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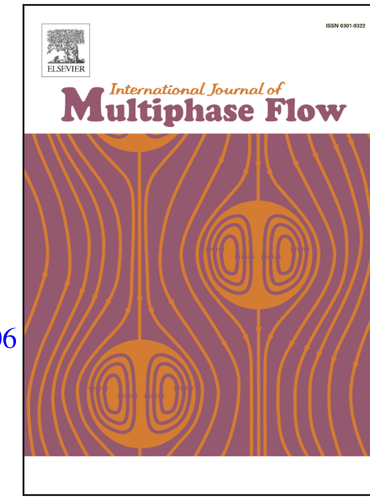

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Drop deformation and breakup

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Abstract

A Volume of Fluid (VOF) method is applied to investigate the deformation and breakup of an initially spherical drop in the bag- and shear breakup regimes, induced by steady disturbances. The onset of breakup is sought by studying steady-shape deformations while increasing the Weber number until breakup occurs. A parameter study is carried out applying different material properties and a wide range of drop Reynolds numbers in the steady wake regime. Density ratios of liquid to gas of 20, 40, and 80, viscosity ratios in the range 0.5-50, and Reynolds numbers between 20-200 are investigated for a constant Weber number of 20. The critical Weber number is found to be 12, in agreement with observations of earlier studies. For Weber number of 20 varying density, viscosity ratios and Reynolds numbers, interesting mixed breakup modes are discovered. Moreover, a new regime map including all modes observed is presented. A criterion for the transition between bag- and shear breakup is defined relating the competing inertial and shear forces appearing in the flow. Furthermore, results on breakup times and the time history of the drag coefficient are presented; the latter is concluded to be a potential parameter to indicate the occurrence of breakup.

Keywords: droplet, deformation, breakup, regime map, breakup time, Volume of Fluid (VOF)

1. Introduction

Fragmentation of liquid droplets has a fundamental importance in various engineering applications where sprays represent one such application. Sprays appear in electro-sprayed painting, ink-jet printing, coating production, industrial-, agricultural-, or pressure-atomized sprays. Furthermore, breakup plays an essential role in combustion by influencing the number and size of droplets, and thereby the rate of mixing as well as the efficiency of the combustion process. This in turn is a crucial factor from an energy- and pollution point of view. As a consequence, problems related to breakup of droplets have attracted increasing research attention during the past few decades.

Conditions for breakup and the concept of the critical Weber number were first introduced in the early works of Giffen & Muraszew [14] and Hinze [18]. As described in these studies, the three forces controlling the deformation and breakup of droplets are the dynamic pressure, viscous, and surface tension forces. The former two enhance whereas the latter counteracts breakup. Breakup occurs if the critical Weber number of the flow is exceeded, reported to be 13 for shock exposure and 22 for a falling drop by Hinze [18]. Gel'fand [13], Krzeczkowski [26], Wierzba & Takayama [43], and Dai & Faeth [7] presented photograph sequences of the fragmentation process for a wide range of parameters. Fig. 1 summarises breakup modes categorised by several authors, namely vibrational, bag, shear or stripping, catastrophic and transitional breakup modes. Transitional breakup modes are referred to as bag-jet, transition, bag and stamen, multimode, bag/plume and plume/shear breakup. It becomes obvious from the graph that critical or transition Weber numbers are approximate values where the reported values vary among the works found in literature, Krzeczkowski [26], Pilch and Erdman [35], and Faeth et al. [6–8]. Furthermore, some of the transitional modes found between bag and shear breakup have much in common although named differently in literature; bag-jet-, bag and stamen-, and bag-plume breakup modes cover nearly the same phenomena. Transition mechanism and multimode breakup as suggested by Krzeczkowski [26] and Faeth

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