Self-Cleaning Diesel Particulate Filter

ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF FREEDOMCAR AND VEHICLE TECHNOLOGIES

Transportation

FOR THE 21ST CENTURY

Background

High-efficiency, advanced diesel engines are a leading near-term option for reducing petroleum consumption in the United States. Today's automotive and heavy-duty diesel engines convert about 40 to 45% of a gallon of diesel fuel to useful power, providing almost 50% better fuel economy than gasoline vehicles. However, diesel engines face serious challenges in meeting the Environmental Protection Agency's (EPA) 2004 Tier 2 vehicle emissions standards for oxides of nitrogen (NO_x) and particulate matter (PM). For light-duty vehicles, new emission control systems must reduce engine-out emissions of NOx and PM by 90%, to 0.02 grams/mile and 0.01 grams/mile, respectively. These reductions in NOx and PM must be achieved while minimizing adverse effects on fuel economy.

Current diesel engine particulate filter technologies depend on a catalyst to assist in the regeneration of the filter. Catalyst technology, however, requires an exhaust temperature of approximately 350°C to be effective. Small diesel engines rarely achieve this exhaust temperature, except at high loads indicative of high speed vehicle operation, requiring adjustments to engine operating conditions or the use of fuel additives.

Since 1997, research carried out at Industrial Ceramic Solutions (ICS), located in Oak Ridge, TN, has focused on finding a more effective means of regenerating a particulate filter at low exhaust temperatures. The research produced a microwave-sensitive silicon carbide fiber technology that enables a particulate trap to be cleaned by microwave heating. The ceramic fiber is incorporated into a cartridge and microwave regeneration system that is connected to a microwave power source. The Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy has been sponsoring the development of this filter at ICS for the past three years. This support, along with DOE's exposure of the technology to the automotive industry, has been the driving force in moving the microwave filter toward commercialization.

Recently, using microwave field finite-element program analysis, the heating efficiency of the filter cartridge was improved from 10% of the filter volume to over 60%, with 100% as the next goal. The mechanical burst strength of the ceramic fiber media was also increased to a point that it is substantially above diesel exhaust pressures.

Diesel engine manufacturers have insisted that 95% particulate matter destruction is necessary to comply with EPA Tier 2 requirements. The technology has been demonstrated on stationary diesel engines at Ford, Oak Ridge National Laboratory, and the University of Tennessee, where test data have demonstrated a particulate removal efficiency greater than 95% across a spectrum of normal engine operating conditions.

The Technology

The Microwave-Cleaned Ceramic Filter, now being prepared for marketing by ICS, utilizes a patented filter system that contains special silicon carbide fibers that convert microwave energy to thermal energy at nearly 100% efficiency. The microwave-powered cleaning cycle requires only a few minutes to achieve combustion of the PM. This combustion restores the filter to its fresh condition for the next filtration cycle. The system can achieve combustion during urban driving, idle, or cold start conditions, and is a solution to the low-temperature urban driving cycle where catalyst technologies are ineffective. It may also be a solution to the cold-start issue that is responsible for a significant portion of both diesel and gasoline engine emissions.

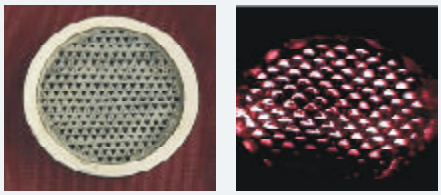
The microwave electronics and controls are isolated from the harsh exhaust stream environment, and sensors can be installed to monitor for leakage. Overall, the system helps reduce the impact of particulate reduction on fuel economy to about 0.3%, or more than 90% less than with other types of filter regeneration systems.

Commercialization

Industrial Ceramic Solutions is preparing to manufacture the patented self-cleaning filter, and plans to conduct a 25,000-mile road test in 2003. Because all of the product applications require high-volume production, component development was moved to commercial-scale equipment very early on. In addition to the cylindrical cartridge format, new technology advances assisted by Lydall Filtration/Separation (Rochester, NH) have made it possible to develop a prototype pleated filter from silicon carbide fibers. Such pleated filter "cassettes" will be used as part of a multi-filter system in which 6 or 8 cassettes are installed in a single panel. The pleated filter assemblies will have the ability to be configured for optimal treatment of a specific volume of vehicle exhaust. ICS plans production of the pleated cartridges in 2003.

Benefits

- **Regenerates at exhaust temperatures below 300°C**
- **Filter backpressure is 5 to 10 times less than extruded honeycomb and increases at a much slower rate**
- **Negligible fuel penalty compared to other filter regeneration technologies**
- **Regeneration independent of fuel, or engine operating conditions**
- **Pleated filter cartridge design suitable for large exhaust flows**
- **System compatible with planned NO_x and hydrocarbon control components**



The new ceramic fiber particulate trap employs an efficient, microwave heating cycle to regenerate itself. A pleated design (below) will be useful for high- volume exhaust streams.

Contacts:

Ken Howden
Office of FreedomCAR and Vehicle Technologies
(202) 586-3631
ken.howden@ee.doe.gov

Dick Nixdorf
Industrial Ceramic Solutions
(865) 482-7552
nixdorfr@indceramicsolns.com

Success Story

November 2002