Aerodynamic Fragmentation of Drops: Dynamics of the Liquid Bag

L. Opfer*[1], I.V. Roisman[1,2], C. Tropea[1,2]
[1]Institute of Fluid Mechanics and Aerodynamics, Technische Universität Darmstadt
[2]Center of Smart Interfaces, Technische Universität Darmstadt, Germany
lopfer@sla.tu-darmstadt.de, roisman@sla.tu-darmstadt.de and ctropea@sla.tu-darmstadt.de

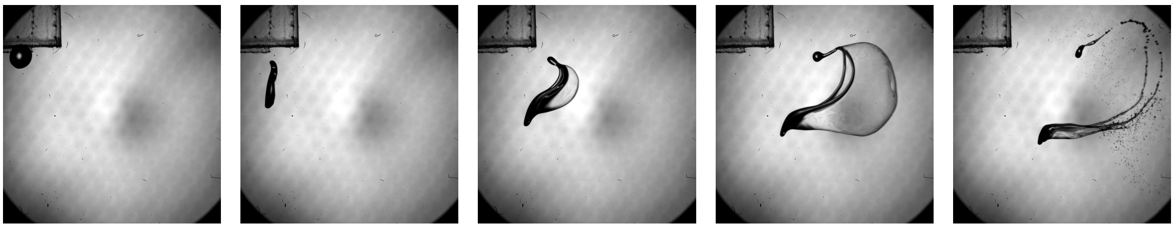
Abstract

Aerodynamic breakup of drops and ligaments is one of the most important phenomena responsible for the atomization of bulk liquid in single fragments. It occurs when the relative velocity between drops or ligaments and the dispersed phase exceeds a certain limit. The aerodynamic breakup is responsible for the final spray characteristics in a variety of technical applications and everyday phenomena, such as: fuel injection in jet engines and internal combustion engines, coatings and rain. Due to its importance the aerodynamic fragmentation has been interest of research for some decades. Recent comprehensive reviews about this topic can be found in Guildenbecher et al. [2009] and Theofanous [2011].

The development and outcome of the aerodynamic breakup mainly depends on the gas Weber number. It can be subdivided in particular modes, which are widely known as bag, multi-mode, sheet-thinning and catastrophic breakup. Among these, the bag breakup is the dominant fragmentation mode for most applications, since it occurs at relatively low Weber numbers.

While the qualitative development and morphology of single bag breakup events is well understood, the exact physics that lead to deformation and breakup of the drops are still unclear. Especially the mechanism that leads to bursting of the bag is not understood up to now. This study is devoted to the further experimental and theoretical investigation of bag breakup phenomena.

A compact open-circuit wind tunnel has been designed in order to conduct the experiments. The test section is made of acrylic glass which provides access for optical measurement techniques. A high-speed video system equipped with microscopic lens is used for shadowgraph visualizations with high temporal and spatial resolution. A typical example for the evolution of a bag breakup is depicted in figure 1. The experiments are carried out for various Weber and Ohnesorge numbers.



(a) spherical primary droplet (b) drop deformation (c) formation of the liquid bag (d) bag growth (e) bursting of the liquid film

Figure 1. Typical evolution of a bag breakup

A qualitative analysis of the breakup evolution is performed by means of digital image processing. Algorithms are developed in order to track the leading and trailing side of the drop and growth of the liquid bag as well as its aspect ratio.

A new theoretical model is developed which describes the dynamics of the liquid bag. The governing equations of the bag motion are solved taking into account for the aerodynamic pressure, inertia and surface tension in the liquid bag. It is shown that the model predictions agree well with the experimental results.

References

Guildenbecher, D.R., López-Rivera, C. and Sojka, P.E., 2009. Secondary atomization. Experiments in Fluids, 46(3), p.371-402.

Theofanous, T.G., 2011. Aerobreakup of Newtonian and Viscoelastic Liquids. Annual Review of Fluid Mechanics, 43(1), p.661-690.

*Corresponding author: lopfer@sla.tu-darmstadt.de