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Numerical simulation of bubble-train flow with heat transfer in a square mini-channel

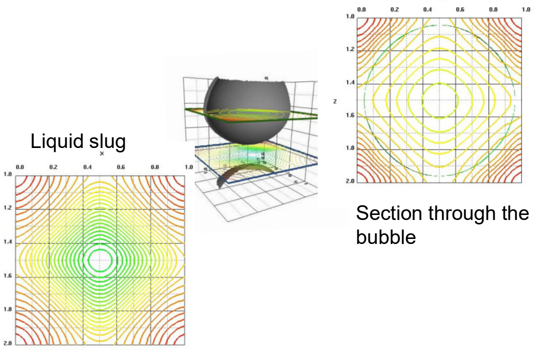
Application

- Periodic incompressible gas-liquid flow: bubble-train flow
- Rectangular channels with hydraulic diameter D_h~1 mm

⇒ Compute the flow of a train of bubbles in a square channel with constant wall heat flux.

- 3D flow structure both in the liquid and inside the bubble
- 3D temperature distribution

Cross-section temperature distribution

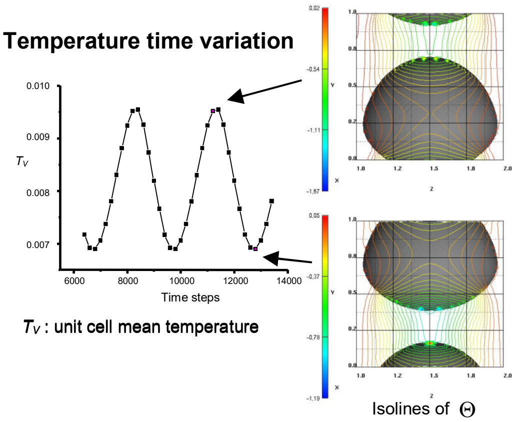


Numerical method

Computer code: **TURBIT-VoF**

- Incompressible single and two-phase flows
- Dimensionless mass, momentum and energy equations
- Interface tracking method: Volume-of-Fluid procedure (VoF)
- Piecewise linear interface reconstruction: EPIRA algorithm
- Finite volume (space) + 3-rd order Runge-Kutta method (time) discretization
- Grid: 64 × 64 × 64 mesh cells (uniform grid)

Temperature time variation



T_V : unit cell mean temperature

Fully developed heat transfer model (two-phase)

- Hydrodynamic fully developed flow
- Stationary regime : Balance between the heat introduced in the system and the one removed from the system
- Wall heat flux uniform in stream-wise direction (y)
- Fluids with constant properties; no phase change at the interface

⇒ Subdivide the temperature in two components:

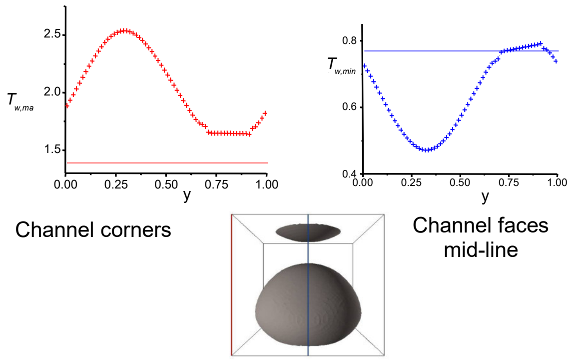
$$T_k(x,y,z) = \theta_k y + \Theta_k(x,y,z) \quad k = 1,2$$

$$\theta_k = \frac{T_k(x,y+L,z) - T_k(x,y,z)}{L} = \theta = const.$$

$$\Theta_k : periodic$$

$$\frac{\partial \langle \rho C_p \Theta \rangle_V}{\partial t} + \nabla \cdot \langle \rho C_p \Theta \mathbf{v} \rangle_V = -\frac{1}{\mathrm{Pe}} \nabla \cdot \langle \lambda \nabla \Theta \rangle_V - \langle \rho C_p v \rangle \theta - \frac{(\lambda_1 - \lambda_2)\theta}{\mathrm{Pe}} a_{int,y}$$

Axial variation of the liquid temperature at the wall compared with single phase case (lines)



Conclusions

- The flow structure for different flow parameters has been studied and the coupling between the flow inside the bubble and in the liquid could be analyzed.

  → Better understanding of the basic hydrodynamics

- Detailed information about the mechanisms of heat transport in the channel have been obtained and a characterization of the bubbles influence on the heat transfer was possible

  → Better understanding of the mixing properties of the flow