Simulation of Aerosol Filtration via Nanofiber Media at Reduced Operating Pressures

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It is important to explore possible ways of predicting a filter's performance when it is challenged with aerosol flows in order to minimize the time and cost of producing more effective products. During the past decades, there have been many pioneering works which have formed the basis for filtration science however, in most of these studies the filter geometry has been simplified to rows of regularly arranged fibers, often in 2-D geometries. In the present work, we simulate unsteady-state collection efficiency of nanofiber filter media at reduced operating pressures in a 3-D space. Our ultimate objective is to better our understanding of filtration properties of different fibrous filters. The media considered in this work are aimed to resemble thin fiber-webs made up of fibers measuring 200 nm or less similar to webs produced by electrospinning. Electrospinning is a one-step process for producing submicron fibers. The fiber diameters attainable via electrospinning can range from 50 to 5,000 nm.

It is well-known that the smaller the fiber diameter, the higher is the collection efficiency of the media having identical weights. This is because the available surface area increases by decreasing the fiber diameter. However, the increased surface area causes the pressure drop to increase too. To simulate the collection efficiency of nanofiber media having different fiber diameters, we generated virtual fiber-webs of 50nm, 100nm, and 200nm diameters having a thickness of about 3.1 µm. To have a meaningful comparison these media were chosen in such a way that they have identical pressure drops (see Figure 1). It can be seen that while all these three filter media have identical pressure drops, their collection efficiencies are very different. The medium with thinner fibers have higher efficiency. Also the most penetrating particle size is found to be about 100nm to 200nm and it moves towards smaller diameters by reducing the fiber diameter.

To simulate cake formation on the filter surface we assumed that the particles stick to the fiber upon a collision its surface. Similarly, a new particle is assumed to deposit on an existing one if a collision occurs. Almost all aerosols are Polydisperse with log-normal particle size distributions. To simulate a Polydisperse cake formation we considered our particles to be taken from a log-normal size distribution similar to that of Diethylhexy Phthalate (DOP) particles generated by the aerosol generator of TSI 8130 filter testers. Figure 2, shows an example of a Polydisperse cake at 75% filter efficiency deposited on the aforementioned filter medium with 100 nm fibers.

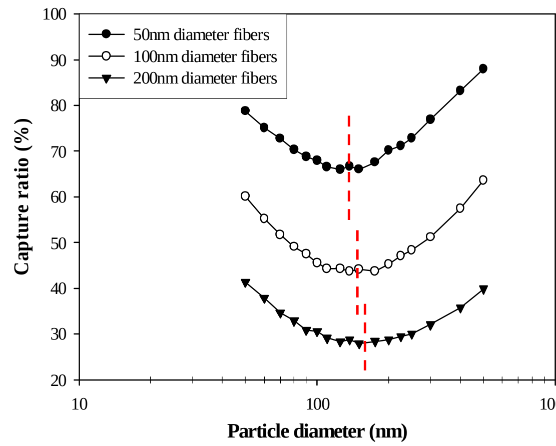

Figure 1: Collection efficiency of three filter media having identical thickness and pressure drops. Note that collection efficacy increases by decreasing the fiber diameter.

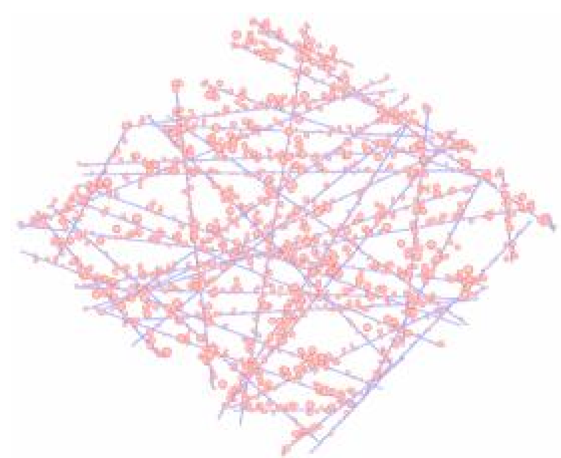

Figure 2: An example of a Polydisperse cake made at a temperatures of 300 Kelvin at 75% filter efficiency.

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