Investigating Dispersion and Emulsification Processes using a Sonolator Liquid Whistle

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Sonolator liquid whistles (ex. Sonic Corp, USA, see Figure 1) are used within industry to create complex multiphase mixtures which form components of high value added liquid products. Despite their relatively common use, the mechanism of their operation is not well understood; the focus of this study is a combined experimental and computational approach to elucidate key phenomena governing drop and jet break-up.

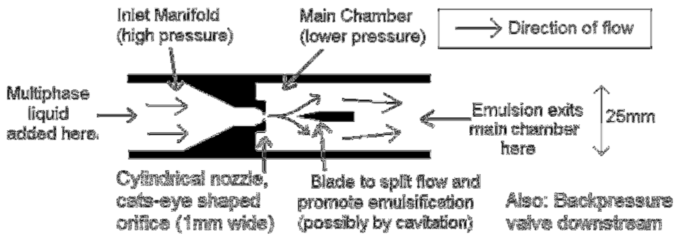

Figure 1: Sonolator schematic diagram (from side of orifice)

The fluid dynamics within the device have been investigated experimentally using Particle Image Velocimetry (PIV) carried out on a pilot scale Sonolator with a Perspex window for visibility; these data have been used to develop and validate steady-state computational fluid dynamics (CFD) simulations. Mean and fluctuating velocity components and local specific turbulent energy dissipation rates (epsilon) obtained from CFD simulations (Figure 3) using a SST (RANS) turbulence model show reasonable agreement with the PIV data. Figure 2 shows the PIV data; the comparison between CFD and PIV is in Figure 4.

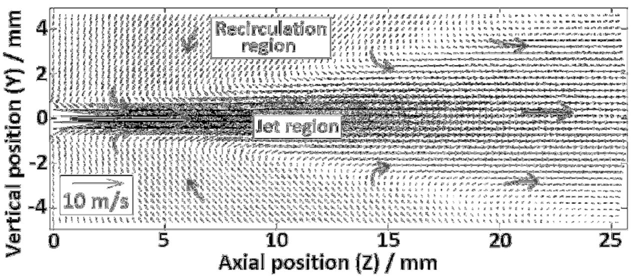

Figure 2: Vector plot of average flow field in the Sonolator from PIV
(averaged from 500 frames, YZ plane for '0110' type orifice, 5.53 kg/min, dT = 5 µs)

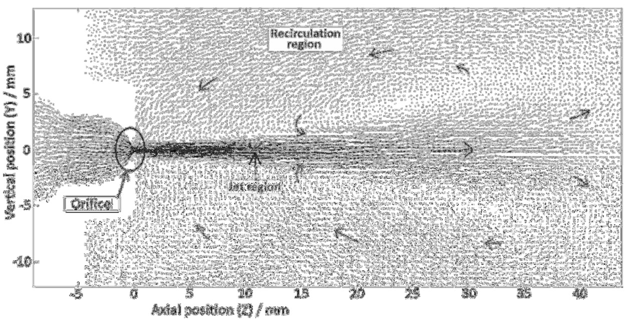

Figure 3: Vector plot of velocities from CFD (same conditions; Octree mesh)

The models of Hinze [1] and Walstra & Smulders [2] in the turbulent inertial break-up regime correlate droplet breakage to epsilon raised to a unique power which is dependent upon the mechanism of break-up; whether break-up is limited by interfacial tension (Hinze) or by dispersed phase viscosity (Walstra). Peak values of epsilon in the region after the orifice calculated from the CFD simulations thus provide a parameter to predict droplet size.

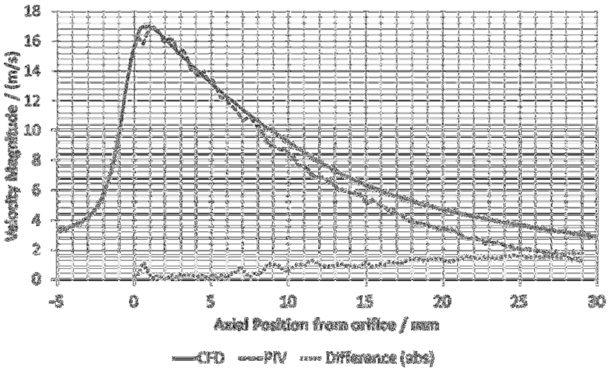

Figure 4: Graph of velocity magnitude along the axial line. CFD / PIV comparison.

Pilot plant experiments have been performed to obtain droplet size distributions within the Sonolator as a function of mass flow rate, orifice size, dispersed phase concentration and dispersed phase viscosity. Silicone oil-in-water emulsions have been generated using Sodium Lauryl Ether Sulphate (SLES) as surfactant. Droplet size distributions have been determined using a Malvern Mastersizer 2000; the dependency of average droplet size on the system parameters has thus been analysed. Figure 5 gives droplet size data for different flow rates and viscosities.

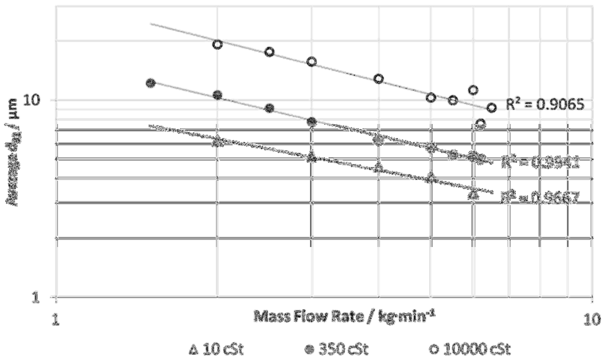

Figure 5: Graph of average droplet size vs mass flow rate (log-log axes)

An empirical model was formed to predict droplet size from pressure drop and dispersed phase viscosity. The comparison between the empirical model and the theoretical models of Hinze and Walstra was only partially successful. Modifications related to the dependence of interfacial tension upon epsilon were made, resulting in better agreement between empirical model and theory.

1. **Hinze J. O.** *"Fundamentals of the Hydrodynamic Mechanism of Splitting in Dispersion Processes."* A.I.Ch.E. Journal, 1(3), September, p. 295. (1955)
2. **Walstra P., Smulders P. E. A.** *"Emulsion Formation",* Chapter 2 of Modern Aspects of Emulsion Science, ed. Binks B. P. pp56-99 (1998)