OVERVIEW OF DETAILED CHEMICAL SPECIATION AND PARTICLE SIZING FOR DIESEL EXHAUST, BOTH REAL-TIME AND FILTER-BASED MEASUREMENT

Chol-Bum Kweon, Shusuke Okada, David E. Foster, Martin M. Shafer, Charles G. Christensen, and James J. Schauer

University of Wisconsin

Deborah S. Gross

Carleton College

ABSTRACT

EPA ambient air-quality measurement protocols have been incorporated into the exhaust measurement system of a research single-cylinder diesel engine. To allow more detailed assessment of the individual chemical components of the diesel particulate matter (PM), the exhaust dilution system includes a residence-time chamber (RTC) to allow for residence times of 30-60 seconds in the second stage of dilution before sampling. Measurements have been performed using the more normal approach of catching the particulate matter on filters and then analyzing the filters, and also using an aerosol time-of-flight mass spectrometer (ATOF-MS), which is capable of analyzing individual particles for size and composition at a rate of up to 150 particles per minute for a particle-size range from 0.15 to 5 micrometers. Additional data on particle size were obtained using a scanning mobility particle sizer (SMPS).

Samples have been collected on a range of different filters where mass loading, elemental and organic carbon (EC/OC), trace metals, sulfate ions (SO_4), volatile organic compounds, and semi-volatile organic compounds have been evaluated. Using the SMPS, particle-size distributions have been measured for the different operating conditions and for different exhaust gas residence times in the RTC.

This paper gives an overview of the results obtained with the different measurement techniques for the range of engine operating conditions covered by the CARB 8 mode test. Results show that the chemical composition and size distribution of the particulate matter are highly dependent on the engine operating conditions. There is a dramatic shift in the ratio of elemental to organic carbon and in the sulfate ions (SO4) when the engine is traversed across a load and speed range. Similarly, there is a shift in the particle-size range for which there is virtually no impact on the mass loading, and the nano-particle-size distribution, at a fixed dilution ratio and temperature, is a function of the time spent in the RTC. Trace metal concentrations in the particulate vary significantly with load and speed and are treated as indicative of oil consumption.

Results of the filter-based measurements are being compared to those obtained using the ATOF-MS, which has been widely used to study atmospheric aerosols but has only seen limited use for assessing internal combustion engine exhaust emissions. Using the ATOF-MS to make fundamental measurements of chemical composition and particle size in engine exhaust has the potential to offer unique insights into the impact of changes in engine operating conditions on the resultant changes in the exhaust characteristics.