Nonintrusive optical diagnostic technique offers low detection limit, high precision

OAAT ACCOMPLISHMENTS

Cylinder-to-Cylinder Distribution of Recirculated Exhaust Gas

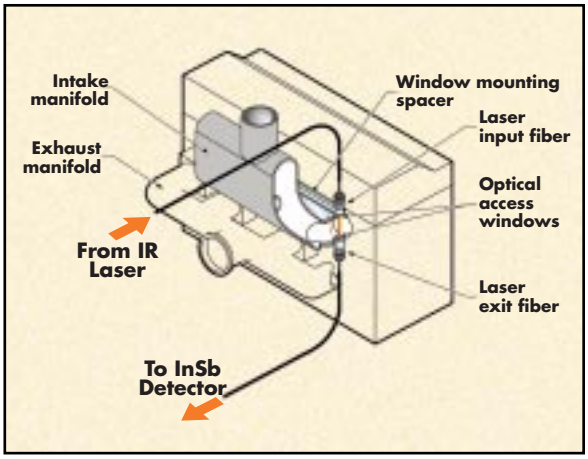
Challenge

The new generation of small-bore compression ignition direct injection (CIDI) engines is expected to use large amounts of exhaust gas recirculation (EGR) to minimize engine-out nitrogen oxides (NO_x) emissions. Ideally, EGR should be evenly distributed across all engine cylinders to minimize NO_x emissions. Poor cylinder-to-cylinder distribution of EGR can lead to serious performance and/or emission problems. Large amounts of EGR create mixing problems that inhibit even distribution, especially during transient operation of a CIDI engine. To help control this potential problem, a method to measure transient EGR behavior must be devised.

Technology Description

A non-intrusive optical diagnostic technique was developed to measure the behavior of EGR in a production CIDI engine. The diagnostic uses laser absorption spectroscopy measurements of carbon dioxide (CO_2), the primary constituent of recirculated exhaust. A spacer plate with windows, inserted between the intake and exhaust manifolds and the cylinder head, provides an optical path through the intake flow entering each cylinder port from the intake manifold. Laser light passes through the optical path and the CO_2 gas, measuring its concentration and spatial distribution.

The diagnostic is applied at both steady-state and transient engine conditions. To provide further insight into transient behavior, the resulting data can be resolved by the number of EGR cycles or the crank angle position during the intake stroke.



Optical fibers transmit laser light to windows in the intake system.

Accomplishments

The laser absorption spectroscopy technique was installed on a Volkswagen 1.9L TDI diesel engine. Even during steady-state engine operation, striking differences in EGR distribution were observed between cylinders positioned at the end of the engine block and those positioned in the middle.

Transient operation was achieved over sequences of 210 engine cycles by rapidly closing the EGR valve at cycle 1 and leaving it closed for 105 cycles, then rapidly opening the EGR valve at cycle 106 and leaving it open for the last 105 cycles. Rapid closing was found to produce uneven distribution of EGR across the cylinders but achieve full purge of EGR from the intake flow within 6 to 8 engine cycles. In contrast, rapid opening was found to produce even distribution but take a long time to achieve steady-state EGR concentration – 90% within 14 engine cycles, but nearly an additional 100 cycles to achieve the final 10%.

Contacts

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Benefits

Optimum cylinder-to-cylinder distribution of EGR provides:

- Uniform combustion performance
- Lower engine-out NO_x emissions
- Reduced engine-out particulate emissions.

Better understanding of EGR behavior under transient engine conditions will help resolve the problem of the uneven distribution of EGR between engine cylinders.

Commercialization

Developers are pursuing cooperative working arrangements with engine manufacturers that involve using the diagnostic technique to perform measurements on development and prototype engines.

Future Activities

The laser absorption spectroscopy technique will be extended to engine configurations different from that of the Volkswagen 1.9L TDI engine.

Issues related to system 'portability' are being addressed.

Partner in Success

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