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Detachment of Liquid Droplets from Junctions of Crossing Fibers Exposed to Air Flow

A number of previous studies have focused on the movements of droplets along a fiber; however, more detailed studies need to be carried out to better understand the behavior and the mechanism of the movements of these droplets when encountering a junction of fibers which is inevitable in real examples of fibrous media. This work presents the results of a microscopic study of liquid droplets detachments from junctions of crossed fibers when subjected to air flow. The crossed fibers were adjusted to create different angles, within a plane, relative to the airflow direction as shown in Fig. 1. These simple combinations of angles of fibers are the basic fiber orientations in a complex fibrous filter structure. The liquid droplets were placed on the intersection point using a syringe method. A correlation was developed for the minimum Reynolds number of gas at which the drops began to move. This correlation allows us to predict the gas flow conditions required to detach the drops from the fiber junction.

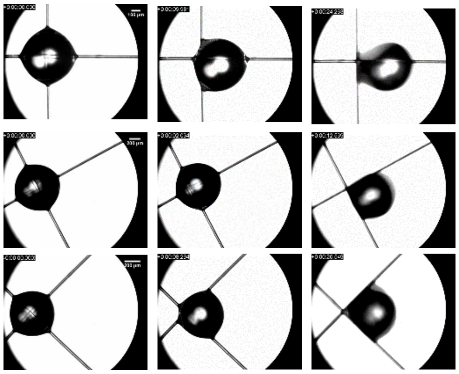

Fig. 1. Top view of ULSD droplets on Polypropylene crossed fibers with different angles relative to the flow direction which is from left to right. From top to bottom: ∝=0 degree, 30 degree, and 45 degree. $0 < \propto < 45$.

The probability of a droplet moving or not on a fiber is a function of contact angle, surface tension, fluid properties, and geometric dimensions. Since the size of the droplets could be controlled, only droplets that could be moved by the air drag force were placed on the fibers. Therefore, the probability function which is assumed to have a power law form is equal to one.

$$1 = a\rho_{gas}^{b}\mu_{gas}^{c}\rho_{liq}^{d}\mu_{liq}^{e}(\cos\theta)^{f}(\cos\propto)^{g}\gamma^{h}V^{i}d_{L}^{j}d_{f}^{k} \tag{1}$$

where the coefficients *a, b, ..., k* are experimentally fitted constants. The relevant Reynolds and Laplace numbers are

$$Re_{gas\ min} = \frac{\rho_{gas}d_{L}V}{\mu_{gas}} \tag{2}$$

$$La = \frac{\rho_{liq}d_{f}\gamma}{\mu_{liq}^{2}} \tag{3}$$

After dimensional analysis and grouping the important variables above into the Laplace number and Re number, the correlation for Re number becomes

$$Re_{gas\ min} = A\ La^{B} (cos\ \theta)^{C} (cos\ \propto)^{D} \left(\frac{d_f}{d_L}\right)^{E} \left(\frac{\rho_{gas}}{\rho_{liq}}\right)^{F} \left(\frac{\mu_{gas}}{\mu_{liq}}\right)^{G} \quad (4)$$

where $A, B, \ldots G$ are constants to be determined from experimental data. $Re_{gas\ min}$ is the minimum Reynolds number of the gas at which the droplet detaches from the junction of the fibers.

The unknown parameters $A, B, \ldots G$ in Equation (4) were determined by regression of the data from the 270 experiments with five different fibers, three different liquids with a range of liquid droplet sizes, and three different angles of fibers.

$$Re_{gas\ min} = 13.33\ La^{0.8} (cos\ \propto)^{-0.32} \left(\frac{d_f}{d_L}\right)^{-0.65} \left(\frac{\rho_{gas}\,\mu_{liq}}{\rho_{liq}\,\mu_{gas}}\right)^{1.59} \quad (5)$$

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