o Computing resources (hardware and software) continue to improve

• Laser-Based Techniques
  o Lasers are reducing in cost and size
  o Lasers are becoming faster, and more powerful
  o Companies offer turn-key solutions with dedicated software
    o But applications to engines are not always straightforward

• Optical access engines will continue to be important for the validation of computer modelling
Any Questions?
Catalyst Light-Off Strategy

• 80% of Emissions Occur During the first 100s of a drive cycle.

• Essential to Have Fast Catalyst Light-Off

• Strategy
  
  • 1st Injection during induction - relatively well mixed but lean mixture in the cylinder before ignition,

  • 2nd Injection close to ignition - stratified fuel rich mixture in the central region of the combustion chamber.

  • Ignition after top dead centre
Combustion with Split Injection

Cylinder 2B, EOI2 -14 bTDC

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Cylinder 2B, EOI2 -14 bTDC
Combustion with Split Injection – 6000 pps

- Misfire
- Normal
- Slow-burn