NEW DIESEL COMBUSTION REGIME: PARTICULATE ANALYSIS WITH THE SINGLE-PARTICLE LASER ABLATION TIME-OF-FLIGHT MASS SPECTROMETER

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ABSTRACT

To meet the new exhaust gas emission laws, most new diesel engines will be using exhaust gas recirculation (EGR). EGR technology has been shown to be very effective means of reducing NO_x emissions; however, typically any change in engine operating parameters to reduce NO_x emissions results in an increase in particulate matter (PM) emissions, which in the case of diesel emissions is of particularly serious concern because of its known carcinogenic effects. Hence, traditionally the point defined as the ultimate EGR limit was delineated by a sudden increase in HC (hydrocarbons) and PM.

Very recently a few studies have suggested that by further increasing EGR, it might be possible to push the engine into a novel low-temperature combustion regime (NLTC) that, unlike the "classic NO_X-PM tradeoff," simultaneously reduces both PM and NO_x emissions. None of the studies have presented any information about the composition and properties of the particulate mass in this combustion regime.

We will present the results of a recent study investigating this NLTC regime. In this study, diesel exhaust particles generated by the Mercedes A-Class 1.7L diesel engine under the entire range of EGR conditions were sampled and characterized by the Pacific Northwest National Laboratory Single Particle Laser Ablation Time-of-Flight Mass Spectrometer (SPLAT-MS). The instrument's extremely high sensitivity to small particles made it possible to detect and characterize individual particles down to 50 nm, demonstrating SPLAT-MS's utility for studying diesel PM emission.

In this study exhaust particle flow was introduced into the SPLAT-MS after dilution by a factor of 100 to 1,000 through an aerodynamic lens inlet. Each individual particle was then aerodynamically sized, and its chemical composition was characterized by using two-step, two-laser JR evaporation followed by ultraviolet ionization. The separation of the process by which ions are formed into two steps -- particle evaporation and ionization -- greatly improves the analytical capability of the SPLAT-MS and makes spectral assignment significantly more tractable.

Particle-size distributions from 3.5 to 500 nm were measured in parallel using Scanning Mobility Particle Sizer (SMPS). In addition, the NTRC group measured gas phase concentrations of NO_x, CO, CO_2, and HC's; recorded engine performance parameters; collected filter samples for gas chromatograph – mass spectrometer analysis; and measured total aerosol mass with TEOM for all EGR conditions.

Increasing EGR from 0 to 45 percent resulted in an increase (a doubling) in the particle number concentration and a shift in the average particle mobility diameter from 85 nm to 115 nm. At the same time the particle average aerodynamic diameter decreased from 97 to 74 nm, suggesting that increasing EGR from 0 to 45 percent results in a decrease of ~25 percent in particle size.