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Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Proposed numerical investigation of subcooled flow boiling heat transfer in microchannels with non-uniform circumferential heat fluxes at different gravitation orientations

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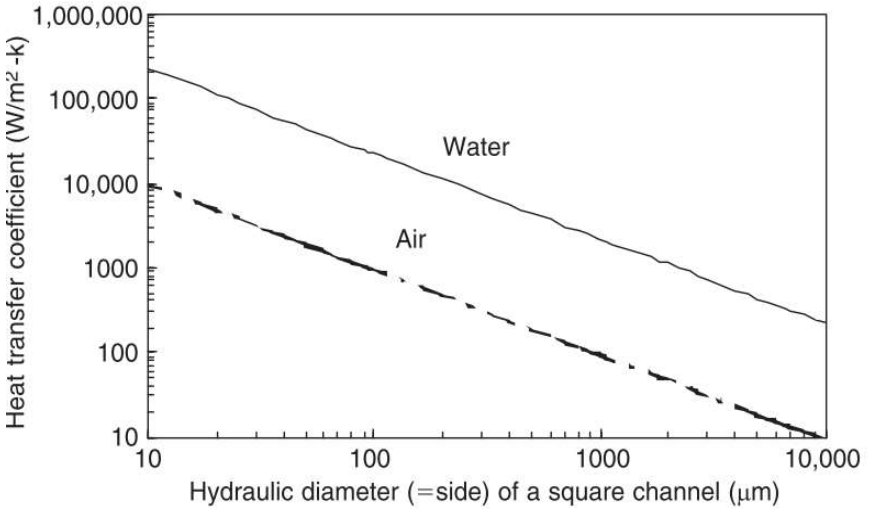
Order of Presentation

- Current state of microchannel flow boiling in literature
- Numerical modelling of flow boiling
- Research performed at the University of Edinburgh
- Proposed numerical model

Current State of Microchannel Flow Foiling in Literature

Single Phase Heat Transfer in Microchannels

- Macrochannels dominate experimental and numerical studies.
- At small scales surface tension begins to play an important role.
- Single-phase flow in microchannels induces higher heat flux than in their macro scale counterparts.
- Higher pressure gradient is required.



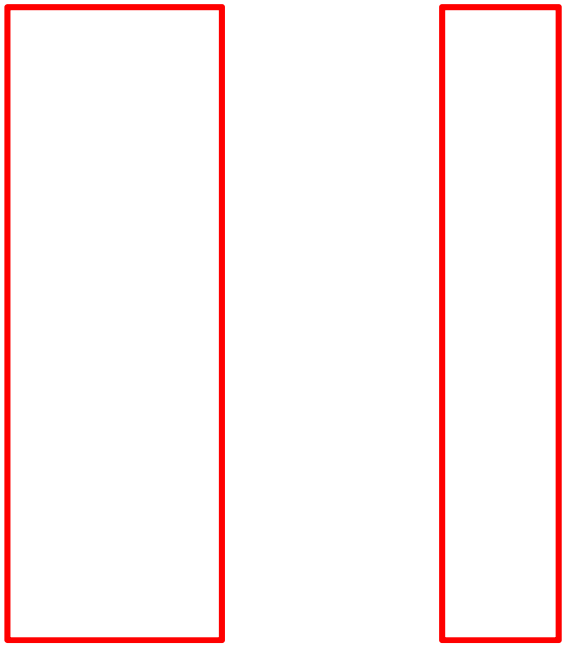
KANDLIKAR, S., GARIMELLA, S., LI, D., COLIN, S. & KING, M. R. 2005. *Heat transfer and fluid flow in minichannels and microchannels*, elsevier.

Subcooled Flow Boiling

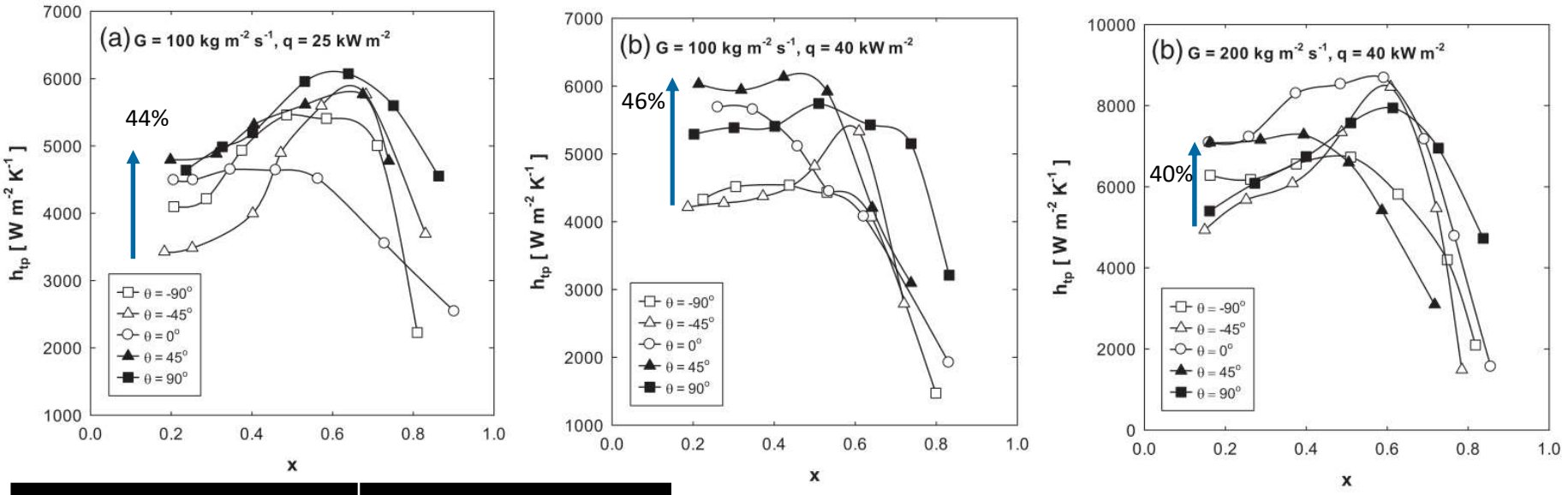
- Subcooled flow boiling increases heat transfer even more.
- Subcooled flow boiling heats a fluid to its saturation temperature and then converts the liquid to a vapour.
- The combination of sensible and latent heating increases the heat vs unit mass that can be absorbed.
- Constant temperature cooling.

Current state of microchannel flow boiling in literature

- Four major categories of flow patterns.
  - bubbly flow (a and b),
  - slug flow (c and d),
  - churn flow (e and f)
  - annular flow (g).
- Liquid layer exits between vapour and wall in slug and annular flow.



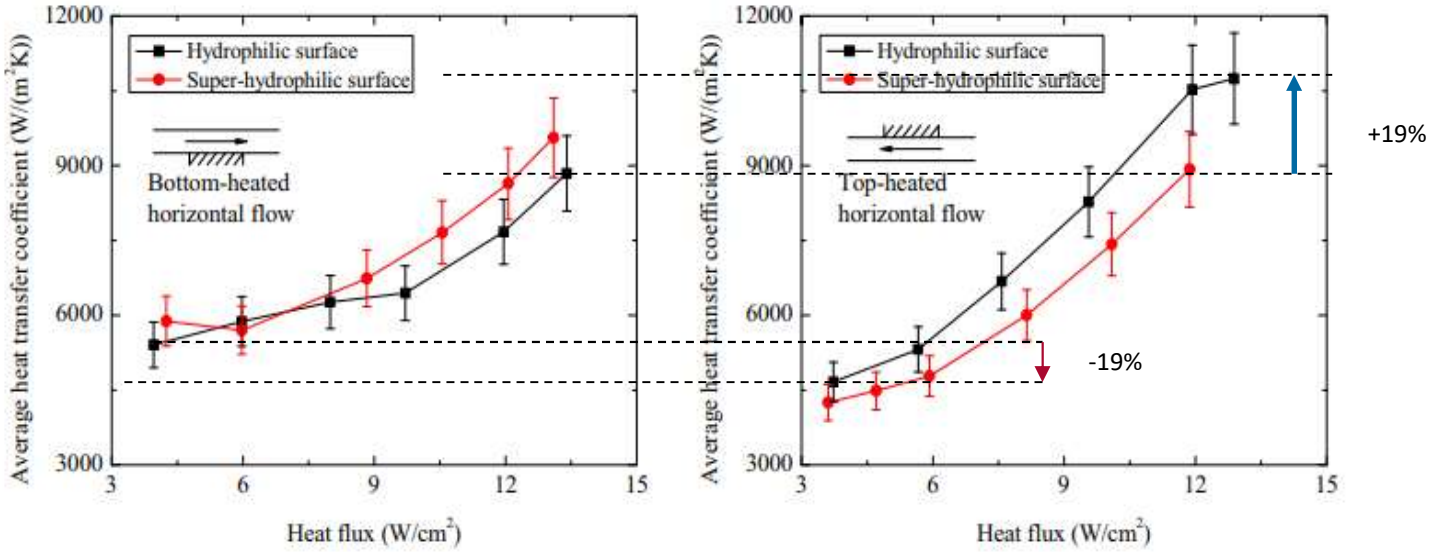
Variable Orientation study 1



Properties	
Hydraulic Diameter	440µm
Fluid	HFE-7100

Hsu, L.-C., et al. (2015). "An experimental study of inclination on the boiling heat transfer characteristics of a micro-channel heat sink using HFE-7100." International Communications in Heat and Mass Transfer **62**: 13-17.

Variable Orientation Study 2



Properties	
Hydraulic Diameter	940µm
Fluid	Water

Wei Li, Zengchao Chen, Junye Li, Kuang Sheng, Jie Zhu, Subcooled flow boiling on hydrophilic and super-hydrophilic surfaces in microchannel under different orientations, International Journal of Heat and Mass Transfer 129 (2019) 635–649

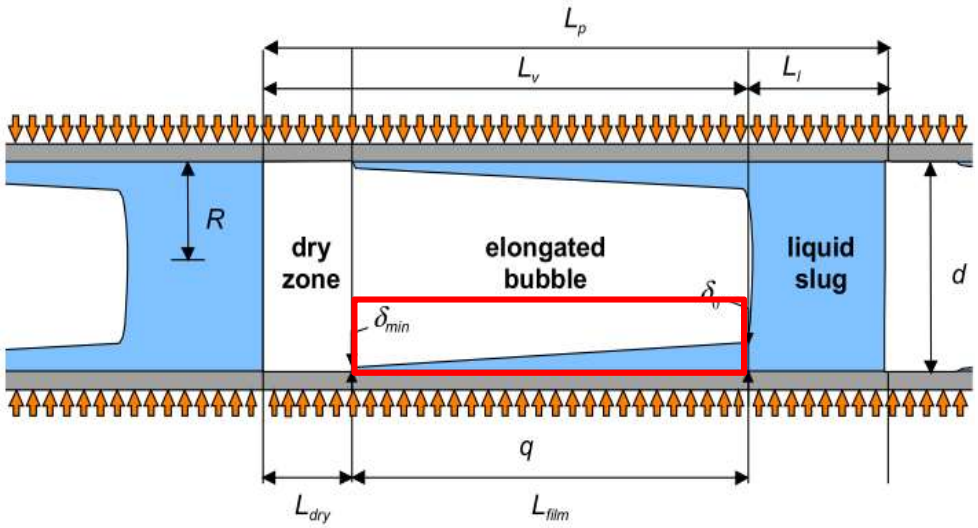
Numerical Modelling of Two-Phase Flow

Numerical Modelling of Flow Boiling

- Technological advancements in data capturing have improved heat and mass transfer correlations.
- Micro-scale phenomena are still difficult to record.
- Numerical simulation software can be used to model systems and can be used in conjunction with experimental results to produce better correlations.

Numerical Model of Slug Flow

- 3- zone produced by Thome et al (2004) which models heat transfer during slug flow.
- The model breaks down the flow into liquid slug, evaporating elongated bubble and then liquid slug.
- Thin liquid layer enhances heat transfer.



THOME, J., DUPONT, V. & JACOBI, A. M. 2004. Heat transfer model for evaporation in microchannels. Part I: presentation of the model. *International Journal of Heat and Mass Transfer,* 47**,** 3375-3385.

Research Performed at the University of Edinburgh

Research Performed at the University of Edinburgh

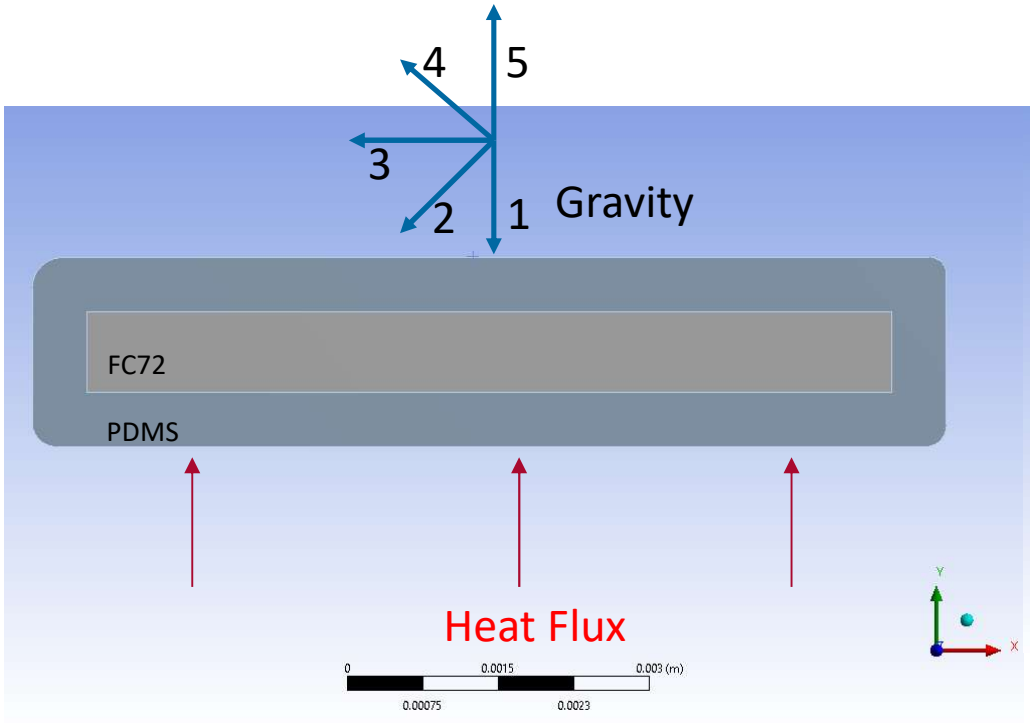
- Many experimental and numerical studies performed under professors Khellil Sefiane and Prashant Valluri.
- Bubble hydrodynamics and the instabilities caused by transient bubble growth by Barber et al.
- External wall temperature mapping and estimation of the local heat transfer coefficients by Vasileiadou et al.
- High resolution two-dimensional heat transfer coefficient maps by Korniliou et al.

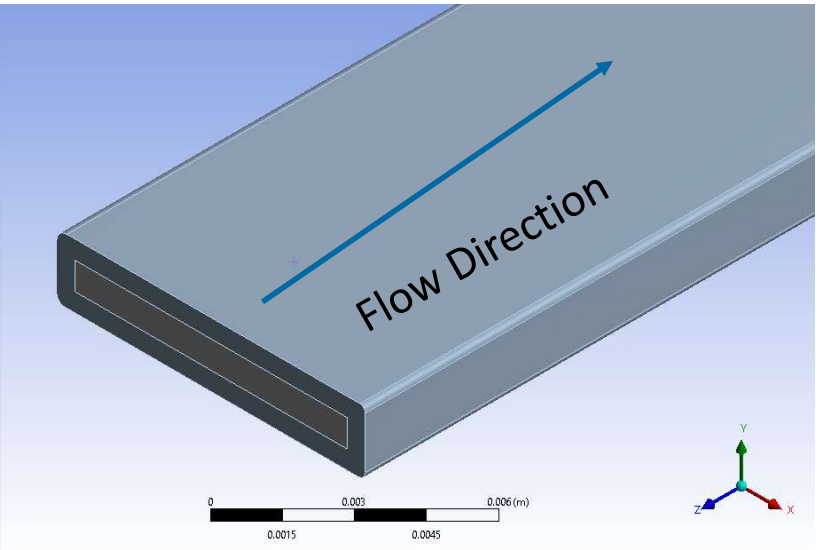
Research Performed by Yuan Wang

- Heat transfer and pressure drop correlations for different heat fluxes, hydraulic diameters and vapour qualities by Wang et al.
- Hydraulic diameters of 571μm, 762μm and 1454μm.
- Mass fluxes of 11.2 kg/m^{2}s, 22.4 kg/m^{2}s and 44.8 kg/m^{2}s.
- Will be used as validation for numerical results.

Proposed Numerical Model

Proposed Numerical Model Geometry



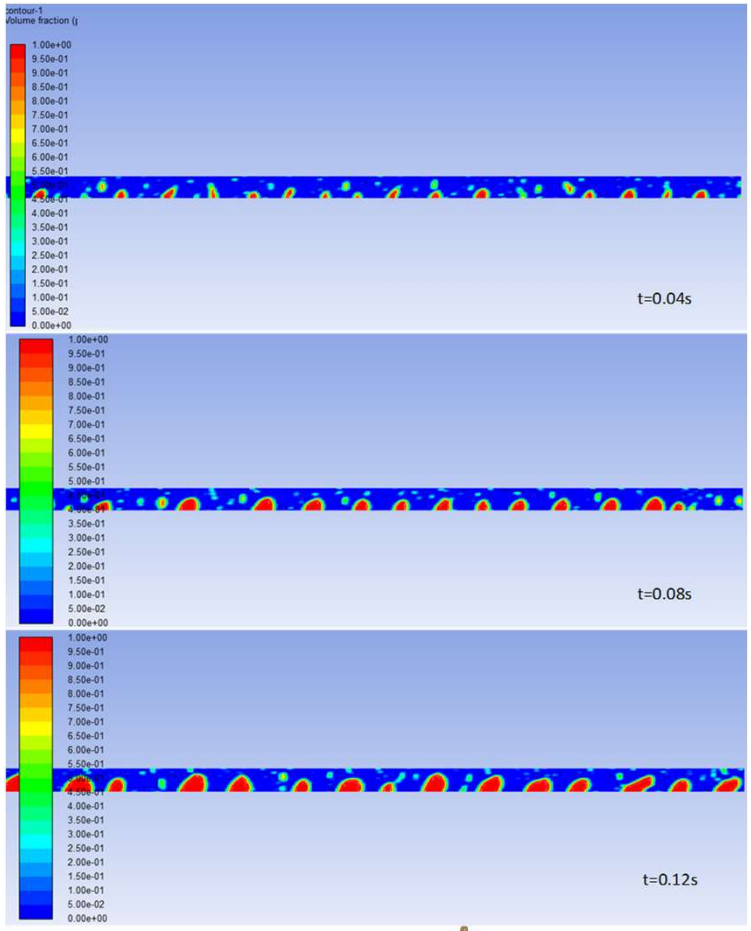


Initial Experimentation

- Gravitational orientation is easily altered using numerical software.
- Many different initial models with varying results have been produced using ANSYS Fluent.
- Correct bubble growth and nucleation has proved to be difficult.
- Mesh and multiphase models have biggest impact.

Initial Results

- High vapour quality bubbles with small liquid-vapour interfaces have been produced.
- Recreating bubble departure and the thin liquid layer during slug flow will be the next step.
- Results will be validated with results obtained in conjunction with Marius Vermaak.



Conclusion

- Flow boiling in microchannels significantly enhances heat transfer. Effects of hydraulic diameter, heat flux, gravitational orientation, mass flux and flow regime will be analysed.
- More work is required to ensure that the phenomenon is accurately recreated by numerical modelling.
- This work will be performed at the University of Edinburgh in 2019.

Thank You For Listening

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