Low-Temperature Low-Emission Diesel Combustion

Fuels, Engines, and Emissions

U.S. Department of Energy

Energy Efficiency and Renewable Energy Program

Oak Ridge National Laboratory

UT-Battelle

Transportation

FOR THE 21ST CENTURY

Background

The accepted model of diesel combustion for the last 20 years has been that any change in engine operating parameters to reduce nitrogen oxide (NOx) emissions resulted in an increase in particle (carbon soot) emissions. Generally, higher combustion temperatures promote complete oxidation of the fuel, thus less soot, but also cause more formation of NOx. In recent years, exhaust gas recirculation (EGR) has been studied for use in diesels to reduce NOx. The exhaust gas dilutes the combustion process and lowers the temperature and NOx. However, EGR causes soot to increase.

The Technology

ORNL has been researching methods for several years to extend the EGR limit for maximum NOx reduction while balancing the soot increase to an acceptable level. Their approach has relied heavily on non-linear (chaos) analysis of engine data and virtual sensors that would predict the operating boundary where soot increases dramatically. In February 2002, while conducting experiments with a diesel engine equipped with a flexible electronic control system, the ORNL team found a combustion regime at very high EGR levels where the soot emissions reached a maximum and *then decreased*.

The ORNL team utilized an innovative combination of fuel injection timing, exhaust gas recirculation, and throttling to enter this "low-temperature combustion" domain where emissions of both NOx and particulate matter were reduced. In order to carry out this project, the team first had to engineer a state-of-the-art engine control system, a significant achievement in itself. After relatively modest parametric experiments in this regime, NOx reductions of about 90% and PM reduction of 45% were simultaneously achieved with no loss of efficiency. Over the past year, there have been limited reports from industry and private labs about the existence of this mode of combustion. ORNL is perhaps the first to explain how it can be done with various control parameters. In addition, by applying powerful analytical methods to characterize the exhaust constituents, ORNL is helping the understanding of the combustion process in this regime.

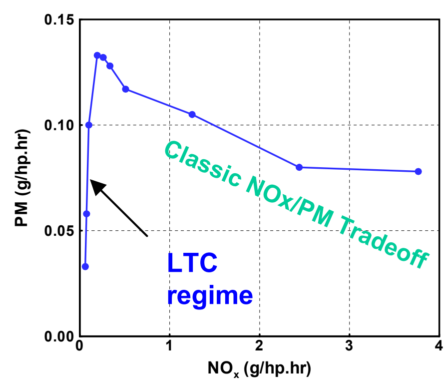
Commercialization

Commercialization challenges and opportunities:

- Low-temperature combustion is more difficult to achieve in larger engines (as for trucks) and at high engine power levels.
- Fuel formulation may be key in expanding the operating regime.
- Recent results in Japan show promise for integrating low-temperature combustion with exhaust catalytic devices for even lower emissions.

Benefits

- Simultaneous reduction of NOx and soot emissions from diesel engines
- No reduction in fuel efficiency
- Better understanding of basic combustion processes



ORNL Data, 1.7 Liter Mercedes-Benz Direct-Injection Diesel

For more information on how ORNL is helping America remain competitive in the 21st century, please contact:

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November 2002

Success Story