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Laboratory of Multiphase Transport and Porous Media (LTPMP), Faculty of Mechanical and Process Engineering (FGMGP)/USTHB, BP. 32, El Alia, Algiers, Algeria.

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Flow pattern prediction using numerical simulation during flow boiling

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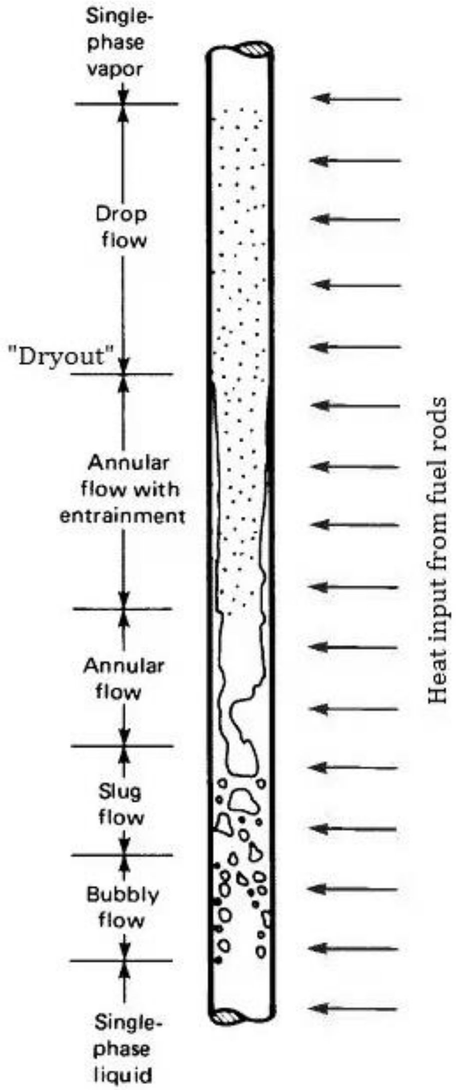
Summary

- Introduction
- Experimental facilities
- Numerical conditions
- Results
- Conclusion

Introduction

One of the most challenging aspects of dealing with the two-phase flow or multi-phase flow is that it can take many different forms. Spatial distributions and velocities of the liquid and vapor phases in the flow channel is a very important aspect in many engineering branches. Pressure drops and heat transfer coefficients strongly depend on the local flow structure.



Motivations and Purposes

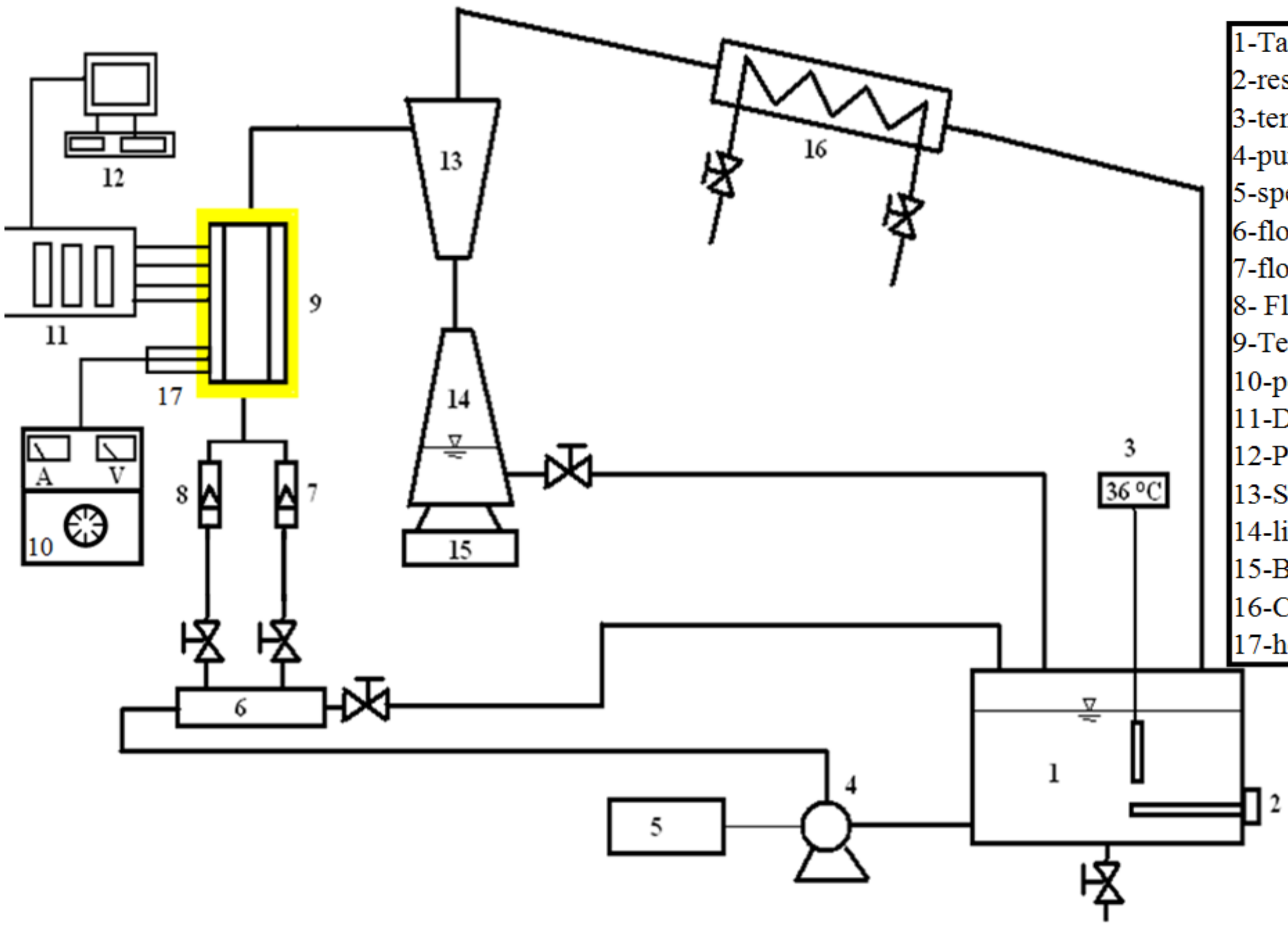
Motivation

- ❑ High-speed camera is expensive
- ❑ More easy to change conditions

Purposes

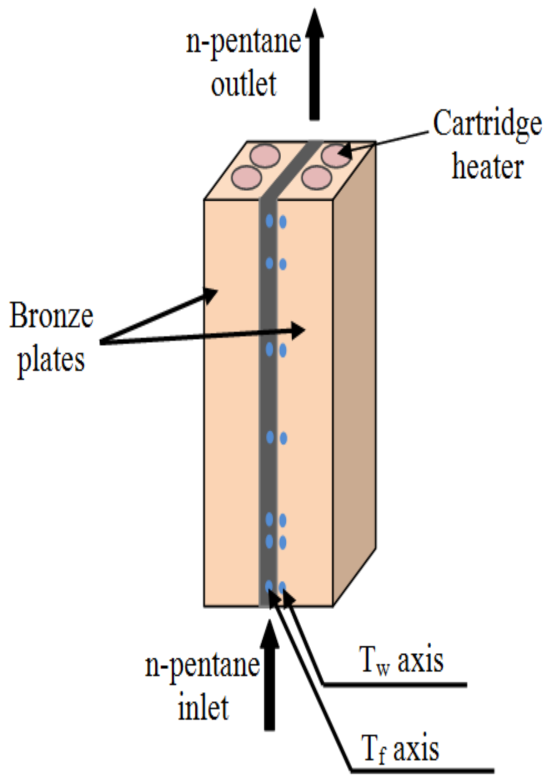
- ❑ Introduction of experimental conditions in numerical simulation software
- ❑ Prediction of flow pattern during flow boiling using numerical simulation.

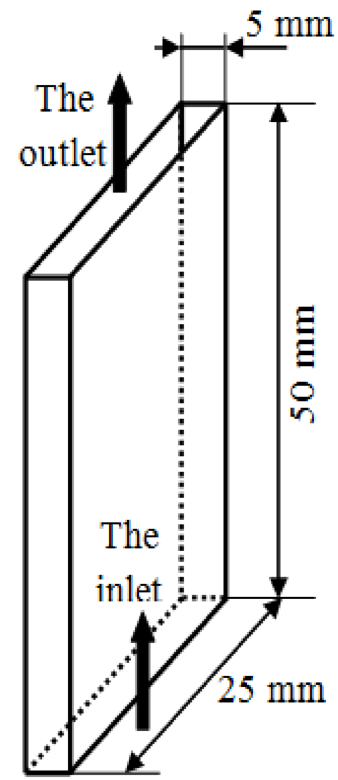
Experimental facilities



1-Tank
2-resistance
3-temperature display
4-pump
5-speed variator
6-flow regulator
7-flow sensor 0-5 l/min
8- Flow sensor 0-1 l/min
9-Test section
10-potentiometer
11-Data acquisition
12-PC
13-Separator
14-liquid recuperator
15-Balance
16-Condenser
17-heaters

Test section





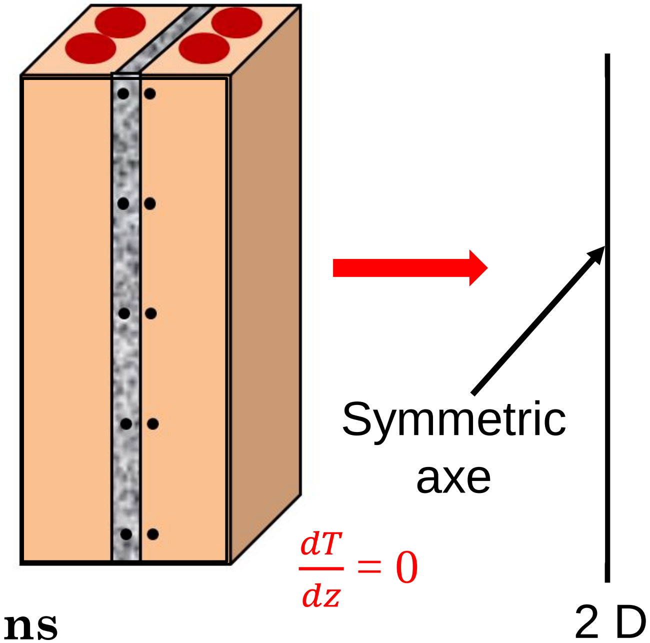
Numerical simulation

Used Software

- ❑ Fluent 6.3

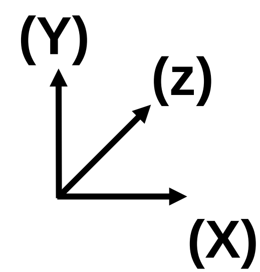
Used model

- ❑ Mixture model for Multiphase flow



Simplifying assumptions

- ❑ Laminar flow,
- ❑ Steady state flow,
- ❑ Incompressible liquid phase « mixture model ».
- ❑ 2D flow with symmetric axe on x.



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Governing equations

Continuity equation

$$\nabla . (\vec{v}\alpha_l) = -\frac{\dot{m}}{\rho_l}$$

Momentum equation

$$\nabla . (\rho\vec{v}\vec{v}) = -\nabla p + \nabla . [\mu(\nabla\vec{v} + \nabla\vec{v}^T)] + \rho\vec{g} + F_v$$

Energy equation

$$\nabla . [\vec{v}(\rho E + P)] = \nabla . (\mathrm{k}\,\nabla T) + Q$$

Mass transfer

$\dot{m}_v = -\dot{m}_l = r\alpha_l\rho_l\frac{T-T_{sat}}{T_{sat}}, T > T_{sat}$ (Lee 1980)

Bubble diameter

$D_b = MIN\,(A_0\, e^{(-1\left(\frac{T_{sub}}{T_{ref}}\right))}, \mathrm{D}_{\mathrm{max}})$ (Kurul and Podowski1991)

UDF

Boundary conditions

Inlet

- ❑ V_{in} = 0.02 m/s,
- ❑ T_{in} = 30°C,
- ❑ α = 0.

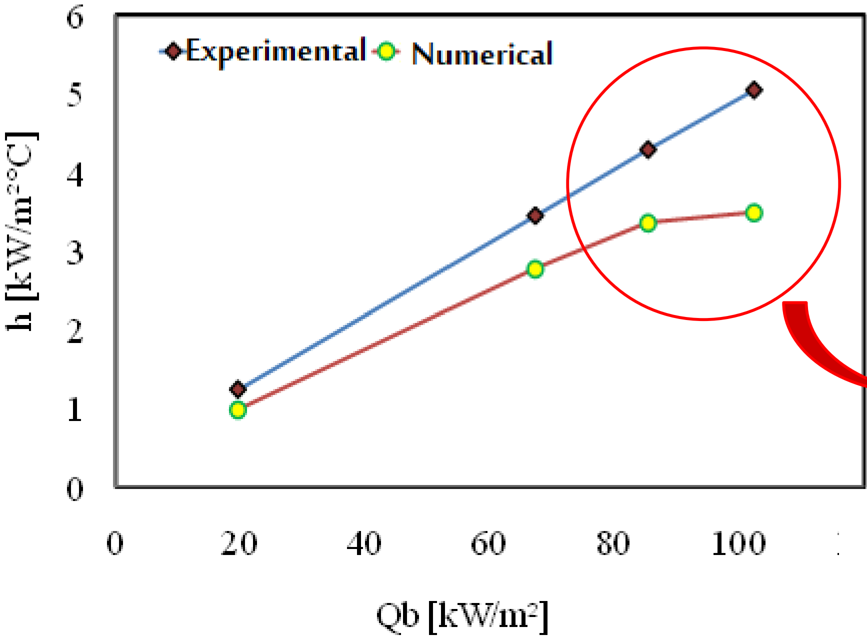
Outlet

- ❑ T_{out} et P_{out} experimentally,
- ❑ α calculated on basis of $X_{exp.}$

Lateral conditions

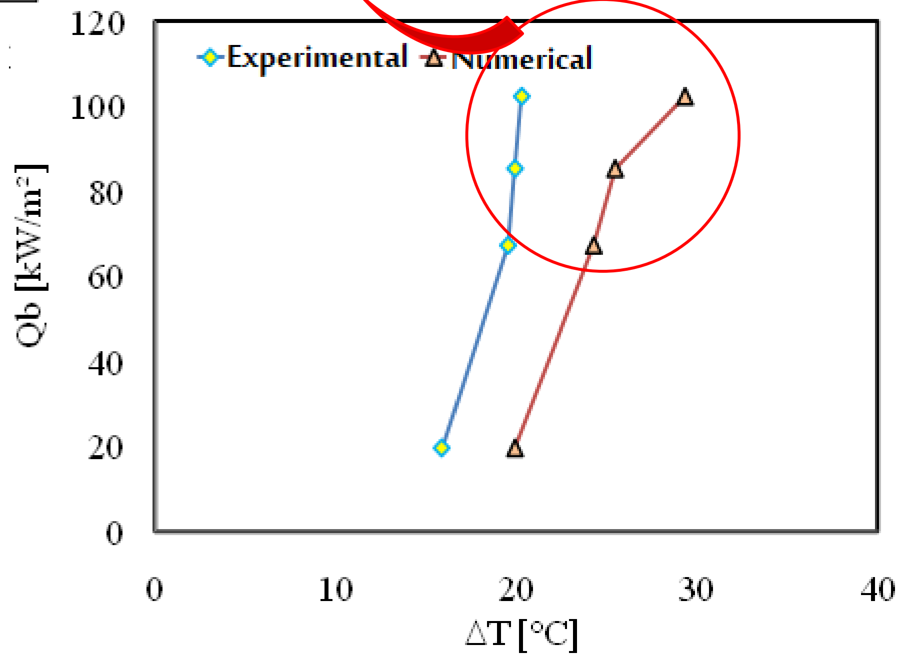
- ❑ Symmetry on x axe ,
- ❑ T° of wall experimentally (UDF).

Results



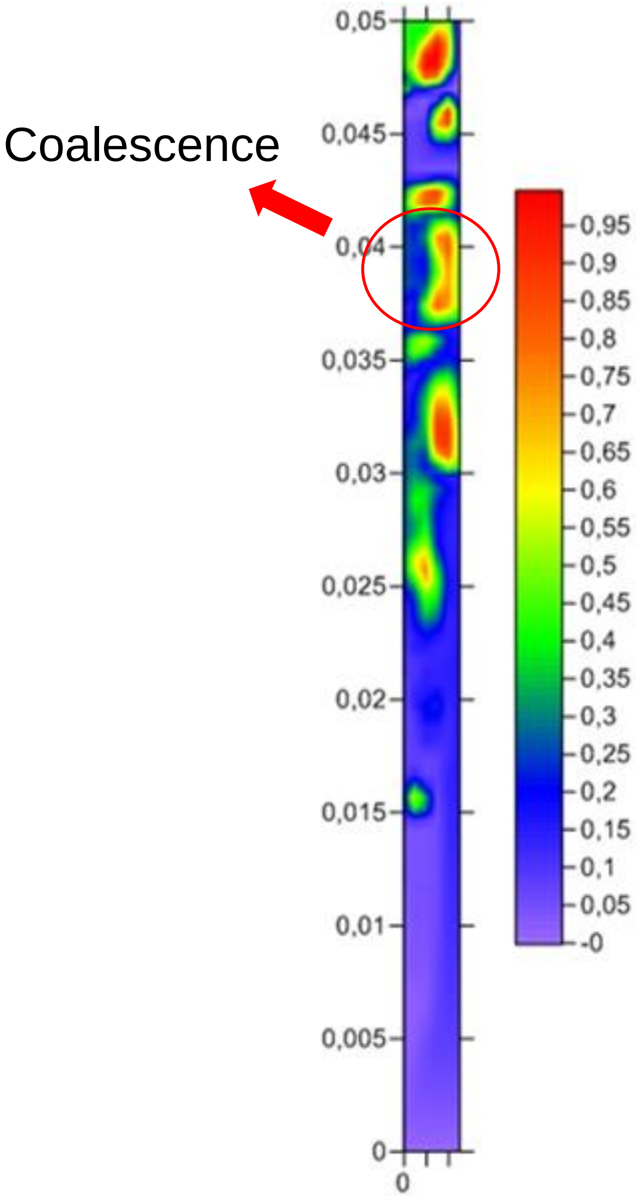
❑ h Coefficient

23 %



❑ Boiling curve

Results (Flow pattern)



Tw = 54 °C

Bubbly flow

D_a=0.85 mm

Elongated bubble
R = 1.8

Boiling front: 25 mm

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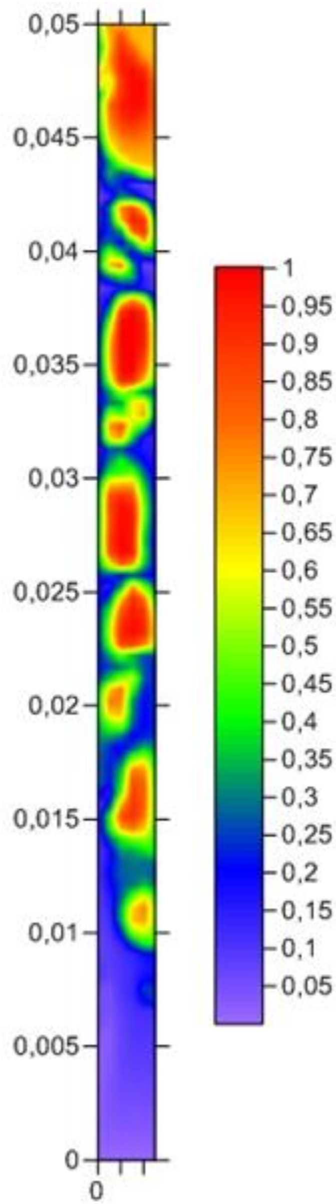
Results (Flow pattern)



Tw = 58 °C

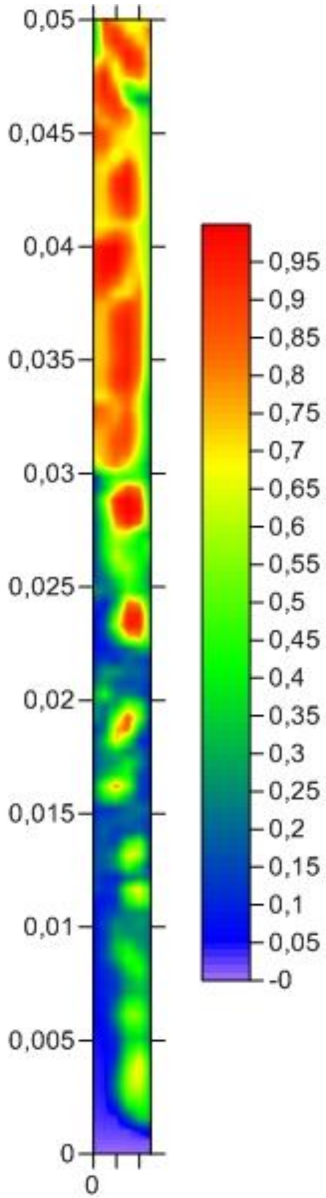
Slug + elongated bubble flow

Elongated bubble
R = 1.81 – 2.66

Slug occuped 86% of channel

Boiling front: 40 mm

Results (Flow pattern)

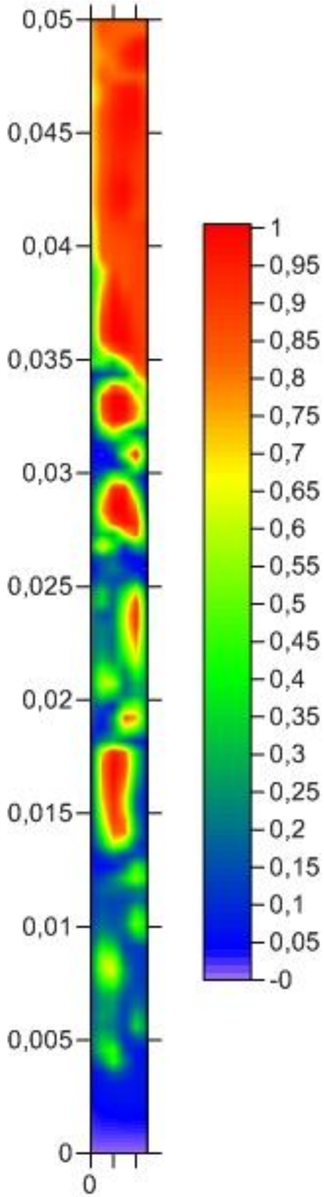


Tw = 60 °C

Churn flow

Boiling front: 45 mm

Results (Flow pattern)



Tw = 61 °C

Annulaire flow

Boiling front: 45 mm

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Conclusion

The experiences carried in the present work allow making some conclusions:

- The numerical simulation was used as complement to the experimental.
- The comparison between numerical and experimental results shows a good agreement with deviation less then 23 %.
- Several flow pattern was identified using numerical simulation, namely: bubbly, slug, plug and annular.

Thank you for your attention