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A MODEL TO PREDICT THE CONDITIONS FOR LIQUID DROP BREAKUP AND THE RESULTANT MEAN FRAGMENT SIZE

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The potential significance of drop fragmentation in sprays and other propulsion-related multiphase flows has been noted in the literature [e.g., Caveny and Gany (1979) and Takagi et al. (1991)]. This has motivated recent experimental and theoretical works to: better understand the fundamental physics of drop breakup processes, and develop models of drop fragmentation suitable for use in multiphase flow codes. The works summarized below [Wert and Jacobs (1994) and Wert (1994)] aim to contribute to both sides of this two-pronged attack.

Development of a model to predict the deformation and conditions for fragmentation of a liquid drop was undertaken by Wert and Jacobs (1994). Though the development was tailored to distortion and breakup by aerodynamic forces (for Re ~ 100-1000), the model provides a framework for consideration of other drop breakup modes, e.g., collision induced breakup or fragmentation in a highly sheared flow. Two independent conditions for fragmentation were developed; one is specified in terms of a critical drop energy criterion, the other is based on stability theory. In agreement with the experimental data of Hsiang and Faeth (1992), Loparev (1975), and Hanson et al. (1963), both criteria predict that for a step change in relative velocity the critical Weber number (We_{crit}) is independent of Ohnesorge number (Oh) and approximately equal to 15 for Oh < 0.03. For Oh > 0.03 both criteria predicted an increase in We_{crit} with Oh, but the energy criterion overpredicts the rate of increase when compared with experimental observations. The predictions based on the stability criteria, however, show good agreement throughout the calculated Oh range. The unique derivation of the energy breakup criterion and its success in predicting We_{crit} for Oh < 0.03 would appear to support the conjecture that for drops that behave dynamically as though inviscid, the energy breakup criterion is the same regardless of the drop breakup mode in question. Additionally, both the energy and stability breakup criteria validate the use of a critical deformation criterion to predict aerodynamic breakup. However, the predictions of the stability model indicate that such a criterion is an increasing function of Oh for Oh > 0.01.

A model was developed by Wert (1994) to predict the Sauter mean diameter of fragments produced in the bag and multimode drop breakup regimes (14 < We < 100). In these regimes the final breakup of liquid drops is viewed as resulting from the growth of capillary instabilities. The model links the time scale for drop breakup and the time scale associated with growth of the unstable waves. The instability scale is approximated from the results of linear stability theory for capillary waves on liquid cylinders. The drop breakup scale is based on correlations available in the literature for drops subjected to a rapid (relative to drop deformation time scales) rise in relative velocity. A constant of proportionality, deduced from the experimental data of Hsiang and Faeth (1992), is introduced. In the bag and multimode breakup regimes, the stability/time-based model offers a significant improvement in ability to correlate the data when compared with an equation proposed by Hsiang and Faeth (1992).

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