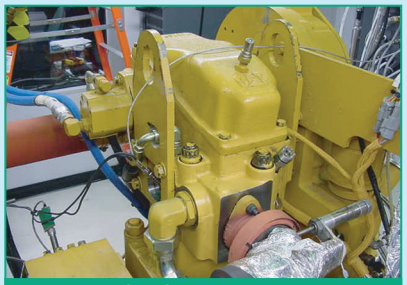
Late-Cycle Injection of Air/Oxygen-Enriched Air to Reduce Diesel Exhaust Emissions

Challenge

Diesel engine manufacturers have long sought techniques to achieve simultaneous reduction of particulate and NO_X emissions in order to meet new regulations taking effect in the next few years. To date, no single technique has succeeded in reducing both of these regulated emissions constituents without producing other negative impacts.

Background and Approach

In a CRADA between Argonne National Laboratory and Caterpillar Inc., researchers are exploring late-cycle injection of air and oxygen-enriched air to reduce diesel engine exhaust emissions.



Modified CAT Cylinder Head on Engine

Past research has shown that injecting air or oxygen-enriched air directly into the combustion chamber late in the combustion cycle reduces particulate emissions. Using a Caterpillar 3401E single-cylinder engine, Argonne researchers are combining this technique with optimized fuel injection characteristics to simultaneously reduce emissions of NO_X and particulates.

KIVA 360-Degree Grid-Edge Injector

Orientation of Gas Jet

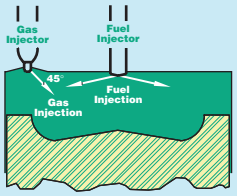
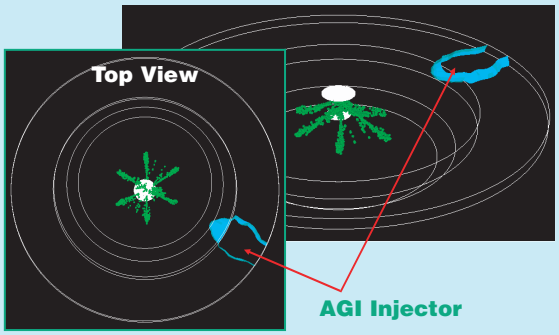
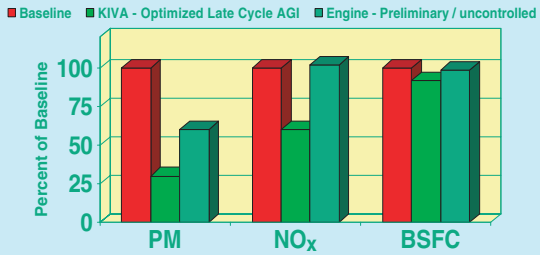


Diagram from Kurtz et al



Engine Results Measured Against Optimized KIVA Model Results



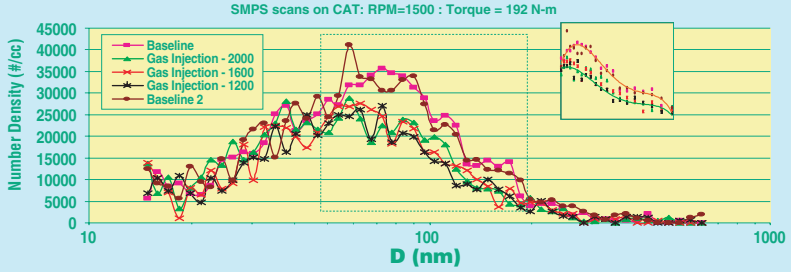
EXPERIMENTAL RESULTS

Caterpillar 3401 Engine Data

Gas Injection Reduces Number of Particles

Greatest Effect on Particle size > 50 nm

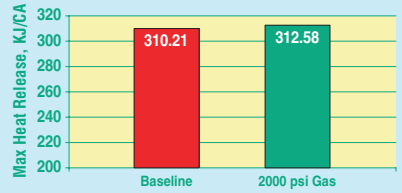
SMPS scans on CAT: RPM=1500 : Torque = 192 N-m



No Significant Change to Combustion Process

5% Increase in Peak Cylinder Pressure

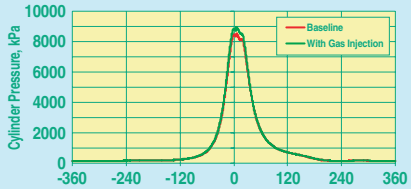
<1% Change in Max Heat Release

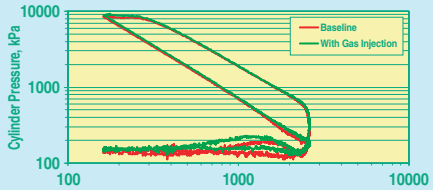


Combustion Process Analysis

Baseline vs. Gas Injection

1500 rpm, 192 N-m (40 hp)





Results and Future Plans

Extensive analytical studies using the KIVA-3 computational fluid dynamics (CFD) model developed at the University of Wisconsin have shown

1. the importance of the gas injection characteristics on the technique's effectiveness in reducing emissions, and
2. a simultaneous reduction of NO_X and particulates when the fuel injection characteristics are optimized in conjunction with late-cycle air injection.

Researchers are currently verifying the KIVA model using the Caterpillar 3401E engine. The experimental work will be compared with the trends predicted by the model.

Benefits: Techniques that produce successful, simultaneous reduction of NO_X and particulate emissions through late-cycle air/oxygen-enriched air injection will enable manufacturers to meet strict new emissions standards and result in cleaner air.

CATERPILLAR

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