Measuring the Cylinder-to-Cylinder EGR Distribution in a Diesel Engine

Bob Green
Sandia National Laboratories, CA

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Project Rationale

- Contemporary Diesel engine designs are using EGR to control NO$_x$ emissions
- A cylinder-to-cylinder mal-distribution of EGR may lead to performance and emission problems
  - Non-uniform combustion performance
  - Excessive NO$_x$ emissions
  - Excessive PM emissions
- Engine operation transients may aggravate the problem
Project Objective

Develop a non-obtrusive, optical diagnostic for measuring the cylinder-to-cylinder EGR distribution in production Diesel engines during both steady operation and engine transients.
Technical Approach

- Develop the diagnostic using a production engine
- Minimize perturbations to the basic engine geometry
- Data acquisition during both steady state and transient operation
- Use IR absorption spectroscopy to measure CO$_2$ concentration in the intake port of each cylinder
- Acquire the data in a manner that is both crank-angle and cycle-sequence resolved as well as being ensemble-averaged
Reference cell spectrum

Abs. Species = $\text{C}^{13}\text{O}^{16}_2$

Nat. Abundance = 1.1%

$P_{\text{Total}} = 5$ torr

WN = 2264.953 cm$^{-1}$
$v^\prime: 00001 - v^\prime: 00011$
$P(22)$

WN = 2264.518 cm$^{-1}$
$v^\prime: 01101 - v^\prime: 01111$
$P(9)$

WN = 2265.335 cm$^{-1}$
$v^\prime: 01101 - v^\prime: 01111$
$P(8)$
Spectrum is superposition of 3 lines

- Composite Transmission Spectrum
- v''(01101) - v'(01111) : P(9)
- v''(00001) - v'(00011) : P(22)
- v''(01101) - v'(01111) : P(8)
Fit of experimental spectrum
Optical fibers transmit laser light to windows in the intake system.
The CO\textsubscript{2} concentration history during the intake stroke for externally pre-mixed EGR
Cylinder-to-cylinder EGR distribution during the intake stroke for steady engine operation
The intake manifold of the Volkswagen TDI engine has a symmetrical design.
Cylinder-to-cylinder distribution of EGR during ‘EGR-OFF’ and ‘-ON’ transients

![Graph showing CO₂ concentration over cycle number during transient for Cylinder #1 and Cylinder #2 with EGR On and Off phases indicated.]

- Cylinder #1
- Cylinder #2

Intake Stroke Averaged
Cylinder-to-cylinder distribution of EGR during ‘EGR-OFF’ and ‘-ON’ transients
Crankangle-resolved EGR concentration during an ‘EGR-OFF’ transient
Crankangle-resolved EGR concentration during an ‘EGR-ON’ transient

Graph showing the Crankangle during Intake Stroke (deg) vs. CO$_2$ Concentration (%) for different cycles.
Project Status

- A non-intrusive diagnostic that measures the cylinder-to-cylinder EGR distribution in the intake charge has been demonstrated
  - Steady operation
  - Transient operation

- Issues related to system portability are complete

- We’ve approached industry regarding cooperative interaction

- We’re prepared to work out the details for performing ‘off site’ measurements on either development or production engines