To the Theory of Drop Breakup at a Relatively Small Weber Numbers

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Abstract

The theoretical explanation of "bag" and "bag-with-a-stamen" generation is suggested. Hydrodynamic instability of drop surface due to inertia forces of drop acceleration is enlisted as a hypothetical mechanism of breakup at low Weber numbers, $We<100$, when the drop deformation exceeds great values. The range $20<We<300$ of Weber number for drop is important, in particular, in processes of homogeneous fuel mixture preparation for combustion in rockets, turbines and other combustion engines, liquid metallurgy, fire suppression, etc.
A simplified model of deformed drop, regarded as a thin liquid accelerating layer, is elaborated for instability treatment. Two opposite kinds of boundary conditions on leeward side of drop surface were tested and it is shown, that at $We<70$, the conditions influence essentially on the dominant disturbance development. By the small perturbation techniques the characteristic equation of boundary-value problem for disturbances was derived, and unstable root, the range of unstable wavelengths and equation for wavenumber of dominant unstable disturbance were obtained. The dependencies of wavelength and characteristic time of dominant disturbance on Weber number for various values of deformed drop thickness are calculated and analyzed. The analysis of the numerical results allowed to determine minimum degree of deformation and wavelength needed for "bag" and "claviform" modes of breakup.
The linear instability analysis showed, that in the considered non-viscid hydrodynamic system with Weber numbers of the range $5 \lessapprox We \lessapprox 100$ a development of aperiodic unstable disturbances can be real mechanism of formation of "bag" and "stamen", which is the preliminary of disintegration itself. Results of present investigation based on mathematical ground allowed to give simple theoretical explanation of such a complicated modes of shattering as "bag" and "claviform". This simplicity as well as uniformity of explanation of other modes at greater values of Weber number [1] get evidence to the favor of the original hypothesis. Some reasons for causing "chaotic" mode of shattering are also suggested.
Obtained here from the linear instability analysis dependences help us to find the critical values of Weber criterion, as a conditions for one- and three half-wavelengths aperiodic disturbances to work under thin liquid layer. This values agree well with known experimental boundaries of "bag" and "claviform" modes of breakup for inviscid drops, despite of some roughness of adopted assumptions about streamlining and weak influence of conditions at the edge of deformed drop. Suggested in present communication elementary theory allowed to give simple visual explanation of preliminary and most complicated stage of these modes of breakup.
Following rupture of liquid film of "bag" is of indubitable interest as final stage of breakup, which forms aerosol cloud of fine daughter droplets. It was the aim of another investigation [2], because mechanism of rupture of liquid film of "bag", which is exposed to free stream, possibly has instability nature too. Connecting results of present paper with published earlier for greater Weber numbers, we can get general qualitative conclusion, that hydrodynamic instability of drop surface is indeed a universal mechanism, which proceeds at various modes of drop breakup.

[1] Girin A. G., *Journal of Engineering Physics and Thermophysics* **48**: 560-564 (1985)
[2] Girin A. G., Ivanchenko Ye. A., *12th ICLASS 2012*, Heidelberg, Germany, Sept. 2-6, 2012, # 1226