Loading of Soot Nanoparticle Agglomerates on Air Filters

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Studies for filtration of nanoparticle agglomerates are still scarce compared to those for spherical particles. Lange et al. (1999) measured the filtration efficiency of fibrous filters for carbon agglomerates and for spherical particles as a function of the mobility diameter. Kim et al. (2009) studied filtration of silver nanoparticle agglomerates by fibrous filters.

The pressure drop across a filter can rise rapidly under heavy particle loading conditions. Endo et al. (1998) performed experiments to measure the pressure drop and the height of dust cake in real time. They derived an analytical expression to correlate the pressure drop with the particle size distribution and particle shape.

We investigate loading of soot nanoparticle agglomerates on fibrous air filter media. The soot agglomerates were generated from a diffusion burner with propane gas as fuel and compressed air as oidant/sheath. The mode of the number distribution was determined to be 120 nm. A Differential Mobility Analyzer (DMA) - Aerosol Particle Mass Analyzer (APM) system was used to measure the mass of agglomerates as a function of the mobility size, which gave a fractal dimension of 1.90±0.1.

We performed extensive studies using electron microscopy. The agglomerates were composed of primary particles of nearly spherical shape. From the sizes of 190 primary spheres analyzed, we found that the mean diameter was 28 nm with a geometric standard deviation of 1.26.

Loading experiments with soot agglomerates were performed with the face velocity of 10 cm/s. The filter used in the loading experiments was HE 1071, a fiberglass media manufactured by Hollingsworth and Vose. A total number of 12 tests were carried out; the loading time was varied in these tests but other conditions were kept the same. Filter mass changes were measured after the loading tests with the accuracy of 0.1 mg. We measured the cake thickness using a video enhanced microscope. The 12 tests had similar values of cake porosity and the average value was 0.95. The pressure drop across the filter was monitored during the loading process and the final pressure drop when the test ended was recorded. We plot the final increased pressure drop as a function of the loading mass in Figure 1. It can be seen that the pressure drop increases approximately linearly with the loading mass.

To better understand the results, we look at the analytical expression derived by Endo et al. (1998):

$$\Delta P_c = 18\mu U_f H \frac{(1-\varepsilon)\upsilon(\varepsilon)}{\varepsilon^2} \frac{\kappa}{d_{vg}^2 \exp(4\ln^2 \sigma_g)}$$

where μ is the gas viscosity; U_f is the face velocity; H is the cake thickness; ε is the porosity; $\upsilon(\varepsilon)$ is the void function; d_{vg} is the geometric mean of the volume equivalent diameter of the loading particles and σ_g is the geometric standard deviation; κ is the dynamic shape factor. The cake could be regarded as formed by primary particles in soot agglomerates. When the size distribution of the primary particles was used in the model of Endo et al., good agreement between the experimental and computed results was obtained as shown in Figure 1.

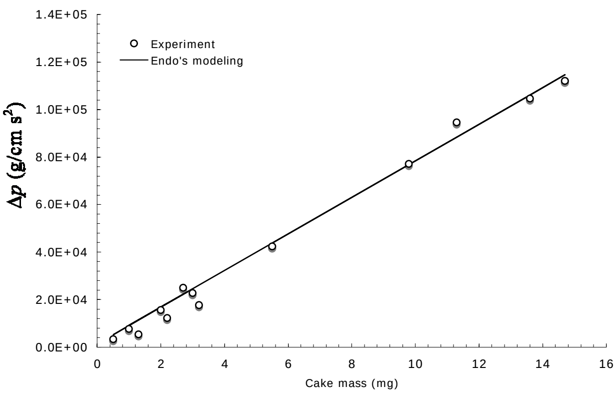

Figure 1. The pressure drop at the end of the loading test as a function of the cake mass.

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