Droplet Breakup Modelling in Spraying

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Abstract

A study of the problem of a liquid droplet in high speed trajectory through ambient gas is presented. The behaviour of such a droplet is of importance to the overall spray characteristics, through the secondary breakup mechanism.

The droplet breakup mechanism is classified in the literature into several regimes according to the relative velocity between the droplet and the surrounding. Krzeczkowski [1] classified the droplet deformation into four different types using the Weber and Ohnesorge numbers, while Pilch and Erdman [2] modified the classification into five regimes, and defined a critical Weber number below which droplet breakup does not occur. In the present study, however, we consider the energetic limiting conditions of breakup as related to possible breakup products, thus defining the borders between droplet deformation without breakup and different modes of breakup.

We consider the following fundamental scenario: Under certain circumstances, a single droplet that travels through ambient can undergo a spontaneous breakup process to yield travelling product droplets. Due to the ambient hydrodynamic drag forces, the travelling droplet is deformed, while the deformation extent and the deformation rate are strongly coupled to the magnitude of the drag force. The drag force itself depends mainly on the trajectory velocity and to a lower extent [3] on the droplet shape (deformation extent). Thus, when a droplet is shot into ambient, deformation develops, which may lead to either droplet breakup or alternatively to droplet further deceleration and reformation of its shape. Breakup can occur into different number of products, depending on trajectory parameters, e.g. length and time. The fate of the droplet depends on the droplet velocity, on the droplet thermo-physical properties, and on the ambient properties, through the time scales of the droplet's trajectory deceleration and deformation rate.

In the theoretical analysis of the problem, we examine an overall energy balance that includes surface and dissipation energies. Transformation between a droplet to its breakup products under trajectory conditions that include drag forces, is a spontaneous process that occurs at a characteristic finite time. The transformation involves reversible surface energy transitions, and irreversible viscous dissipation energy. Results propose simple relations for time of breakup, trajectory length, and breakup limits.

Results of breakup limit show good agreement with various available published results. A breakup limit criterion correlates Weber and Ohnesorge numbers.

References

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