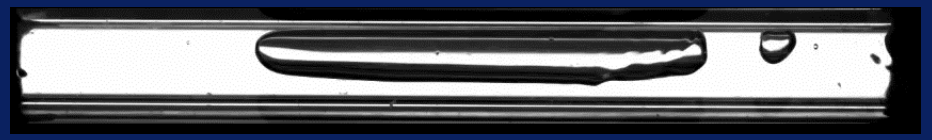
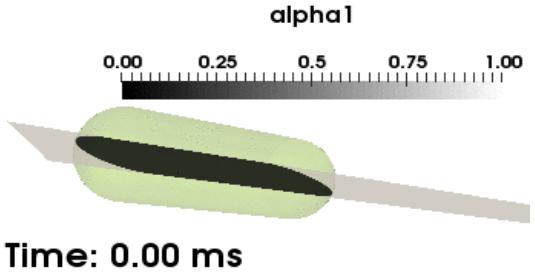
Break-up Mechanisms and Conditions for Vapour Slugs Within Mini-Channels

Dr. Manolia Andredaki, Dr. Anastasios Georgoulas, Dr. Nicolas Miche, Prof. Marco Marengo

INWIP - “Innovative Wickless Heat Pipe Systems for Ground and Space Applications”
Microgravity Applications Promotion Programme for the International Space Station (MAP)

HyHP-Novel Hybrid Heat Pipe for Space and Ground Applications
Engineering and Physical Sciences Research Council (EPSRC)





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Presentation Overview

- ✓BACKGROUND & MOTIVATION
- ✓NUMERICAL FRAMEWORK
- ✓RESULTS
- ✓CONCLUSIONS
- ✓FUTURE WORK

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BACKGROUND & MOTIVATION

- Heat transfer systems have become somewhat ubiquitous; they are to be found in electronic devices, in energy and transportation and in households in general.
- The demand for increasingly higher performances, has pushed researchers and engineers to develop a new generation of systems based on the local phase-change of a working fluid.
- The latent heat associated to the phase change of a fluid is indeed a very efficient way of absorbing or releasing heat in such heat transfer systems.
- Efficient thermal control especially in space applications and the reduction of moving mechanical elements is of crucial importance and ***two-phase closed-loop systems*** can meet these requirements.

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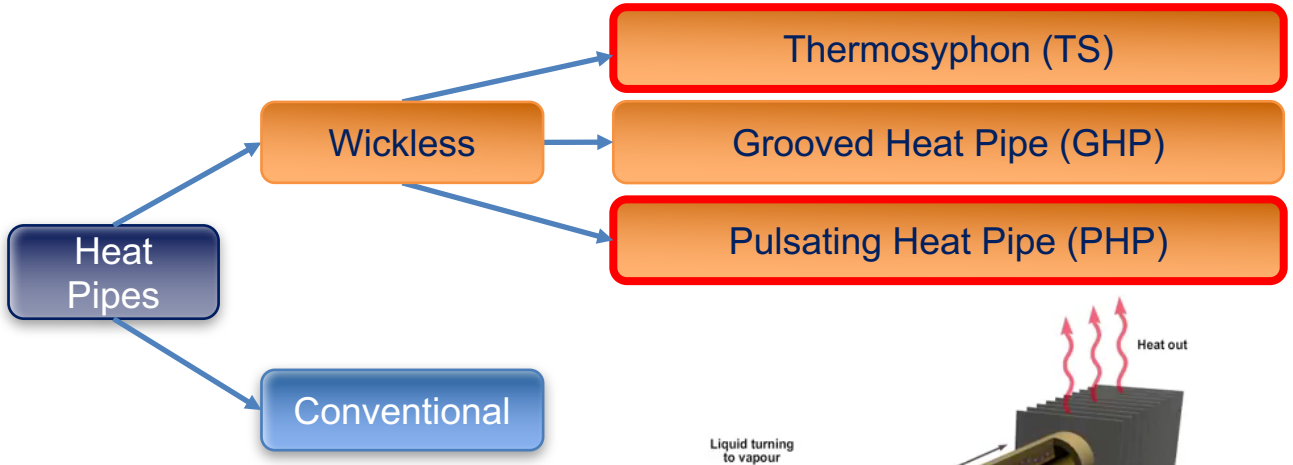
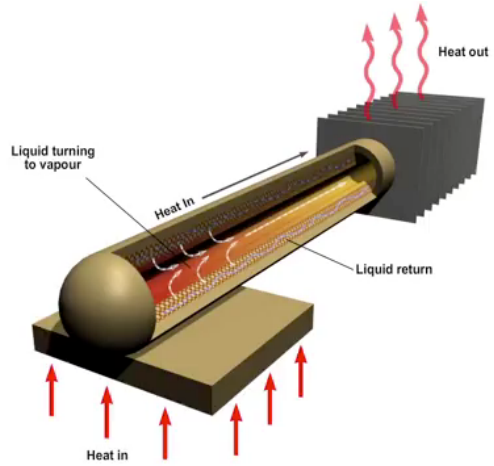
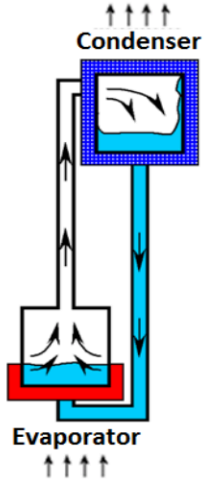
BACKGROUND & MOTIVATION

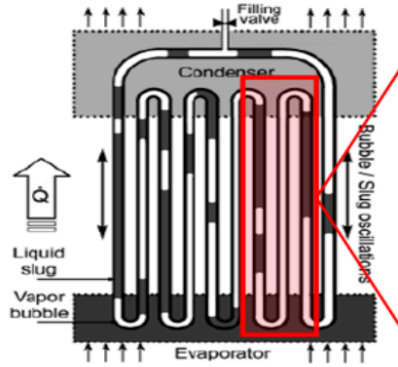
- The use of heat pipes consisting of mini- and micro-channels is a promising alternative to conventional heat transfer systems, due to their much higher heat flux removal rates and the possibility of direct integration into the heat-dissipating substrates.

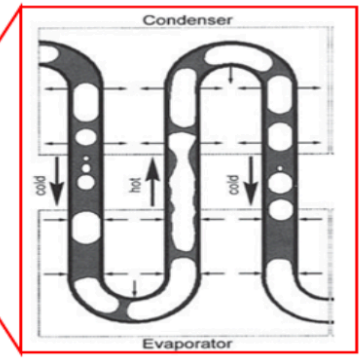
- A heat pipe device is mainly based on capillarity and phase-change of an operating/working fluid.











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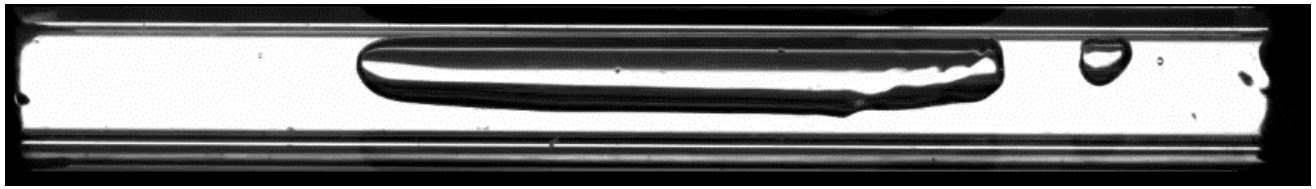

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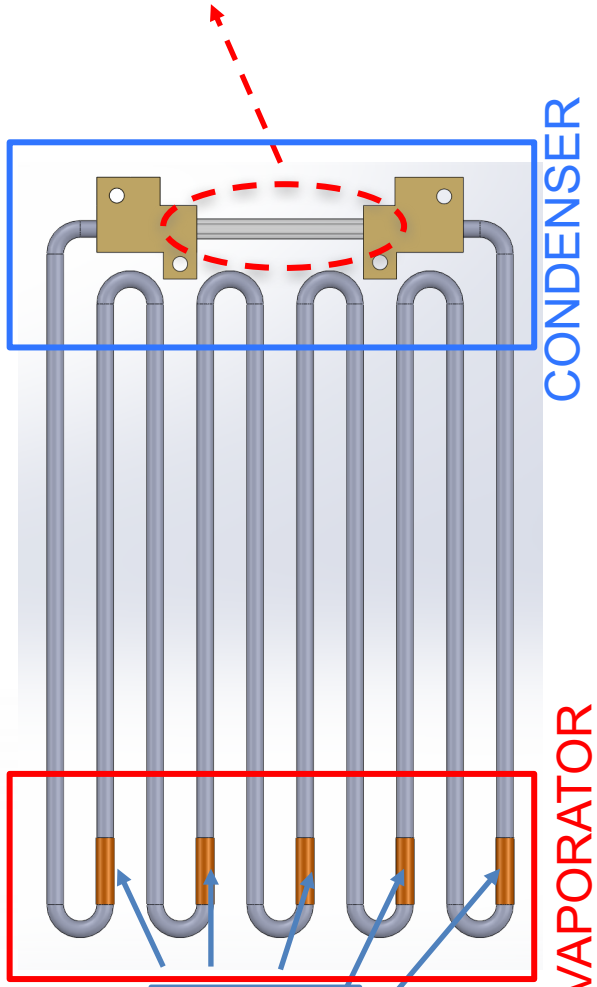
1 g: Stratified flow

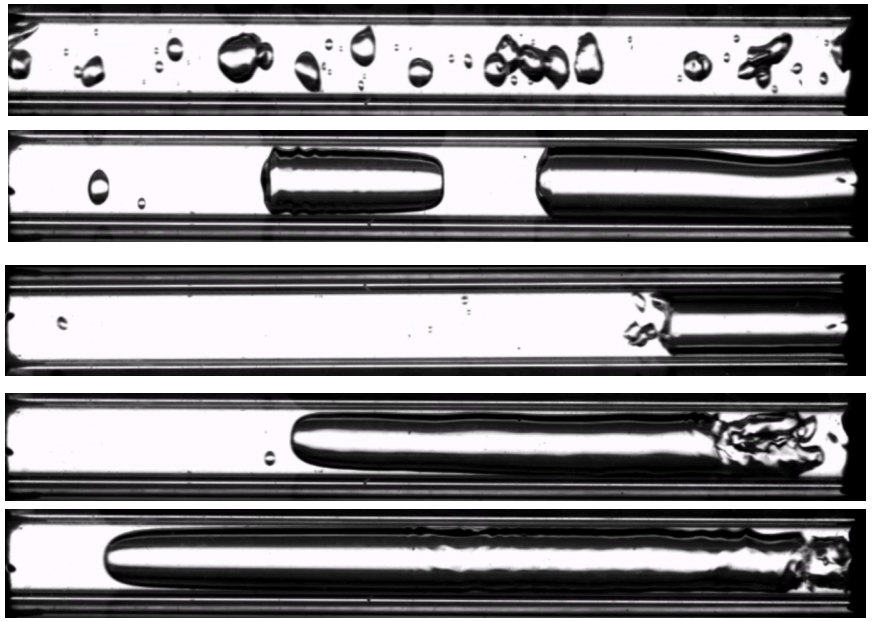
1.8 g: Stratified flow

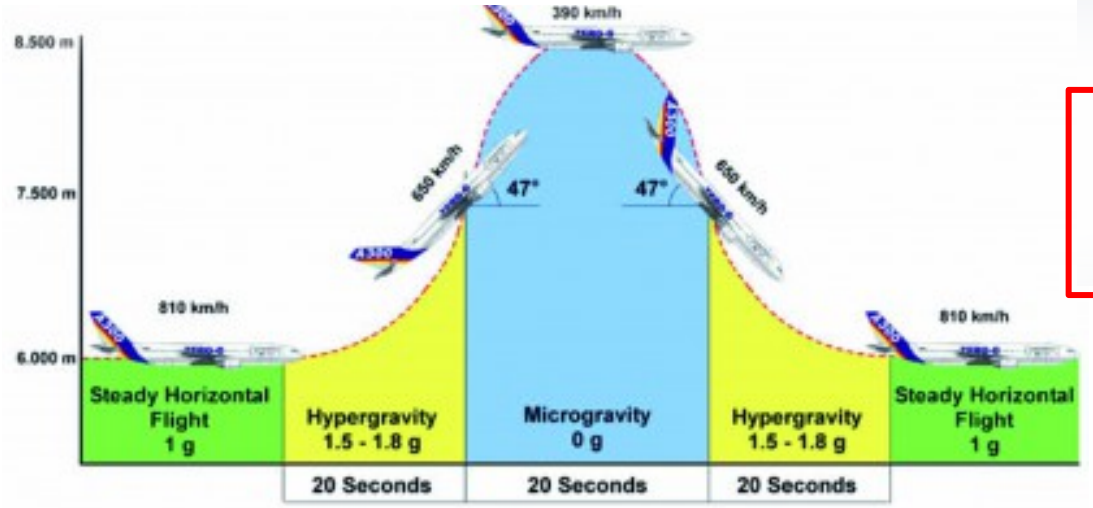
0 g: Slug/plug flow activation

1.8 g: Stratified flow

1 g: Stratified flow







International Journal of Thermal Sciences 95 (2015) 53–63

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

A pulsating heat pipe for space applications: Ground and microgravity experiments

D. Mangini [a], M. Mameli [a, *], A. Georgoulas [a], L. Araneo [c], S. Filippeschi [b], M. Marengo [a, d]

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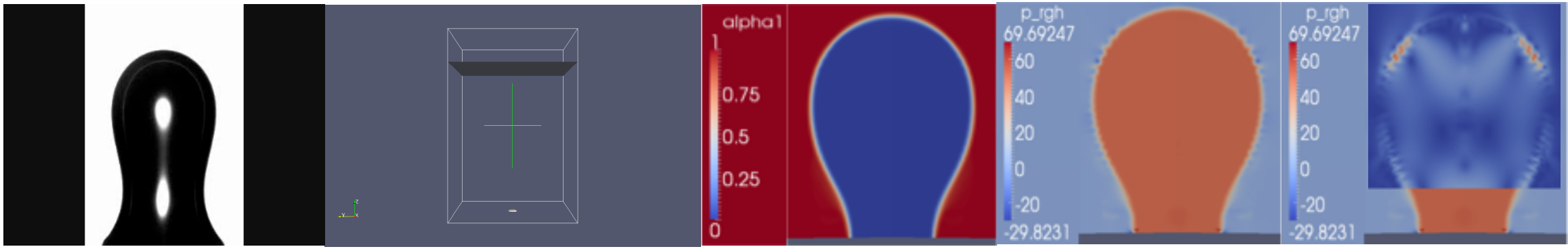
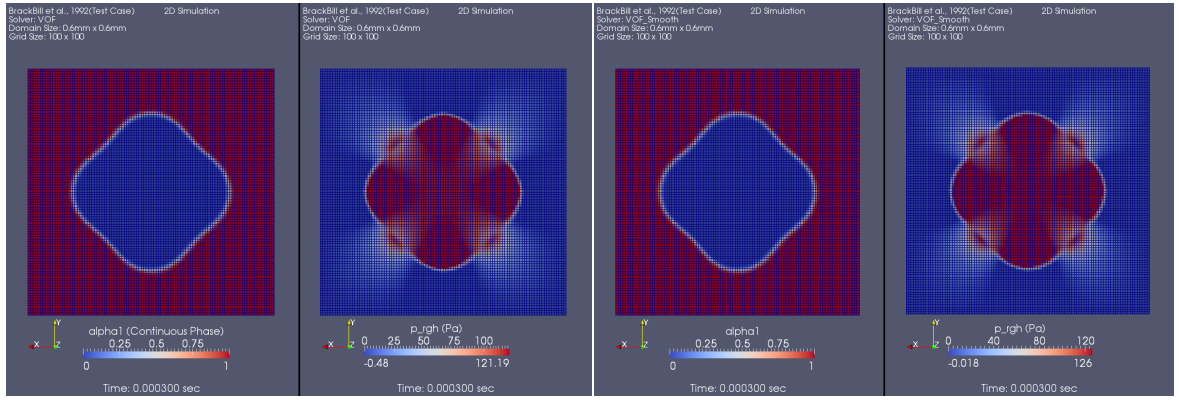
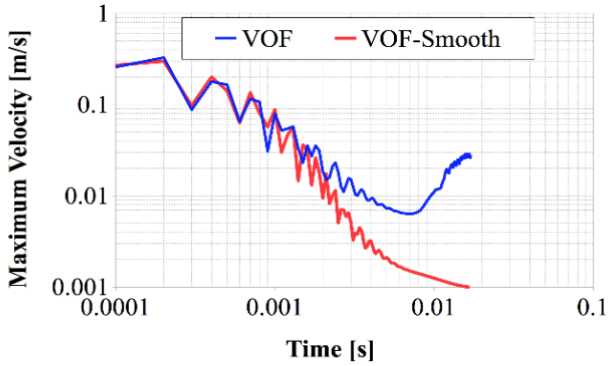
NUMERICAL FRAMEWORK

Original VOF based solver (OpenFOAM)

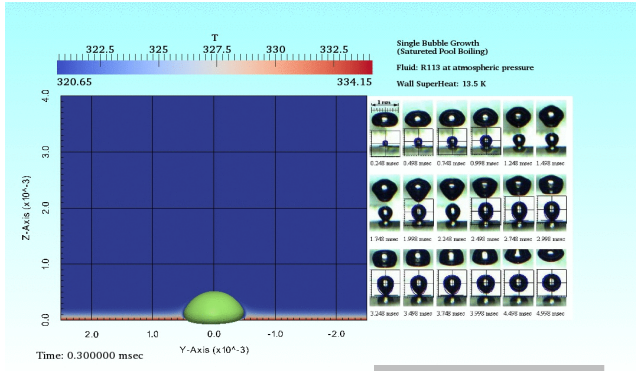


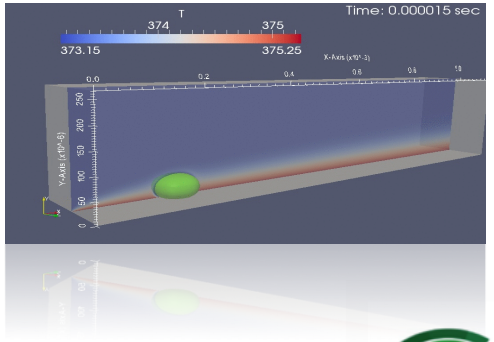
Treatment for spurious velocities dampening

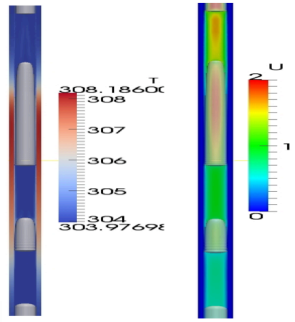


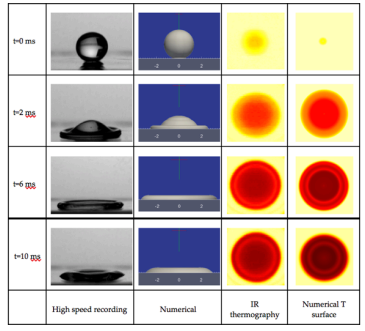


Addition of Energy Equation and Phase-change model of Hardt & Wondra (2008)









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NUMERICAL FRAMEWORK

International Journal of Multiphase Flow 74 (2015) 59–78

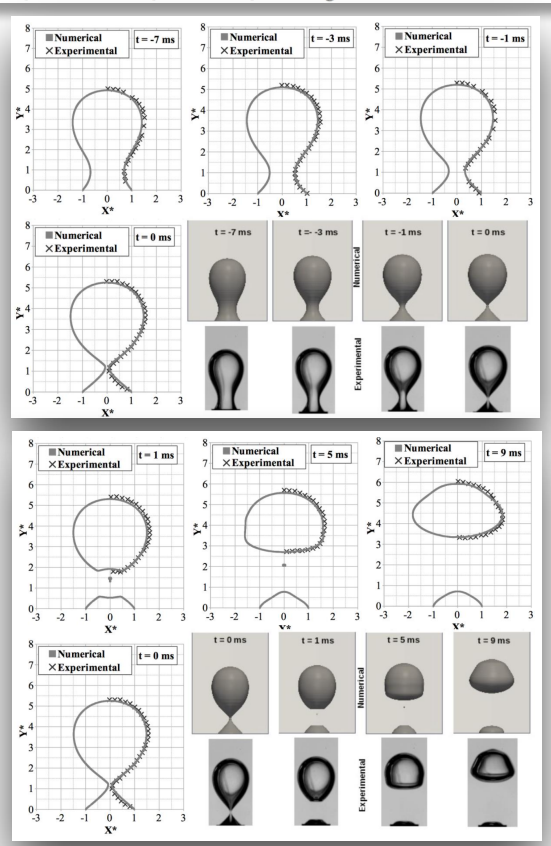
Contents lists available at ScienceDirect

International Journal of Multiphase Flow

journal homepage: www.elsevier.com/locate/ijmulflow

Numerical investigation of quasi-static bubble growth and detachment from submerged orifices in isothermal liquid pools: The effect of varying fluid properties and gravity levels

A. Georgoulas [a,b,*], P. Koukouvinis [c,d], M. Gavaises [c], M. Marengo [a,e]



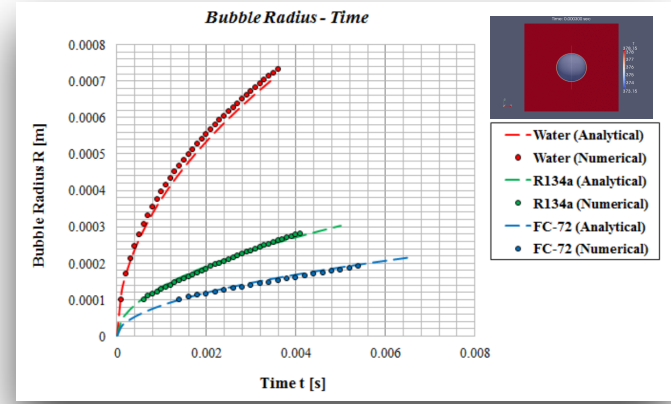
energies

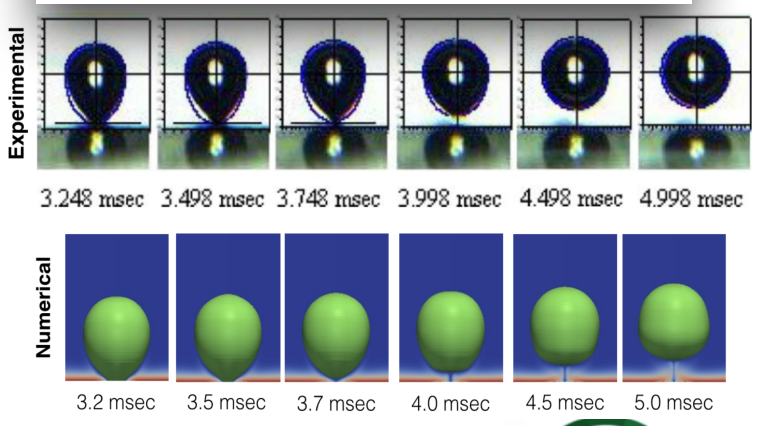
MDPI

Article

An Enhanced VOF Method Coupled with Heat Transfer and Phase Change to Characterise Bubble Detachment in Saturated Pool Boiling

Anastasios Georgoulas *, Manolia Andredaki and Marco Marengo





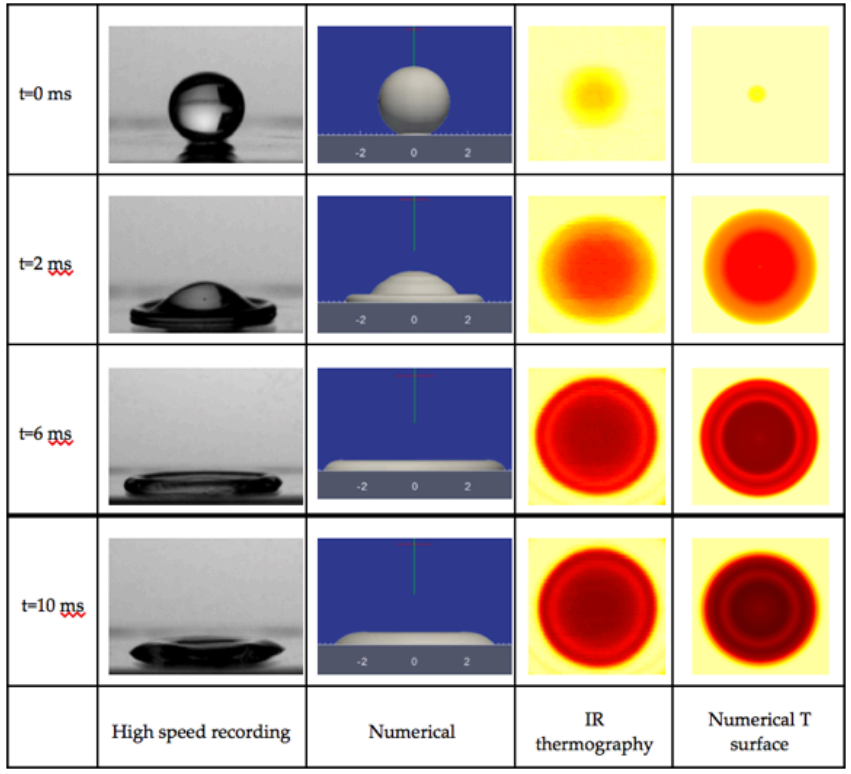
energies

MDPI

Article

Sensible Heat Transfer during Droplet Cooling: Experimental and Numerical Analysis

Emanuele Teodori [1], Pedro Pontes [1], Ana Moita [1], Anastasios Georgoulas [2,*], Marco Marengo [2] and Antonio Moreira [1]



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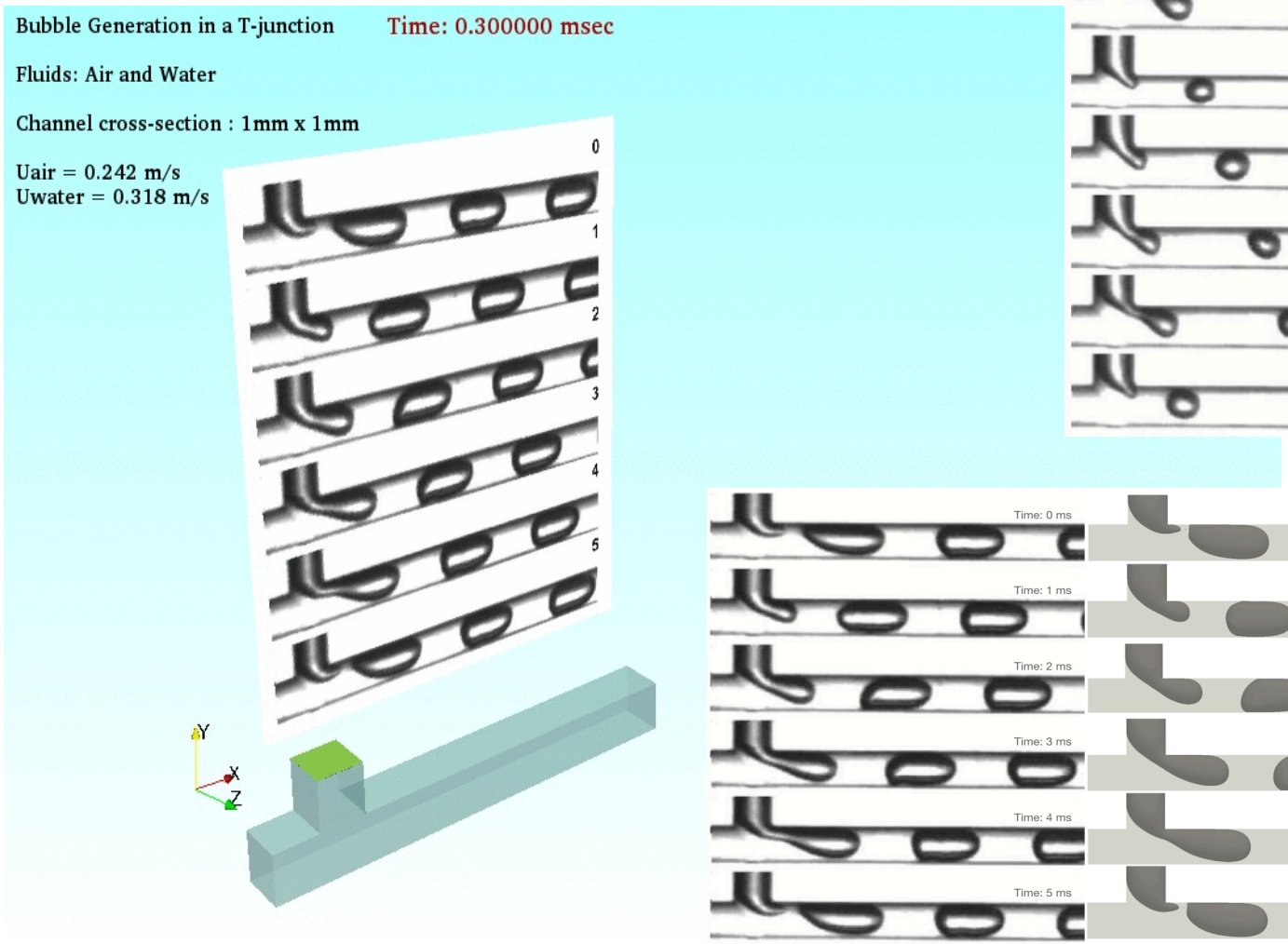
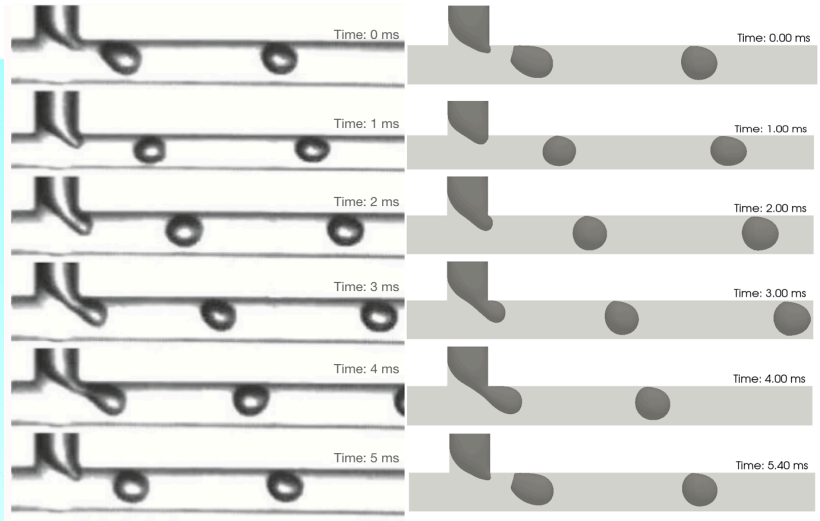
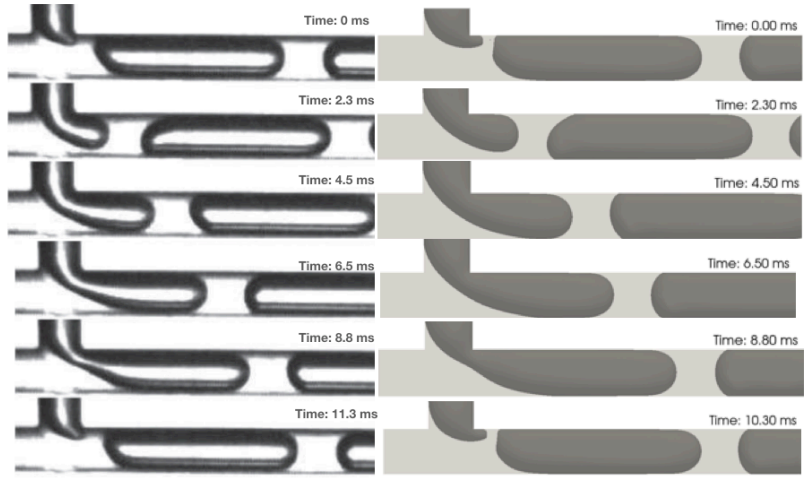
RESULTS

Further Validation of Numerical Framework







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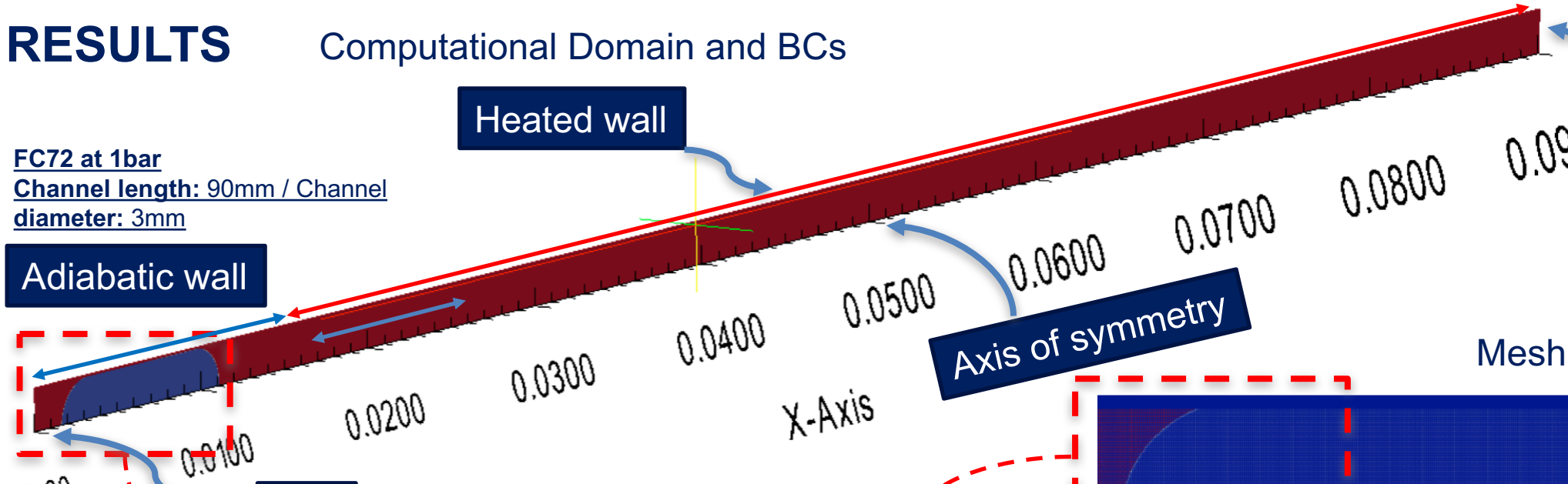
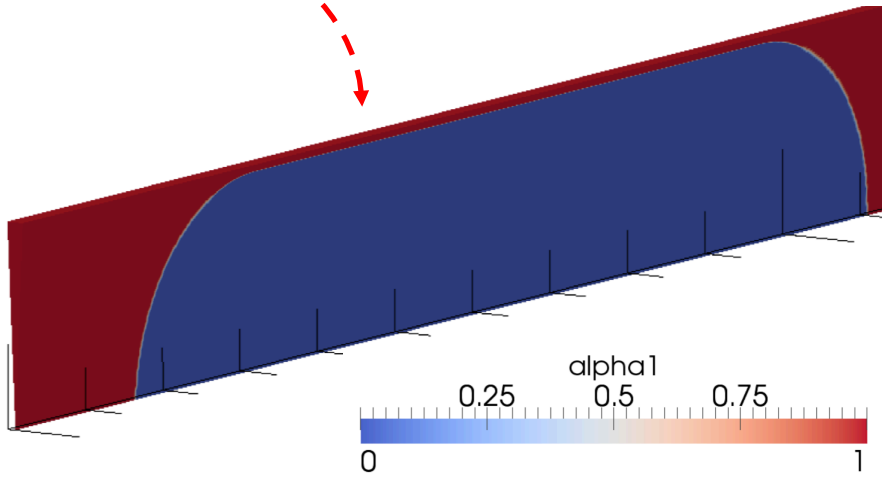
RESULTS

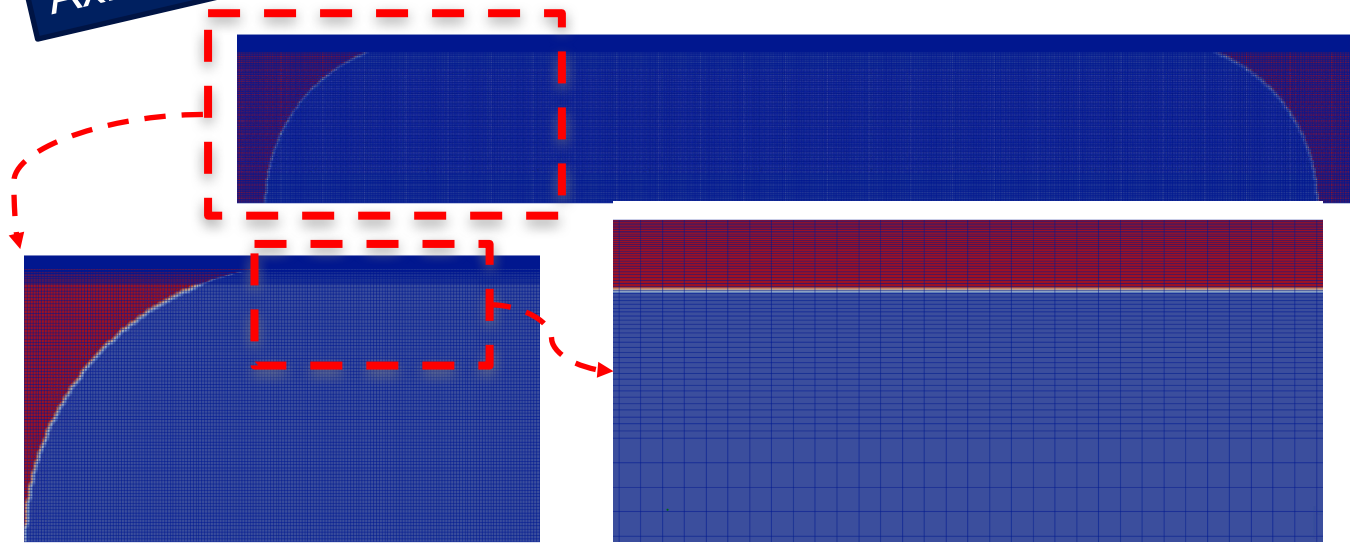
Computational Domain and BCs

FC72 at 1bar
Channel length: 90mm / Channel
diameter: 3mm





Mesh Details



Simulation Type:
2D Axisymmetric (5◦ Wedge)
Computational Domain Size:
90mm x 1.5mm (Wedge of 5°)

Grid Type:
Structured with local refinement, Hexahedral cells
Total No. of Cells
840,000

Cell dimension
Min: 1μm

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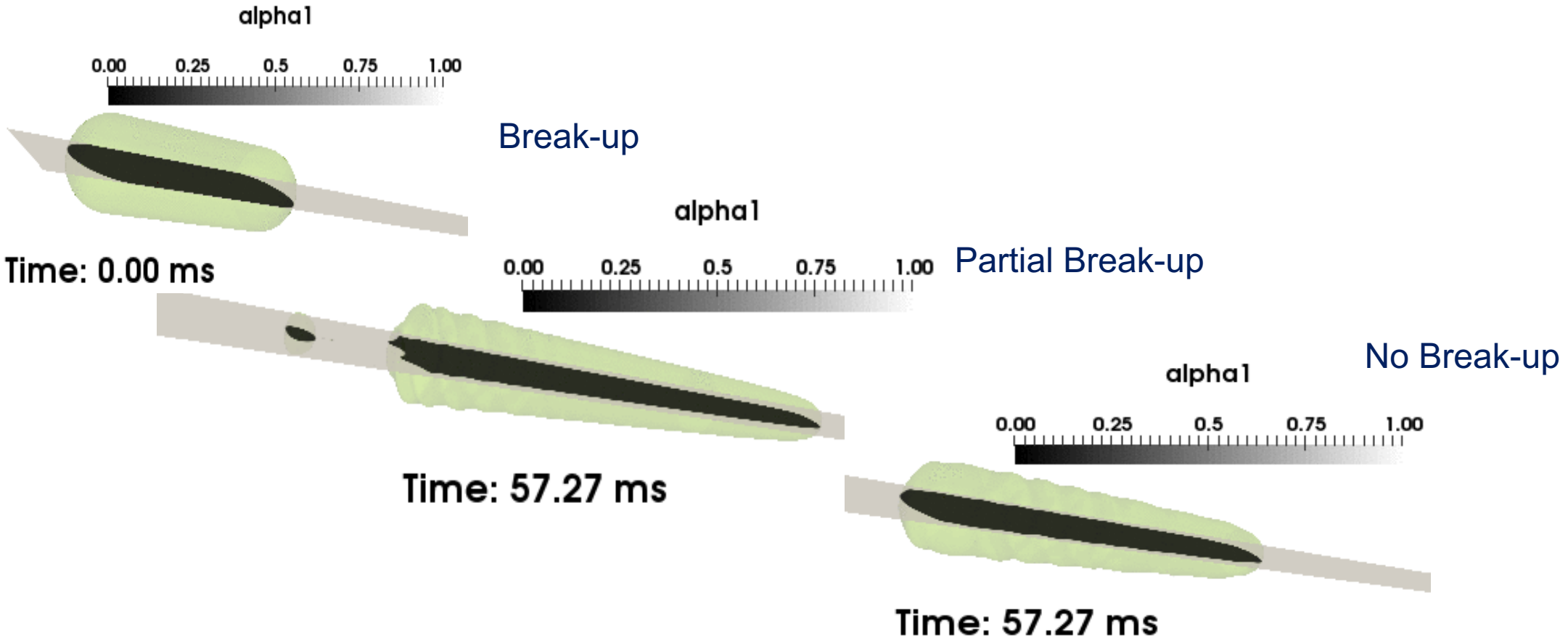
RESULTS

Identified break-up mechanisms



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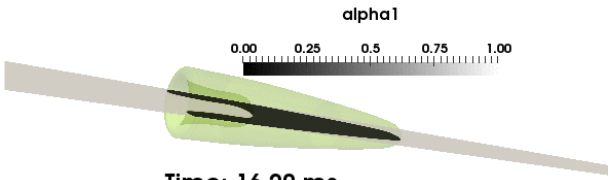
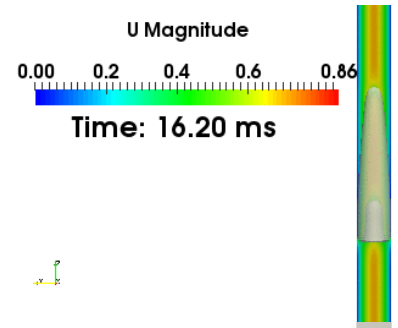
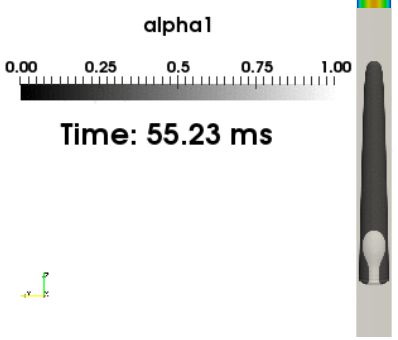
RESULTS

Effect of applied pressure drop

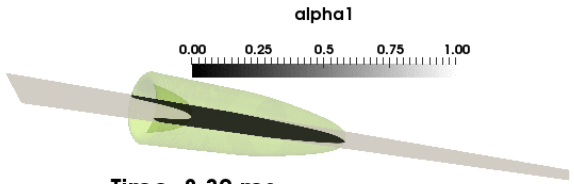
ΔP=50 Pa

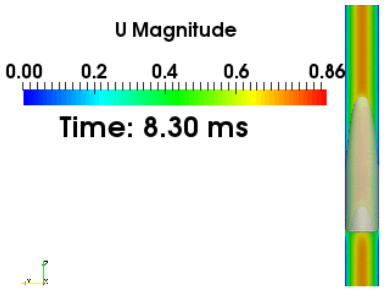


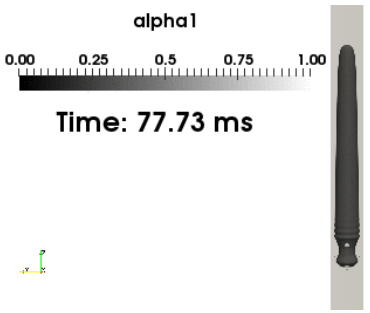




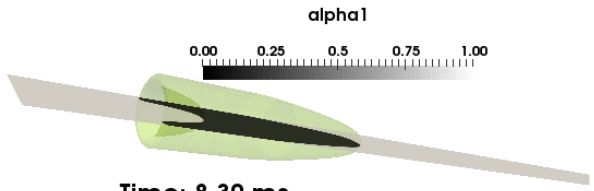
ΔP=65 Pa

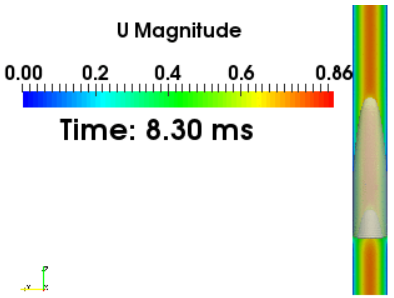


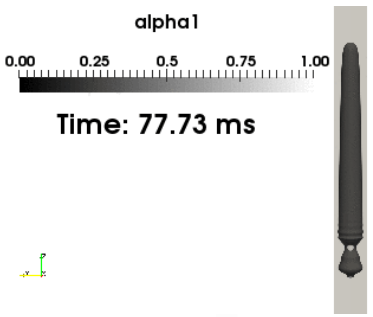




ΔP=70 Pa







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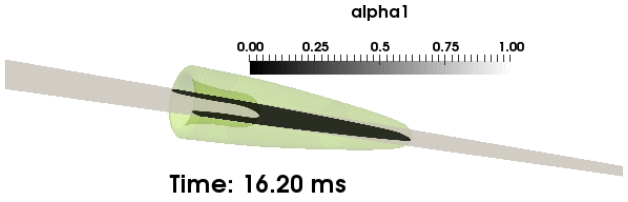
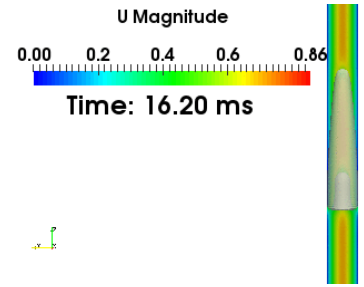
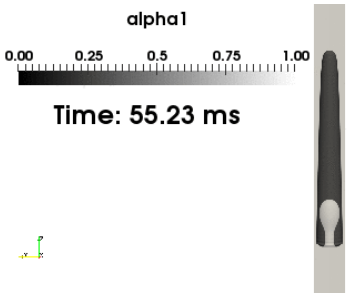
RESULTS

Effect of surface tension

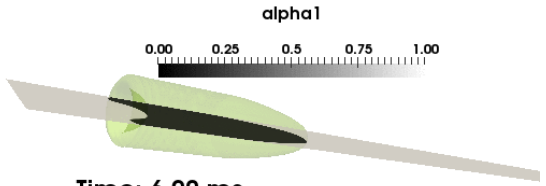
σ

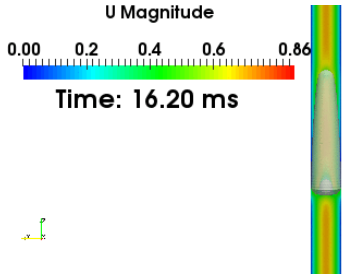


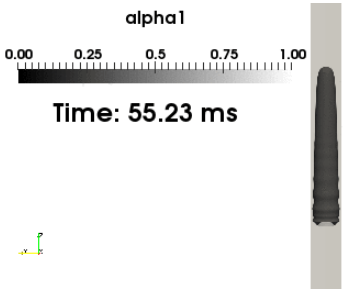




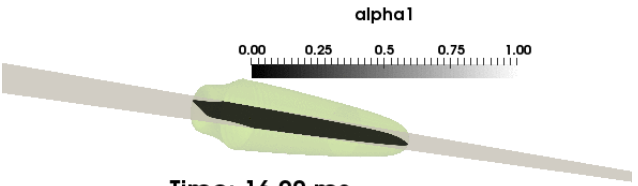
2xσ

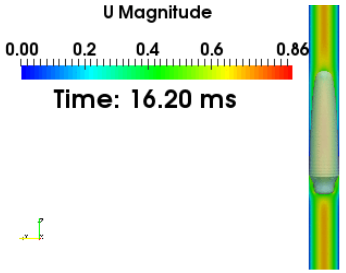


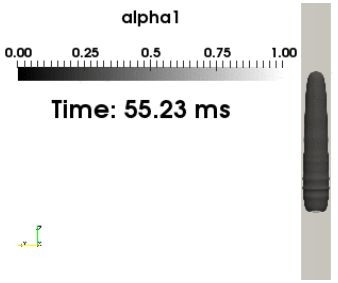




3xσ







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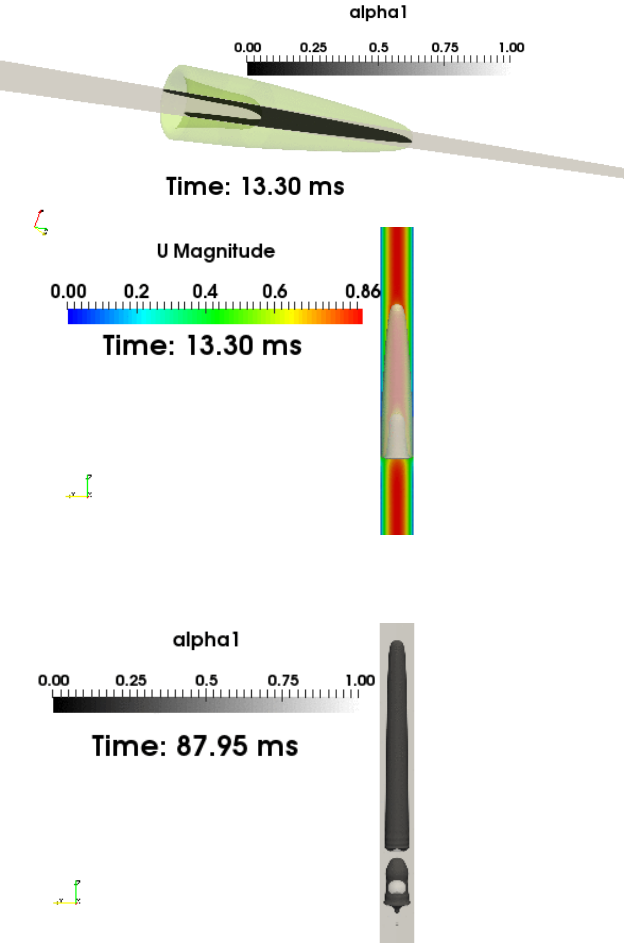
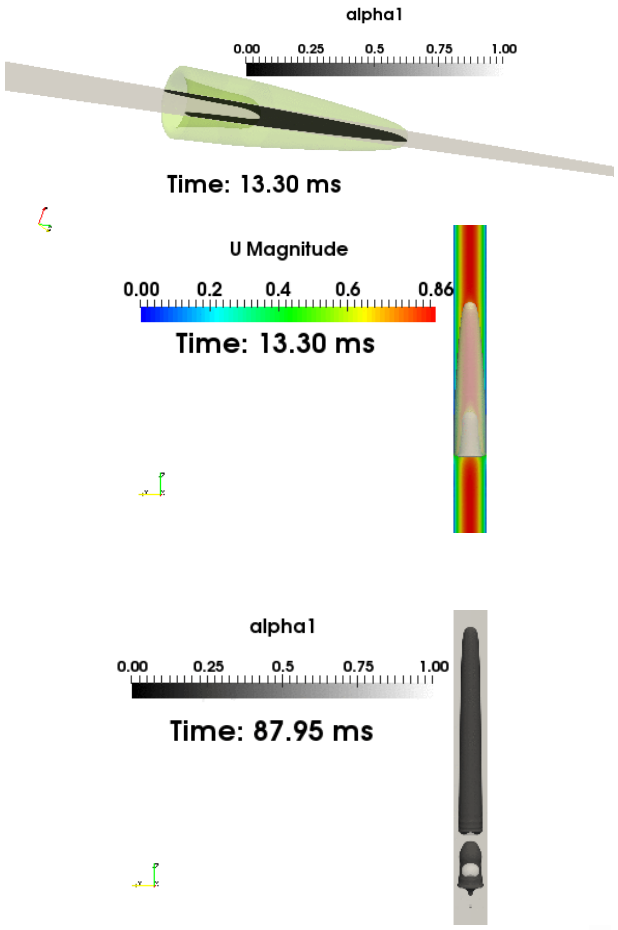
RESULTS

Effect of initial film thickness

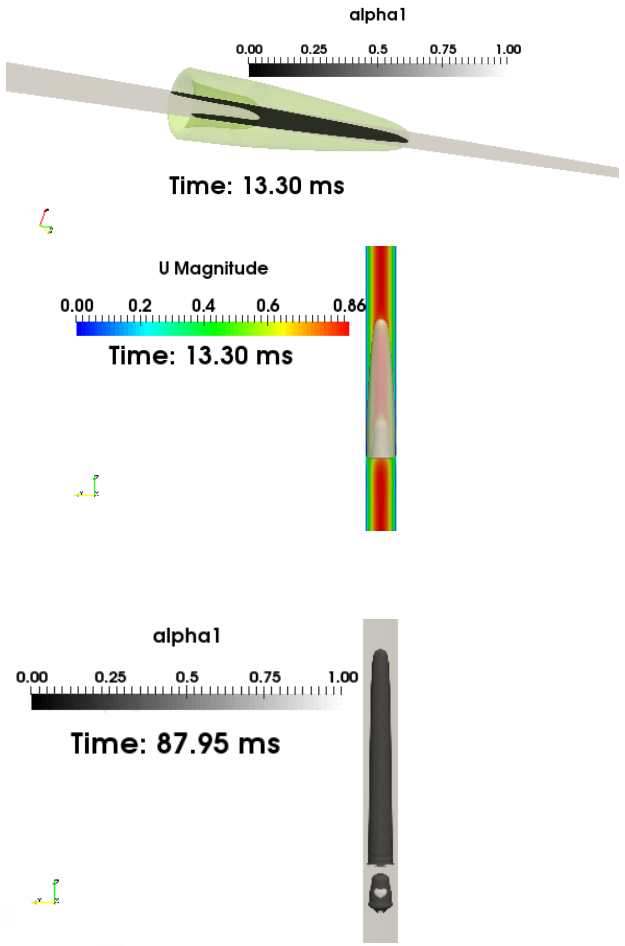
12.5µm



25µm



75µm



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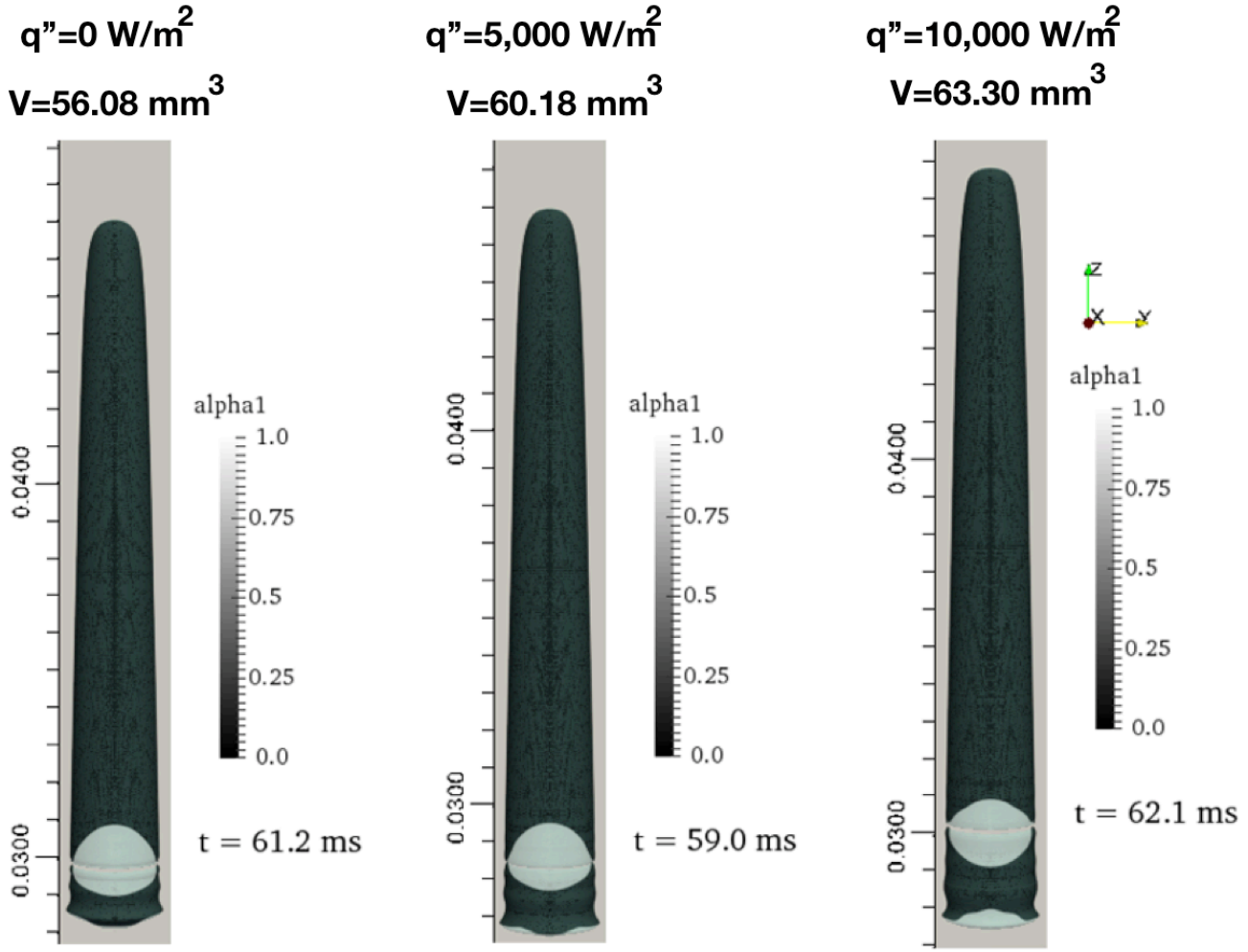
RESULTS

Effect of applied heat flux in heated part of the mini-channel



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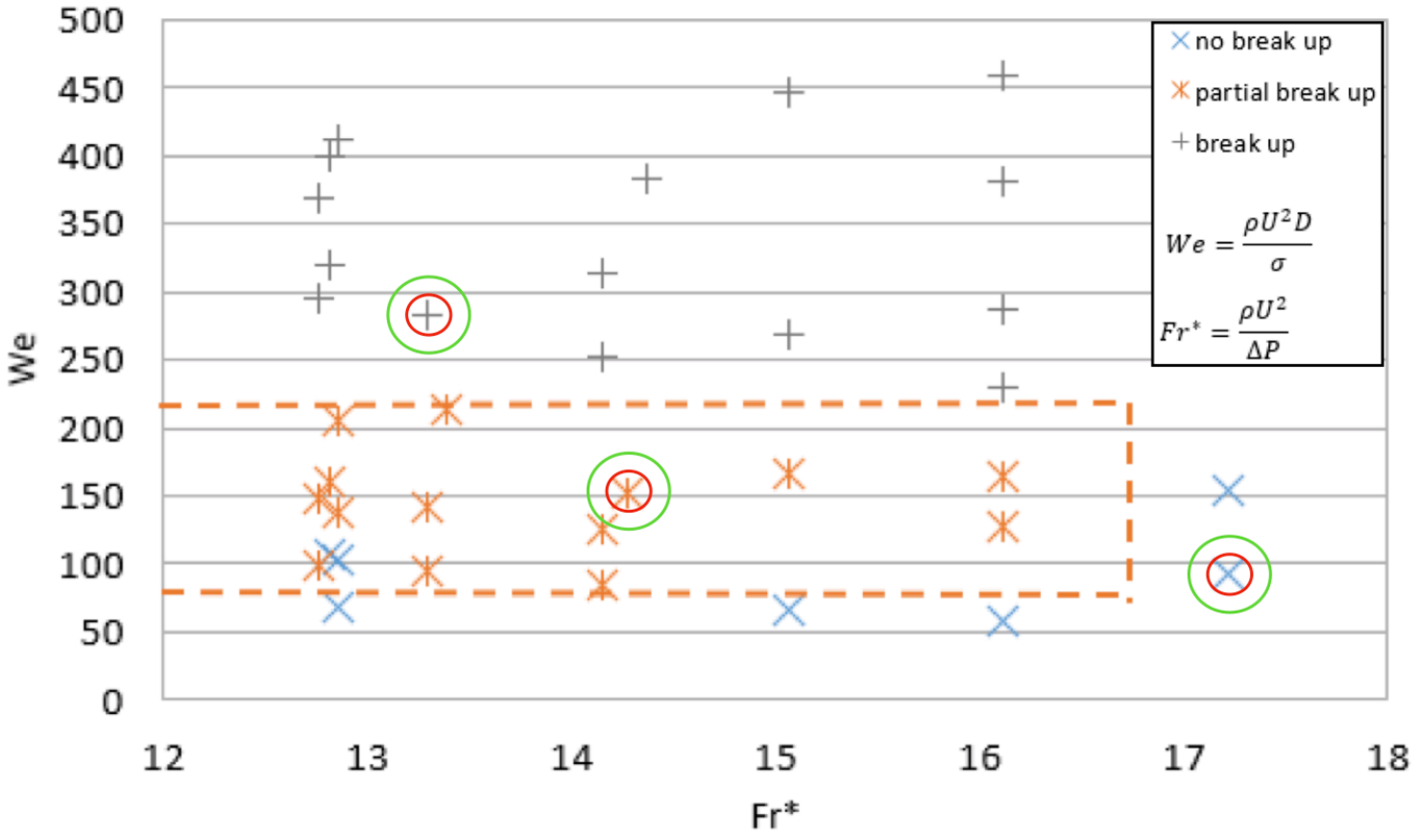
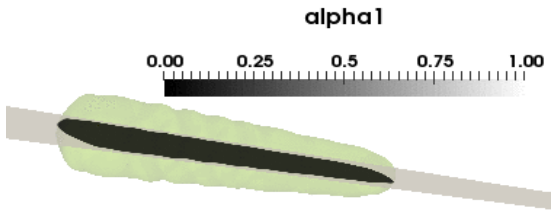
RESULTS Dimensionless Analysis



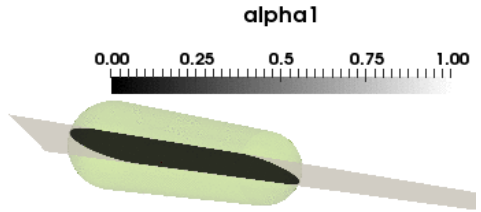
No Break-up

Break-up

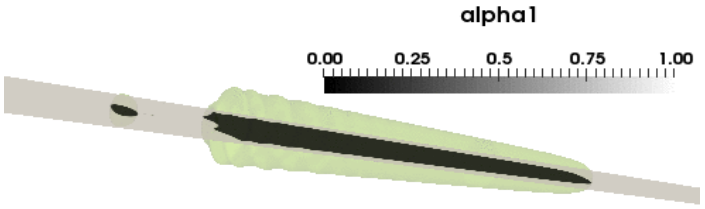
Partial Break-up



Time: 57.27 ms



Time: 0.00 ms



Time: 57.27 ms

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Presentation Overview

- ✓BACKGROUND & MOTIVATION
- ✓NUMERICAL FRAMEWORK
- ✓RESULTS
- ✓***CONCLUSIONS***
- ✓FUTURE WORK

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CONCLUSIONS

- A wide series of parametric simulations have been performed so far, identifying 3 major break-up regimes.
- The numerical simulations revealed some interesting phenomena (e.g. liquid jet penetration, capillary waves) to which the resulting vapour slug break-up can be attributed, something that was not possible to be identified from the experimental high speed images.
- The further post-processing of the results indicates that these break-up regimes can be grouped into appropriate dimensionless flow maps and be predicted by the global flow conditions.
- Such flow maps can be incorporated in the form of sub-models in Lumped Parameter 1D codes to improve their predictability.
- It is interesting that the applied heat flux at the heated section of the channel does not influence the resulting break-up regime.

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FUTURE WORK

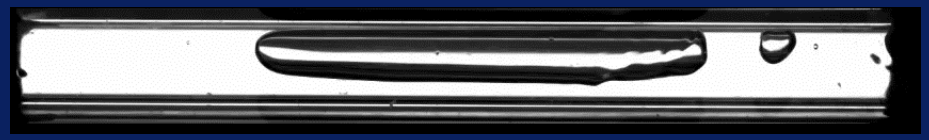
- More channel diameters and working fluids need to be tested (2D-Axissymetric simulations).
- Slug to Slug interaction simulating a series of vapour slugs separated by liquid plugs (3D simulations).
- Time varying pressure conditions at the ends of the channel, in order to investigate the effect of a pulsating flow field in the identified break-up regimes (3D simulations).

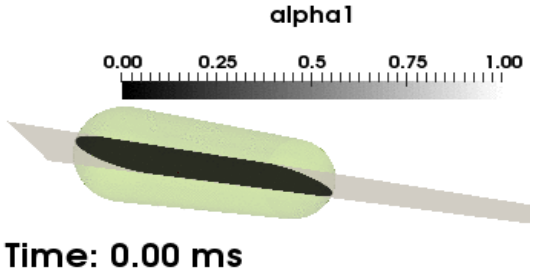
Thank you very much for your attention!

Dr. Manolia Andredaki, Dr. Anastasios Georgoulas, Dr. Nicolas Miche, Prof. Marco Marengo

INWIP - “Innovative Wickless Heat Pipe Systems for Ground and Space Applications”
Microgravity Applications Promotion Programme for the International Space Station (MAP)

HyHP-Novel Hybrid Heat Pipe for Space and Ground Applications
Engineering and Physical Sciences Research Council (EPSRC)





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