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Investigation of Droplet Motion and Grouping

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The behavior of liquid particles is of great importance in connection with many industrial applications in the world of engineering. Flows involving liquid droplets are an inseparable part of work-principles in motors and combustion systems in general, so understanding these flows is essential for improving the performance and capabilities of relevant applications. A very basic and popular example of liquid particle motion is the problem of two or more droplets, falling along their line of centers. Recent controlled experiments performed at the University of Stuttgart considered a liquid jet which disintegrates into droplets when pressed through a small orifice. By applying an appropriate frequency to the droplet stream generator a monodisperse droplet stream is obtained. However, even an initially monodisperse droplet stream with equally spaced droplets becomes irregular as very small inevitable disturbances increase and droplet groups are formed randomly resulting in droplet coagulation. By manipulating the excitation of the droplet stream generator it was possible to initiate regular droplet groups from the beginning on.

The current research project was aimed at trying to understand the observed (isopropyl fuel) droplet motion which included grouping of consecutive pairs of droplets, and, subsequently, droplet triplets. An analytical/numerical approach was adopted to model the physics of the droplet motion, with as little artificial modification as possible, for the case of a small Reynolds number for the droplets, based on the terminal velocity of their downward fall. The model had to account for both the interaction between the falling droplets and the occasionally-observed attraction between them. Early theory from the literature suggested that the bottom droplet of a falling pair is slowed more than a single droplet owing to inertial forces and that the slowing is a function of Reynolds number only. The upper droplet, however, is not at all affected and will fall according to classical Smoluchowski theory. More sophisticated theory from the literature was applied to this problem for the first time. Comparison with the aforementioned independent experimental measurements for droplets, having an initial diameter of about 112 microns, generally yielded good agreement, particularly for the behavior of the distance between the centers of the pairs of droplets as they approached one another. Other aspects of the problem, that do not seem to have been hitherto quantified, were also investigated. These included (a) expanding the basic model to allow for pairs of different-sized droplets, and (b) permitting droplet evaporation to occur as the droplets were in motion.

Some discrepancy between the simulation and the experiments, regarding relative distances between droplets from different groups, and/or relative distances after the occurrence of coalescence are ascribed to the model's/simulation's omission of both interaction between different droplet groups and coalescence effects, or due to the experiments' more moderate Reynolds number. However, the general droplet motion predicted by the model seems to match well the experimental results.

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