Measuring Number, Mass and Size of Diesel Exhaust Particles with the Dual Pegasor Particle Sensor

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The Pegasor Particle Sensor (PPS) is an aerosol instrument designed to measure directly the hot, undiluted vehicle exhaust. The sensor operates by combining diffusion charging with the “escaping current” method. The PPS charging area is followed by an “ion trap”; this is an electrostatic precipitator that collects free ions which failed to collide with particles, so that the escaping current measured is proportional only to particle concentration. Except from free ions, the ion trap has the capacity to trap particles as well, and this presents the opportunity to use PPS as a size selective sensor.

The PPS signal is proportional to the “active” particle surface; it can be converted to particle mass and number concentrations if one assumes values for other aerosol parameters, primarily mean diameter. In the case of diesel and GDI vehicle exhaust the PPS has been successfully tested with the assumption of $D_g=50\,\text{nm}$ (Ntziachristos et al., 2013). While this approximation is reasonable, it would be preferable to avoid using a fixed mean particle size.

In this study we demonstrate the possibility to measure exhaust particle mass, number and mean size in real time with the dual-PPS. The concept is based on sampling in parallel with two PPS units set at different ion trap voltage, so that each sensor detects a different fraction of the size distribution. Comparing the two signals can be used to first estimate mean particle size, and with this to convert PPS signal to number and mass concentrations.

The PPS charging efficiency as a function of particle size was measured with CAST soot particles. Ion trap penetration as a function of flowrate, particle size and trap voltage was explored with both CAST soot and diesel exhaust particles. Based on these, a data inversion algorithm was developed and evaluated with diesel engine exhaust.

The results demonstrate that the dual-PPS was generally in good agreement with reference instruments. Size estimation during drive cycles was much more challenging than steady state tests due to the highly transient aerosol. Nevertheless, the dual-PPS could clearly detect particle size fluctuations (Figure 1) as a result of the very good linearity between the two PPS units.

![Figure 1. Real-time measurement of particle number and mean size during the NEDC drive cycle.](image-url)

In addition to providing information on the mean particle size as an aerosol parameter, the dual-PPS offered significant improvements to the original, fixed-size, mass and number calibration. In specific cases, error reductions exceeded 50%. This present prototype may likely be optimized by integrating the two separate PPSs into a single unit with two measuring cells, as well as with continuously monitoring sample inlet and sheath air flowrates.