REAL-TIME PORTABLE EXHAUST ANALYZER

Argonne National Laboratory has developed a low-cost portable instrument that can be used to characterize, in real time, particulate emissions in the exhaust of diesel engines. The instrument can measure mean particle size in nanometers (one-billionth of a meter) and number density (i.e., number of particles per cubic centimeter), in addition to mass concentration (i.e., grams per cubic centimeter). This innovation has far-reaching implications because it makes characterizing particles fast, easy, and cost-effective.

The instrument works on the basis of a technique called Laser-Induced Incandescence (LII). In this technique, a high-energy laser pulse heats the tiny particles in combustion exhausts. Upon heating, the particles emit light, which, when collected appropriately, indicates how many grams of particles there are per cubic centimeter of the exhaust. By combining this technique with another laser-based technique, researchers can also measure the mean size of the particles and the number of particles per cubic centimeter. The instrument can be used in real time — that is, during transient operation of an engine.

Background

Diesel engines have proven to be the workhorses of industry and transportation because they are highly efficient, but they have one key drawback: high levels of particulate emissions. Industry, regulators, and other groups that are investigating ways to curtail particulate emissions are hindered by the difficulty in measuring these particles by using current instruments and techniques. Although affordable, instruments (commonly referred to as smoke or opacity meters) used to measure the opacity, or the degree to which the exhaust obstructs the transmission of light, have been unreliable for gathering accurate, consistent information about particles in exhaust. Also, there is a lack of consensus among manufacturers of smoke meters about defining a common scale for opacity, which makes comparisons difficult.

Even so, researchers often use smoke meters in tandem with the U.S. Environmental Protection Agency's (EPA's) recommended procedure for collecting information on particles. The EPA's procedure involves collecting particles in a diluted stream of exhaust gases on a filter paper and then weighing the filter paper with the collected particles to determine mass concentration. The total cost of instrumentation used in this procedure is very expensive: it averages about $100,000. Another problem is that researchers cannot use such equipment to monitor particulate emissions when the engine's operation changes from moment to moment (also known as transient operation).

The Argonne Approach

In contrast, Argonne's new instrument solves these problems. It can be used to reliably measure particulate emissions from diesels, even during transient operation, because measurements can be taken in less than 1/20th of a second. In addition to being affordable estimated to be $30,000–60,000 per unit in the market place., Argonne's instrument is portable, so it can be used in the field. And unlike previous instruments, this single instrument can provide data on the three parameters that are essential for understanding diesel aerosols: the mass concentration, number density, and mean size of the particles.

This instrument could play a pivotal role in the development of technologies to reduce particulate emissions. Over the last decade, various agencies have implemented regulations aimed at reducing the mass emission of particles from diesels. In response, industry has developed advanced technologies that have reduced the mass emission of particles from diesels by over a factor of eight. However, these technologies have resulted in the emission of fine particles (less than 50 nanometers) in large numbers. To reduce the environmental and health impacts associated with these particles, many government agencies are considering a further regulation based on the number of particles. Argonne's new instrument — with its ability to measure the number of particles in the exhaust — would be a very useful tool if such a regulation becomes the law.

Certain transient phases of engine operation result in increased emission of particles (e.g., an engine accelerating from idle). Because industry lacks instruments that can measure particles during transient operation, engine designers are unable to fine-tune the engine parameters to reduce the emission of particles during transient operation. Argonne's new instrument — with its ability to collect information during transient operations — could help engine designers overcome that obstacle and help them design a cleaner-burning engine.

Benefits

Particles emitted from diesel engines pose a significant health hazard to the general public because they are of the right size to be inhaled and deposited deep inside the lungs. An additional concern is that certain substances that condense on the surface of these particles are carcinogenic. Argonne's innovation will help researchers to develop advanced technologies for reducing particulate emissions and thereby reduce human exposure. Specifically, diesel engine manufacturers could use it for evaluating diesel particulate emissions, thereby making cleaner diesel engines; refining companies could use it for evaluating fuel quality, thereby making cleaner fuel; and regulatory agencies could use it for checking on-road vehicle compliance for emissions. As a result, everyone will benefit, because the environment will be cleaner.

Argonne's instrument has been calibrated successfully against soot particles from burners. Its application for characterizing hot exhaust gases from diesel engines is under development.

Based on material prepared by Kevin Brown of Argonne's Technical Services Division.

For More Information

For more information, contact Argonne's Office of Technology Transfer (800-627-2596, partners@anl.gov).