Experimental Setup for the Study of Jet Interactions

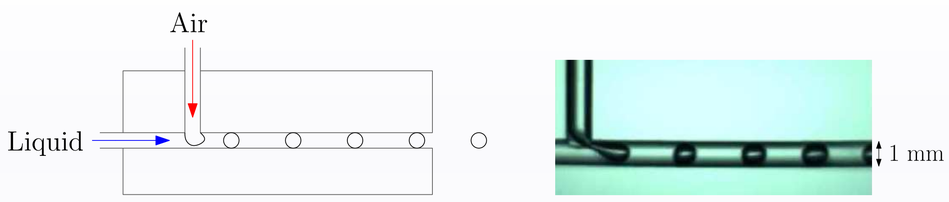
F. Suñol, R. Pino, O. Maldonado and R. González-Cinca
Departament de Física Aplicada, Universitat Politècnica de Catalunya, Barcelona, Spain

Introduction

- New experimental setup for the study of bubble coalescence and bubble jet interactions in microgravity conditions is presented [1].
- Test section consists of a cavity full of liquid containing two bubble injectors whose separation distance and relative orientation angle can be controlled.
- Injection of bubbles is based on the generation of a slug flow in a capillary T-junction [2].
- On ground results on bubble trajectories, maximum distance reached, and the delimitation between turbulence and buoyancy regions are presented.
- The influence on these results of the inclination angle of an injector with respect to gravity has also been considered.

Generation of bubbles

Main idea of the device used to generate the bubbles:

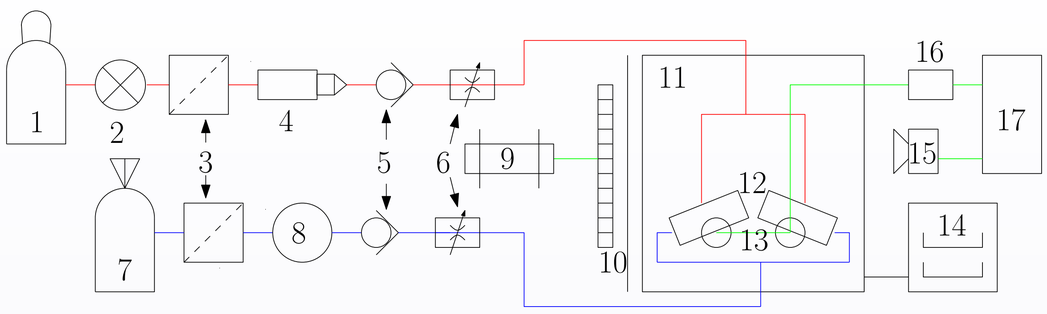


Scheme of the injectors used (BUBGEN)[2]. This method is able to generate up to 500 bubbles per second.

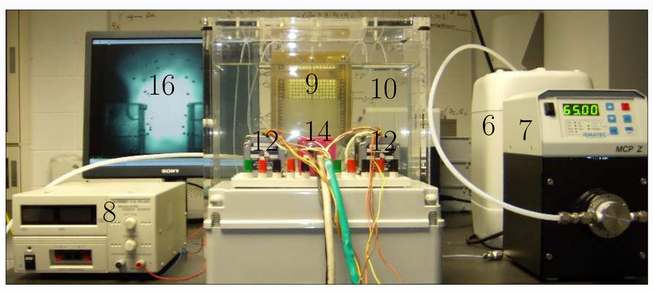
- Operation independent of the gravity level (low Bond numbers, $Bo = \Delta\rho g L^2/\sigma \ll 1$).
- Bubble generation frequency controlled via Liquid and Gas flow rates (Q_l and Q_g, respectively).

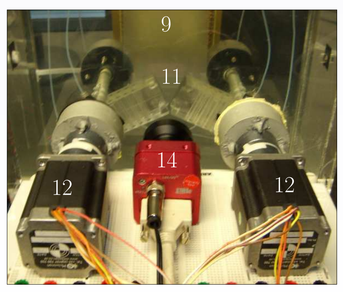
Experimental Setup

A methacrylate cavity full of liquid, in which the bubbles are injected, is surrounded by the corresponding control and data acquisition devices.

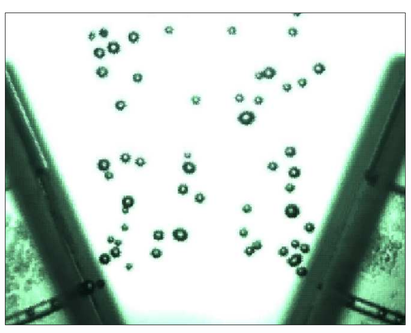


Connections: Air, Liquid, Electric.
1: Air bottle, 2: Pressure regulator, 3: Filters, 4: Choked orifice, 5: Anti-return valve, 6: Flowmeters, 7: Liquid Tank, 8: Pump, 9: DC supply, 10: Leds, 11: Cavity, 12: Injectors, 13: Motors, 14: Tank, 15: Camera, 16: μcontroller, 17: PC.

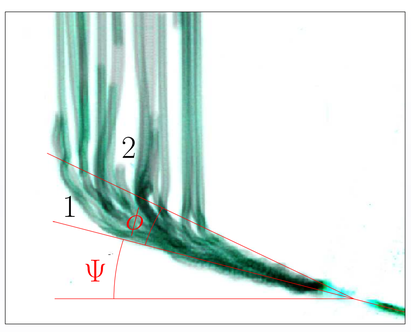




Scheme and pictures of the experimental setup.



Snapshot of the bubble jets at $\Psi = 23°$.



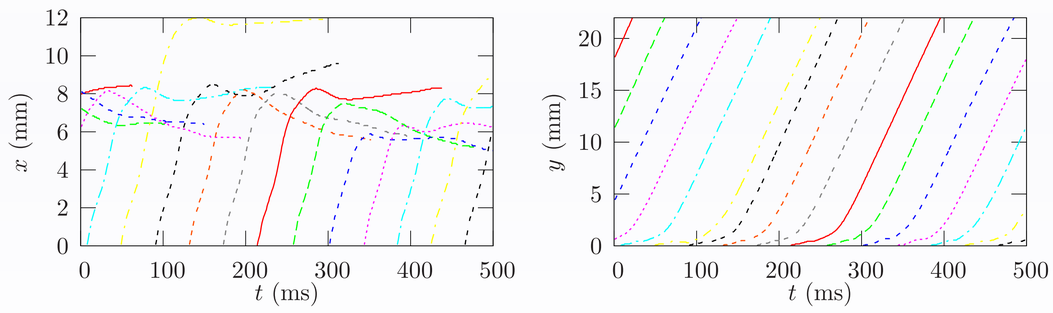
Definition of angles ϕ and Ψ, and distinction between turbulence (1) and buoyancy (2) zones.

Results in $1g$

Individual trajectories

These results are taken at 1000 fps, with $Q_g = 1$ ml/min and $Q_l = 16.7$ ml/min, and $\Psi = 0$.

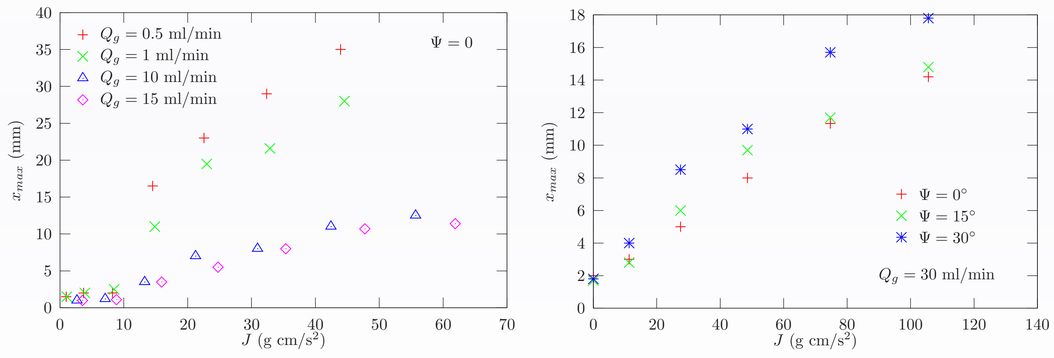
- $\boldsymbol{x}$: direction of injection.
- $\boldsymbol{y}$: direction of gravity.



Variation of x and y coordinates versus time. We can see in the x coordiante plot that the generation frequency is uniform. In the y coordinate plot all the bubbles have the same rise velocity, demonstrating that they have the same size.

Maximum distance

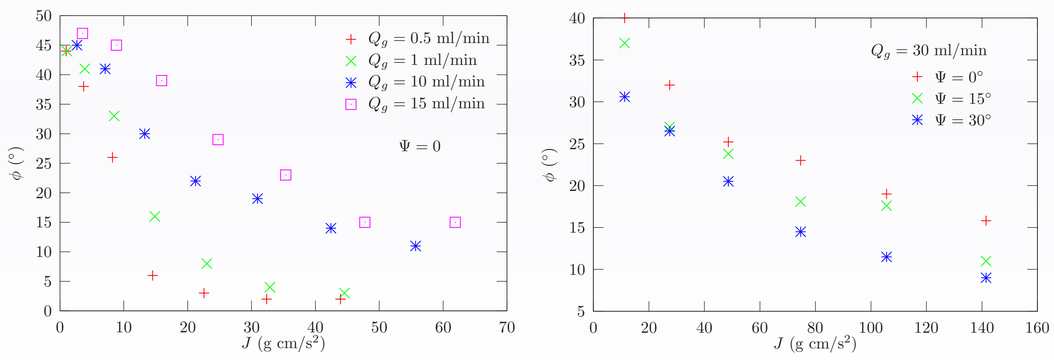
- $\boldsymbol{J}$: momentum injection rate (main parameter that characterizes the structure of the jet). Negelcting the gas density, it can be computed as $J = \rho_l Q_l (Q_l + Q_g)/A$ where $A = \pi d_C^2/4$ is the area of the capillary tube and $d_C = 1$ mm its diameter.
- $\boldsymbol{x_{max}}$: maximum distance reached by the bubbles in the direction of injection for $\Delta y = 1\, d_C$:



Variation of x_{max} for different values of the momentum injection rate J. ***Left:*** Different values of Q_g, and $\Psi = 0$ (injectors oriented face to face). ***Right:*** Different values of Ψ (different angles between injectors), and $Q_g = 30$ ml/min.

Buoyancy and turbulence zones

Two different behaviours can be observed: Turbulence zone (1) where is impossible to predict the trajectory of individual bubbles, and buoyancy zone (2) where all the bubbles are rising in a linear path. The angle ϕ separates these zones.



Variation of ϕ for different values of the momentum injection rate J.

Conclusions

1. New design to study bubble jet interactions, dynamics and coalescence.
2. Bubble size, velocities, generation frequency and incidence angle can be controlled.
3. Individual and collective behaviour of bubbles have been studied.
4. Several tests carried out in $1g$ for a further use in $0g$.

1. F. Suñol, O. Maldonado, R. Pino, and R. González-Cinca, *Experimental design for the study of bubble jet interactions in microgravity*, preprint, 2007.
2. J. Carrera, X. Ruiz, L. Ramírez-Piscina, J. Casademunt, M. Dreyer, *Generation of a Monodisperse Microbubble Jet in Microgravity*, submitted to AIAA Journal, 2007.