Analytical and Experimental Study of Small Droplet Formation in a Pneumatic Drop-on-Demand Generator

A. Amirzadeh Goghari* and S. Chandra
Department of Mechanical and Industrial Engineering
University of Toronto
Toronto, ON M5S 3G8 Canada

Abstract

Pneumatic droplet generators operate by applying pressure oscillations to the liquid inside a nozzle, which creates a periodic motion of the free liquid surface. In this work, an upward-shooting pneumatic droplet generator, made of stainless steel tubes and pipe fittings, is described. The main body of the generator consists of a simple stainless steel cross-junction. A cylindrical nozzle is attached to its bottom outlet, and the top port is connected to a gas cylinder through a solenoid valve. The third outlet of the cross-junction is open to the atmosphere through a stainless steel vent tube. When the valve is opened for a short duration, a gas pressure pulse is applied to the liquid. The gas moves back and forth inside the vent tube which sets up alternating negative and positive pressure inside the generator and oscillates the free liquid surface. The gas pressure oscillations were recorded using a dynamic pressure transducer, which is connected to the last port of the cross-junction. During positive pressure, a liquid jet emerges out of the nozzle; its tip becomes unstable, and finally detaches and forms a small droplet. The negative pressure then pulls the remaining liquid back. Photographs of droplets emerging from the droplet generator showed the oscillation of the liquid surface prior to droplet ejection and the time lag between the pressure oscillation and droplet ejection. The time lag increases as liquid viscosity decreases or the nozzle diameter becomes greater. An approximate analytic model of incompressible liquid motion in the nozzle is also studied. The model demonstrates that the motion of the surface is out of phase with the exciting pressure oscillation. It also predicts that maximum liquid velocity is obtained at an intermediate value of viscosity, making it the most favorable for producing liquid droplets. Experiments confirmed that the largest liquid motion was achieved with a mixture of 60 wt% glycerin with water, and droplets the same size as the nozzle diameter could be produced with this mixture, even when droplets were not formed from pure water or glycerin. Varying the duration of the pressure pulse made it possible to produce droplets smaller than the nozzle (approximately 38% the nozzle diameter).

Key words: experimental design, fundamental analysis, industrial

*Corresponding author, afsoon@mie.utoronto.ca