DYNAMICS OF TWO-PHASE FLASHING LIQUID JETS

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Liquid flashing phenomena holds an interest in many areas of science and engineering. As examples one can mention: a) the accidental release of flammable and toxic pressure-liquefied gases in chemical and nuclear industry; the failure of a vessel or pipe in the form of a small hole results in the formation of a two-phase jet containing a mixture of liquid droplets and vapor, b) fuel atomization for improvement of fuel injector technology, c) flashing mechanism occurrence in expansion devices of refrigerator cycles etc. Violent boiling and aerodynamic fragmentation control the two-phase behavior of flashing flows. The initial, flashing stage of the jet, where the system is furthest from equilibrium is least understood. To investigate theoretically these source processes, knowledge of accurate and reliable data such as distribution of droplet size, velocity and temperature is mandatory. These models are needed in design and safety assessment. This PhD study focuses on the understanding of the source processes with emphasis on flashing release of flammable pressurized liquids, characterize the two-phase jet after the release and the effects of initial conditions such as initial storage pressure, temperature, geometrical effects of the release points.

The flashing phenomenon occurs when a liquid is out of thermodynamic equilibrium such as sudden changes in the pressure or temperature of a liquid system. In the case of rapid depressurization, the liquid keeps its initial temperature constant, so that, because of thermal inertia, the internal temperature finds itself above the saturation temperature in the final condition. The meta-stable liquid will return violently to its equilibrium condition through evaporation (i.e. consuming its superheat as latent heat). Evaporation will occur within the liquid through bubble growth. This process can be extremely sudden and explosive. Because a maximum surface exchange is crucial for evaporation, the jet will disintegrate into small droplets. Equilibrium will be reached when partial vapor pressure at the interface equals to that far a way from the droplets.

High quality data sets to study the flashing expansion in detail are being provided by employing advanced measurement techniques such as high-speed visualization, Particle Image Velocimetry (PIV), Phase Doppler Anemometry (PDA), Infrared Thermography as well as conventional intrusive techniques. Figure 1 is an example of the disintegration pattern change with increasing superheat and Fig.2 displays the change of the representative droplet sizes statistically averaged over the total cross-section at a selected axial distance from the nozzle for different superheats. Both figures show that the superheat of the liquid plays a very significant role in the atomization process and leads to smaller droplet sizes.

The direct application of this research is the operation and design of safe industrial plants dealing with flammable and/or toxic gases due to improved prediction capabilities and thus leads to improved safety design of industrial plants and reduces the possible consequences both for human lives and investment, if an accident occurs.

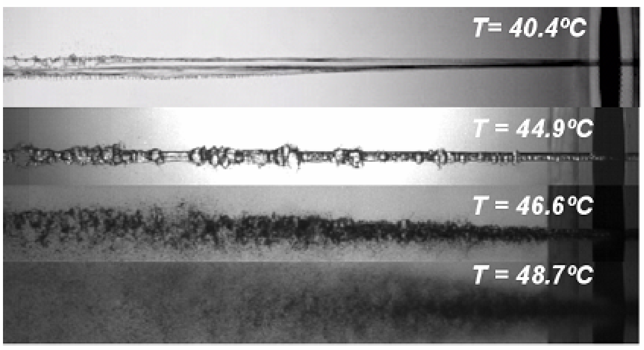

Figure 1: High-speed image sequences for nozzle diameter of 1 mm

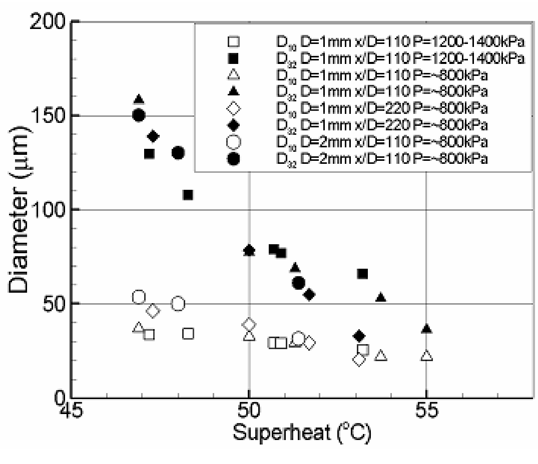

Figure 2 : The effect of superheat on droplet size evolution for 1 mm nozzle