SHOCK-LESS BREAKUP OF LIQUID DROPLETS: CRITERIA AND TEMPORAL CHARACTERISTICS

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The special mode of the breakup of droplets in the absence of pressure disturbances (compression or rarefaction waves, shock or blast waves) is considered. The discussed mode of droplet shattering is realized, for example, when liquid particles penetrate the layer (jet, sheet) of moving gas. The presented variant of liquid atomization is determined as shock-less droplet breakup (SLDB) as a distinction from the ordinary investigated case, where gas flow is caused by different type pressure disturbances.

On the basis of careful analysis of main SLDB examples, it was shown that during SLDB the liquid particle experienced the impact of the soliton-type Π-shape aerodynamic force impulse. The duration of such an impulse is very often close to characteristic time scale of droplet deformation, or may be compared to the period of their natural oscillations. This feature is determined by the specific non-quasistatic droplet response under the aerodynamic loads.

The critical conditions for the onset of SLDB (in terms of the first critical Weber-number $We_1^* = \rho u^2 d/\sigma$, where σ - liquid surface tension, ρ and u – gas density and velocity, d – droplet diameter) and those for the onset of the shear SLDB sub-mode (in terms of the second critical Weber-number We_2^*) are determined in a wide range of initial pressures, $p_0 = (1 \div 80)$ bar. For ethanol droplets the values We_1^* and We_2^* are measured at $p_0 = (1 \div 40)$ bar. For liquid oxygen (LOX) droplets We_1^* and We_2^* are obtained at $p_0 = (1 \div 80)$ bar. The value of We_1^* is not dependent on p_0. For the value of We_2^*, the empirical correlation is obtained in terms of the Reynolds number ($Re = \rho\, u\, d/\mu$, μ is the gas viscosity) and ratio of liquid/gas viscosity and density. A remarkable coincidence of the critical conditions of breakup phenomena at SLDB-modes and other types of loading of droplets by aerodynamic forces is indicated. However, the response of the droplet on Π-shape aerodynamic impulse depends on the ratio of characteristic temporal scales of the deformation and natural oscillations with respect to the residence time of the droplet in the domain of enhanced gas-dynamic loads. Empirical correlations are suggested for the evaluation of the total breakup time and the duration of the destruction at specific case of non-quasistatic aerodynamic loads. The SLDB of liquid particles, penetrating with a velocity $W_{\Rightarrow}$ into a cross-current gaseous jet with a velocity $V_{\Downarrow}$, is shown to be dependent on the relative velocity $U = \left(W_{\Rightarrow}^2 + V_{\Downarrow}^2\right)^{0.5}$. Generally, the main parameters of SLDB process (We, Re numbers, characteristic times) must be calculated based on this relative velocity, U. The ratio $V_{\Downarrow}/W_{\Rightarrow}$ also defines the deflection of flatted out droplet axis from the direction of the gas jet velocity vector. Up till now, this important factor in pressurized gas systems, was not taken into account. As a result, the quantitative description of the SLDB was incorrect.