Experimental characterization of a microbubble injector

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Microgravity group

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Outline

1. Motivation & objectives
2. Theory of bubble generation
3. Experimental setup
4. Results and discussion
5. Conclusions
6. Future developments

Motivation

- Two-phase flows are essential to space technology:
  - Power generation
  - Bioreactors
  - Propulsion systems
  - Heat management techniques
  - Environmental Control and Life Support Systems (ECLSS)

- Fundamental and technological aspects.

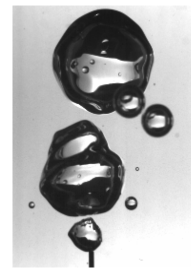
- Bubble generation and management is extremely sensitive to gravity.

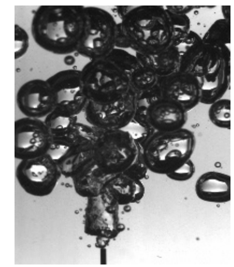
- Develop new techniques and systems.

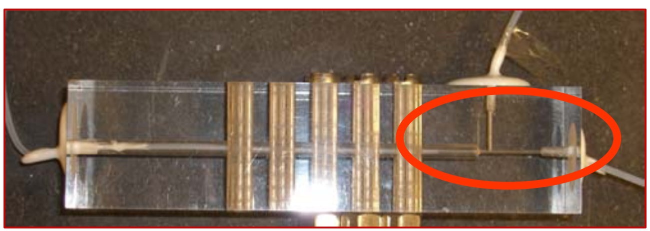
Objectives

- A new microbubble injector for generating small bubbles (from 0.5 to 1.5 mm in diameter) is proposed [1].
- Characterization of a new microbubble injector insensible to the gravity field.

Carrera, Parthasarathy, Gollahalli (2006)







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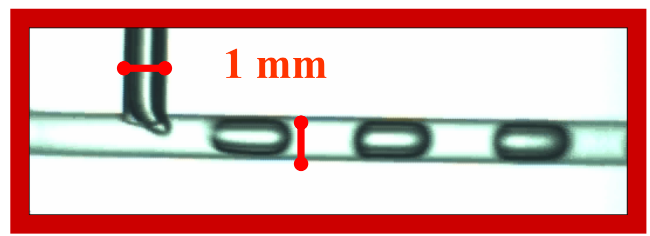


[1] J. Carrera, X. Ruiz, L. Ramírez-Piscina, J. Casademunt, M. Dreyer, Generation of a Monodisperse Microbubble Jet in Microgravity, submitted to AIAA Journal (2007)

Theory of bubble generation

Fundamental physics:

- $We^0 \sim 1, 10$
- $Bo \sim 10^{-1}$
- $Re \sim 10^6, 10^7$

→

- Capillary regime
- Independent of gravity
- Turbulent regime

Prediction for dimensionless bubble size [1]:

i) Bubble diameter of the order of the capillary

ii) Weak dependence of We

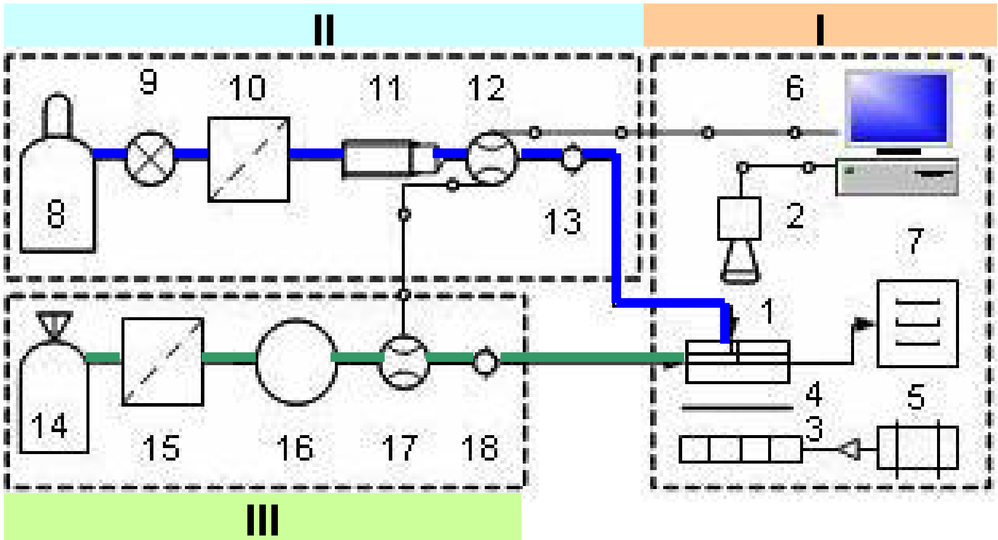
iii) Reduced size dispersion

$$\phi_B = \phi_C \left(\frac{1}{\alpha} - \frac{1}{2\alpha^2} \left(\frac{We^0}{We^c} \right)^{1/2} \right) + o(We^o)$$

$$We^0 = \frac{\rho_l u_l^2 \phi_l}{\sigma}$$

[1] J. Carrera, X. Ruiz, L. Ramírez-Piscina, J. Casademunt, M. Dreyer, Generation of a Monodisperse Microbubble Jet in Microgravity, submitted to AIAA Journal (2007)

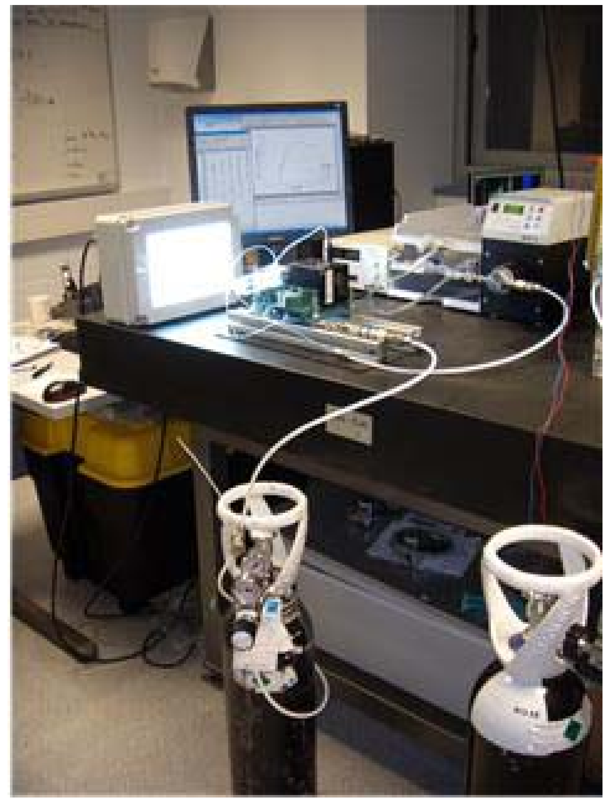
Experimental Setup



I) test section (1: injector, 2: HS camera, 3: light source, 4: diffuser, 5: power supply, 6: computer, 7: residual tank)

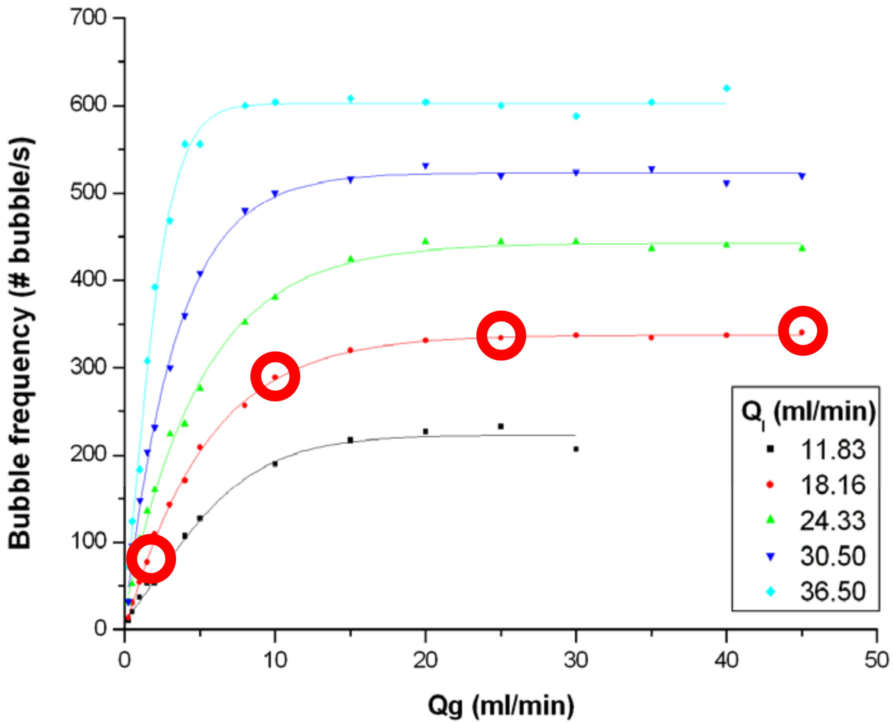
II) air supply system (8: air bottle, 9: manometer, 10: air filter, 11: chocked orifice, 12: air mass flow meter, 13: check valve)

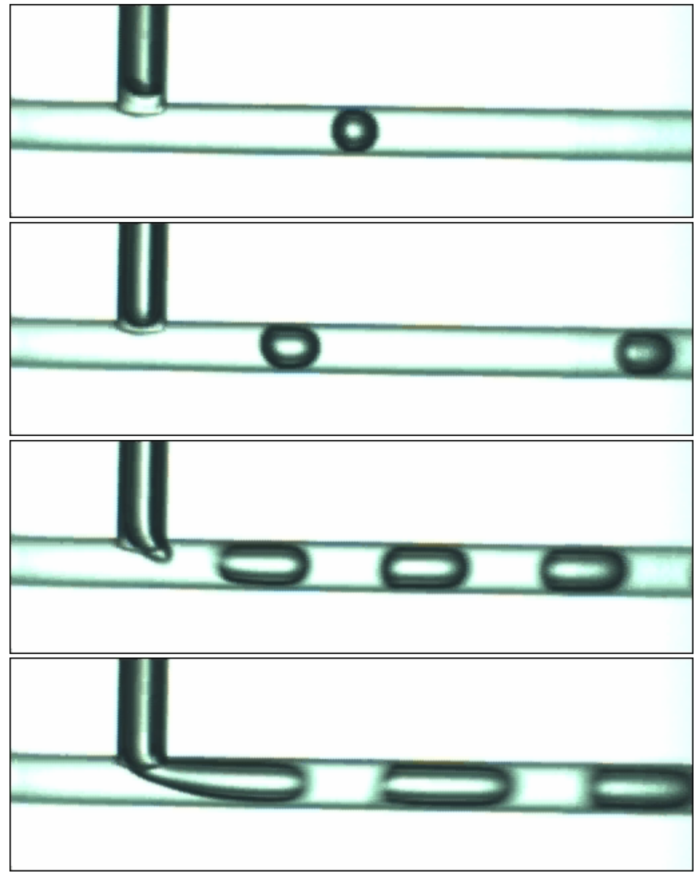
III) water supply system (14: water tank, 15: filter, 16: pump, 17: water mass flow meter, 18: check valve).



Results: bubble frequency

- **2000 fps**
- **Play velocity: 10 fps**



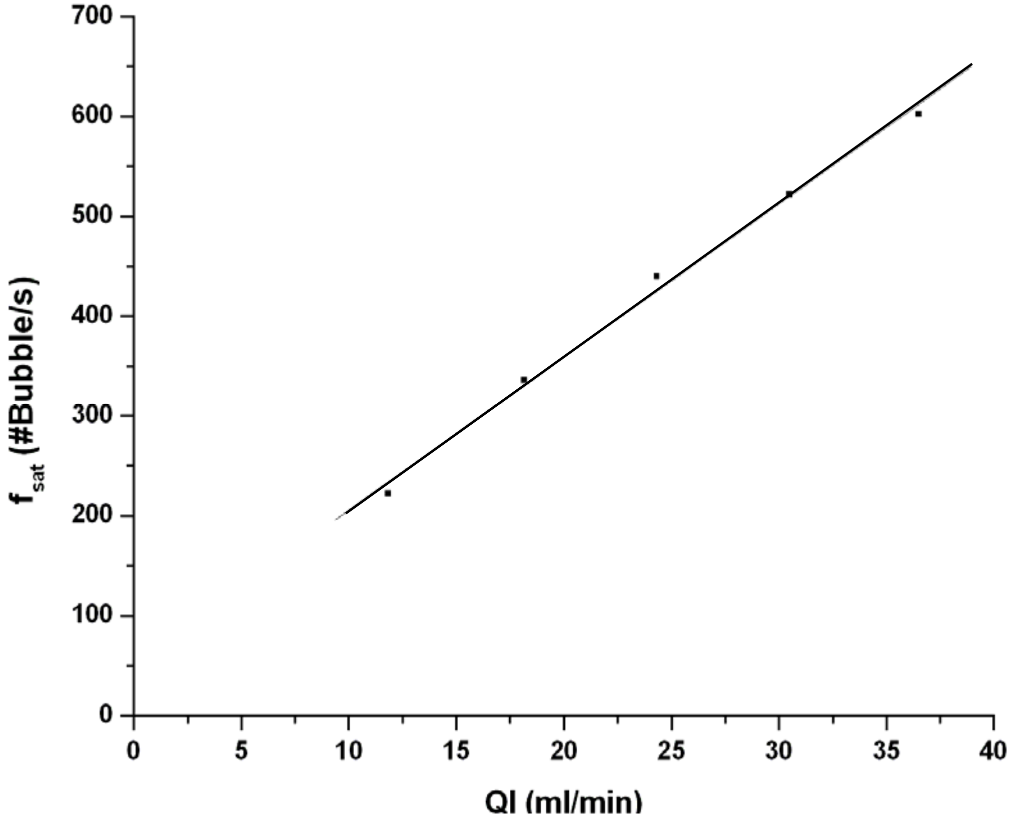


Two regimes can be distinguished:

a) Bubble generation frequency as a linear function of Qg.

b) Saturation.

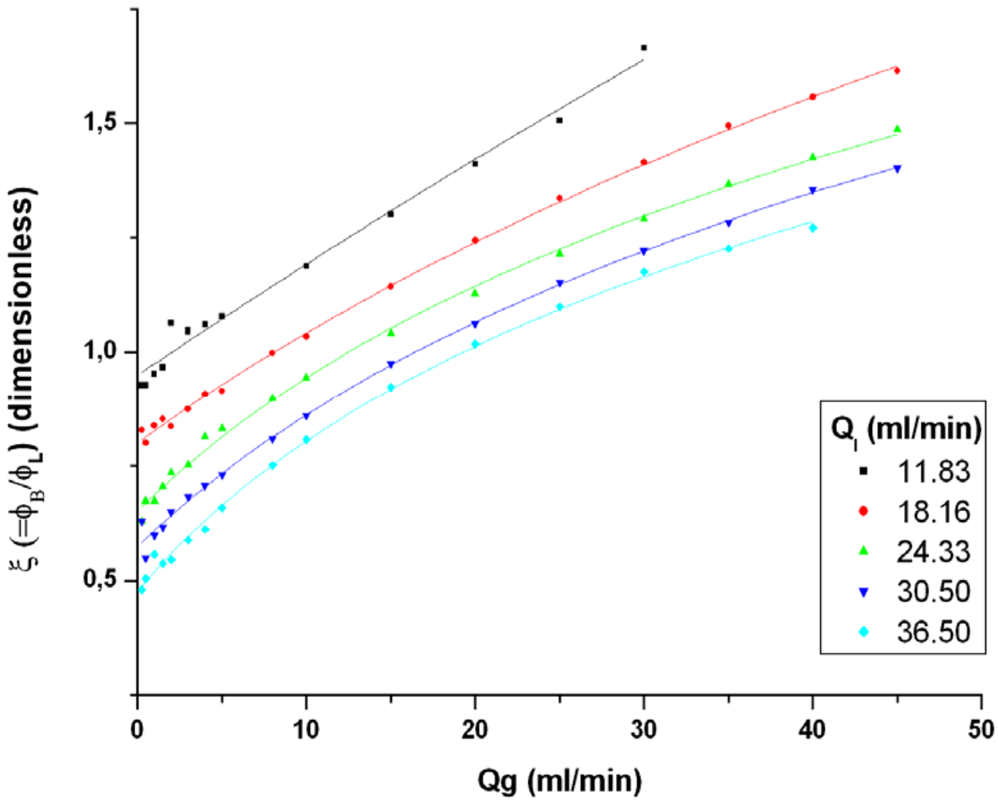
Results: saturation frequency



$$f_{sat} = \frac{Q_l}{\phi_c^3}$$

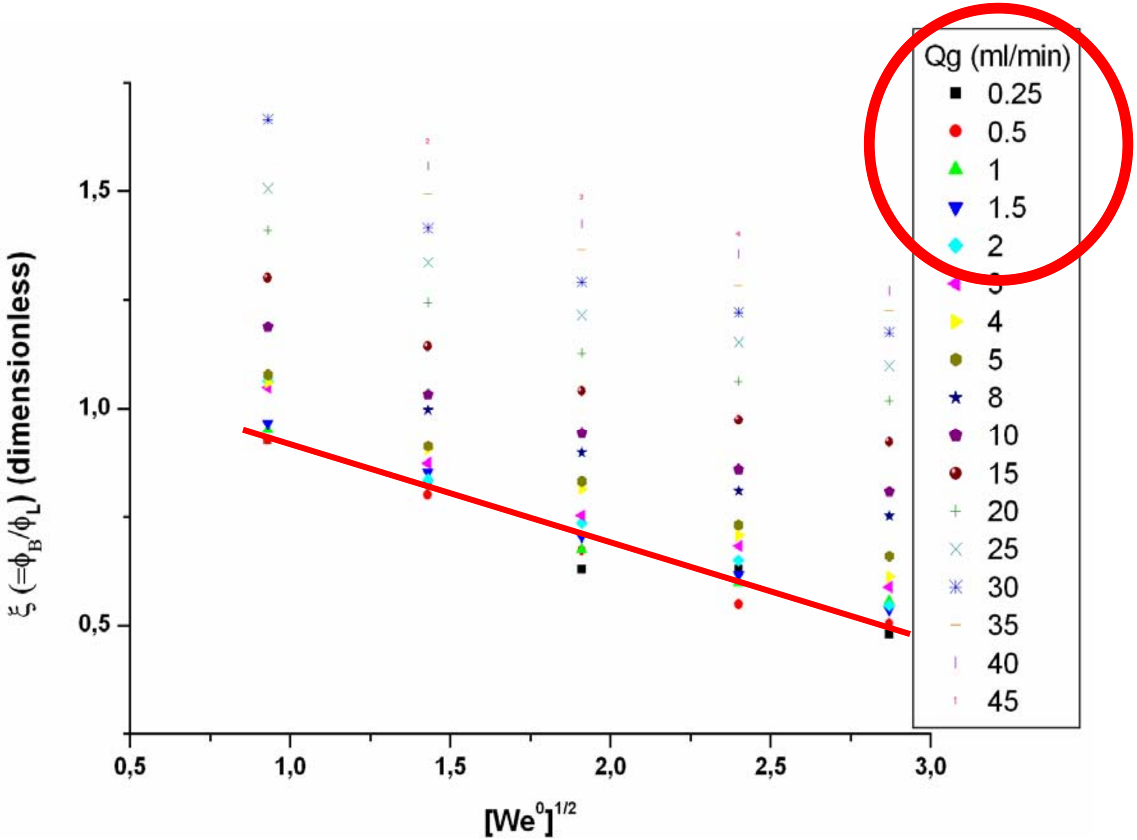
- Bubble frequency saturates at a nominal value which depends only on Ql.
- A simple scaling law for the bubble generation frequency at saturation.

Results: average bubble size



- Control over the bubbles sizes (of the order of the capillary diameter).
- Excellent performance of the injector.

Agreement with theory



- Bubble size depends linearly on $We^{0\ 1/2}$.
- Points corresponding to the smaller gas flow rates (roughly up to 2 ml/min), tend to superpose, consistently with predictions.
- Excellent agreement with theory

Conclusions

Extensive characterization of a bubble injector (1 mm) was performed:

- The performance of the capillary T-junction injector, insensitive to gravity, is excellent.
- Excellent agreement with theory which explains the performance of the injector, and predicts the bubble diameter generated (with dependence on $We^{0\ 1/2}$).
- Generation of a regular slug flow in a turbulent regime.
- Presence of two distinct operation regimes of the injector { Linear / Saturation

Future developments

- Current on-ground experiments:
    - Changes of the capillary diameters.
    - Changes in fluids.
    - Explore other parameters regimes.
    - Universal flow regime map.

- Numerical simulations:
    - Modellization of the injector.
    - Study the different regimes.

- Experiments in microgravity conditions:
    - Drop tower INTA.
    - Next campaign of ESA parabolic flight.


Thank you for your attention!!
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