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ADVANCED MODELLING & SIMULATION – AMS

CMFD SIMULATION OF LOOP HEAT PIPE (LHP) USING TRANSAT

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MOTIVATION AND BACKGROUND

Background

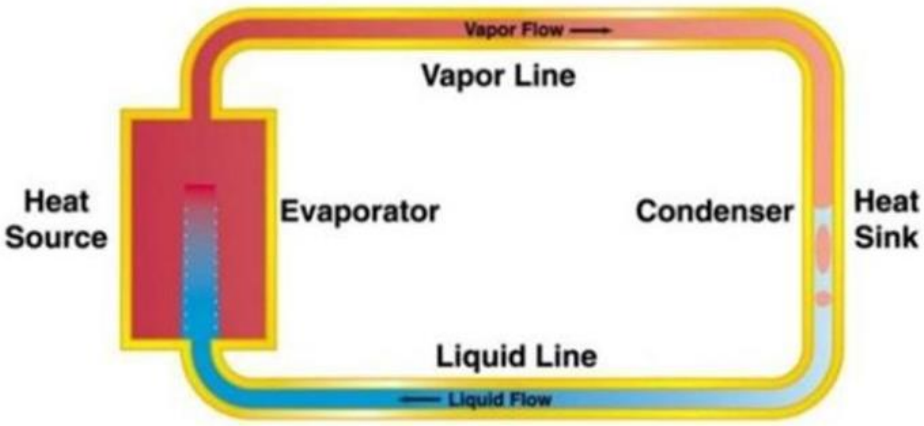
- Interest in simulation of flow in LHP with a view to,
  - Analyze effect of geometry modification, filling quantity, etc.
  - Predict temperature, pressure, phase volume fraction, heat transport limits etc. to guide design

Objectives

- Demonstrate capability of TransAT to simulate flow and heat/mass transfer in LHP
- Discuss current status and improvements if necessary

EXPERIMENT LHP

- Ethane as medium
- Copper tube with filling 15.061 g
- Gas pipe: 800 mm
- Liquid pipe: 605 mm
- Condenser coil: 538 mm
- Pipeline: o.d. 6 mm, thickness 1.5 mm



LHP SIMULATION WITH TRANSAT (WATER AS A MEDIUM)

Model

- Compressible 2-phase flow with phase change
- Evaporator not modelled → Left wall direct heat flux imposed
- Condenser coil not modelled → Right wall is set with subcooling
- Dispersed phase-change model with specified bubble/drop radius
- Peng-Robinson EoS for liquid and vapour phases
- Antoine equation for saturation curve

Conditions

- 2D domain with mass filling of ~ 3 g
- Initialized as 10% liquid with initial pressure of 1 atm and temperature of 100°C
- Length: 610 mm
- Height: 410 mm
- Pipeline cross-section: 6 mm x 2.4 mm
- Left heat input: 1 W
- 10°C subcooling at Condenser wall

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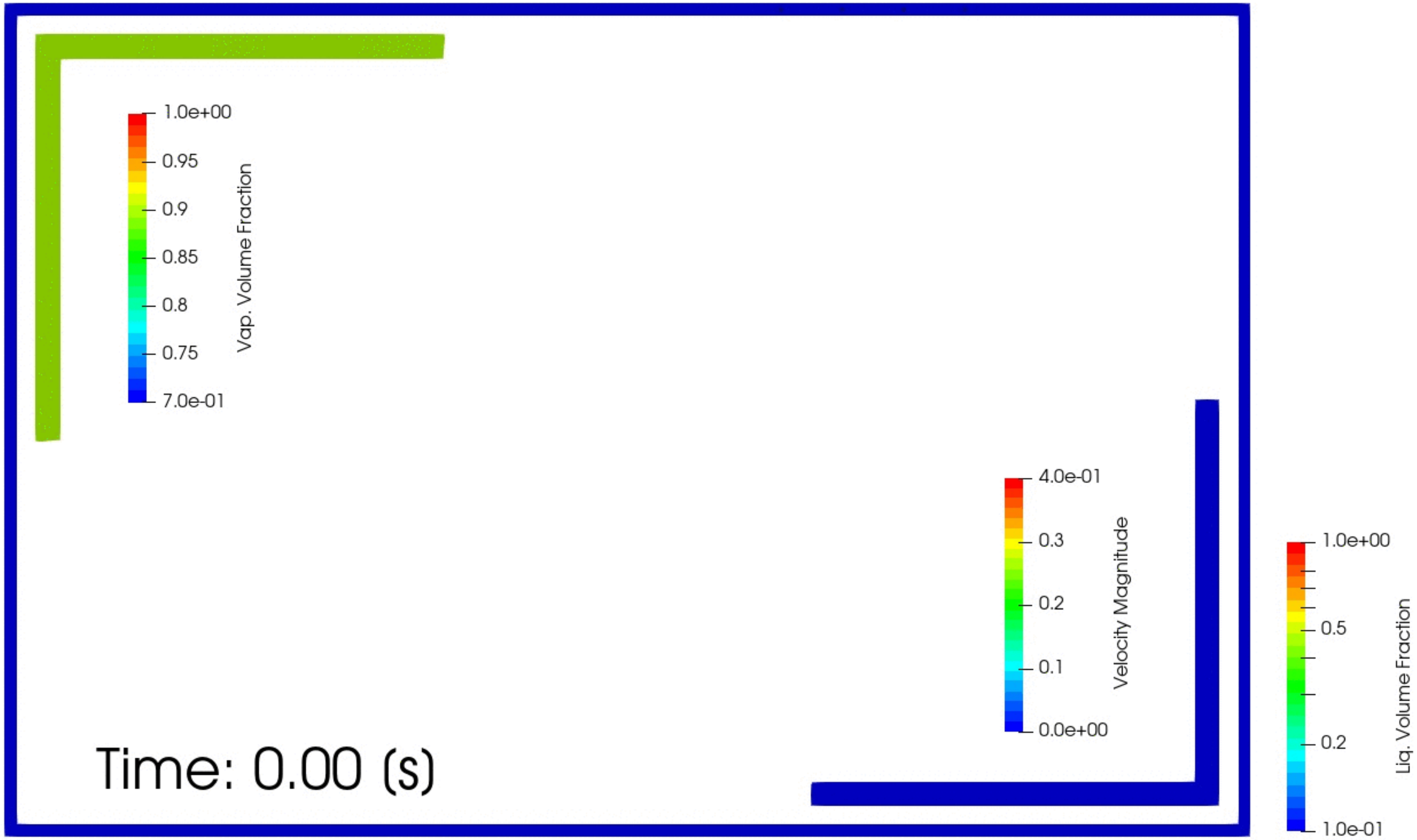
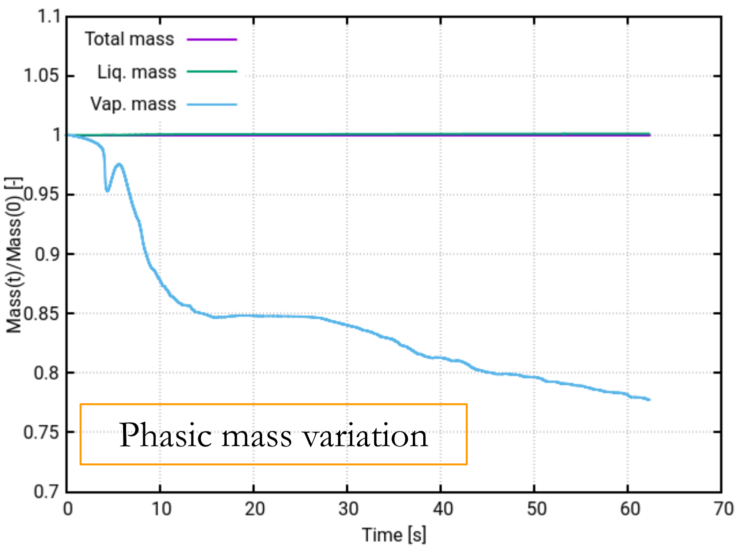
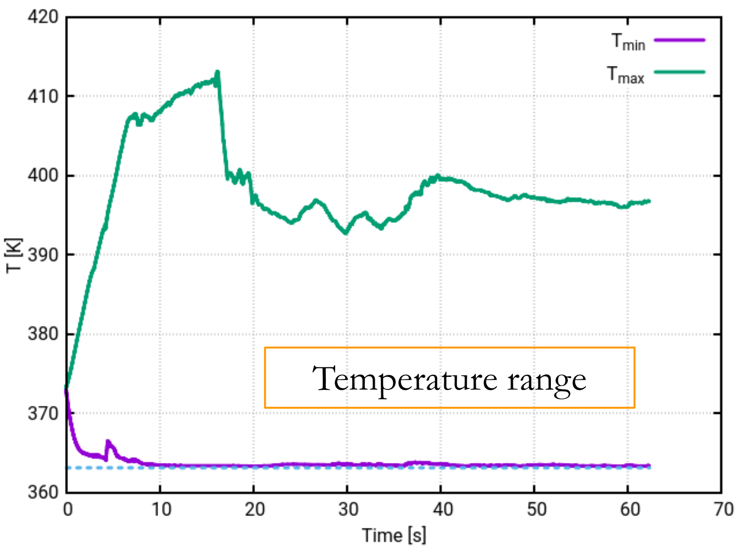
LHP SIMULATION WITH TRANSAT



LHP SIMULATION WITH TRANSAT

- Temperature range has equilibrated
- Pressure and average quality are still evolving
- Clockwise flow has been established by introducing momentum sources to mimic the capillary suction of the wick in the evaporator section.
- Vapour condenses on the right pipe segment and flows towards the evaporator segment
- Loop is established, but the establishment of a steady-state would take longer time.





LHP SIMULATION WITH TRANSAT (ETHANE AS A MEDIUM)

Model

- Compressible 2-phase flow with phase change
- Evaporator not modelled → Left wall direct heat flux imposed
- Condenser coil not modelled → Right wall is set with subcooling
- Dispersed phase-change model with specified bubble/drop radius
- Peng-Robinson EoS for liquid and vapour phases
- Antoine equation for saturation curve

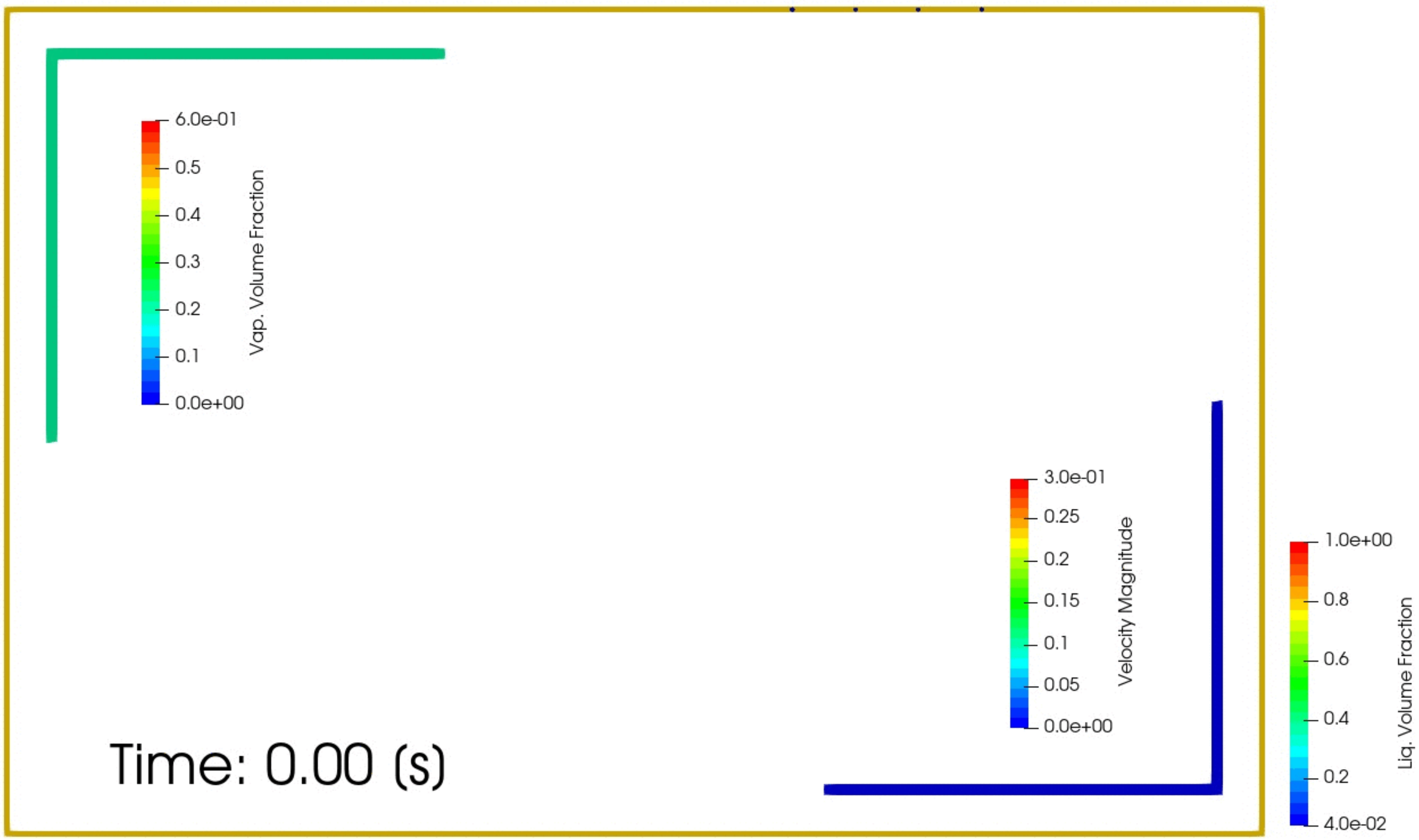
Conditions

- Square channel (2.8 mm) with mass filling of ~ 8 g
  - Initialized as 80% liquid with initial pressure of 0.43 bar and temperature of 170 K
- Length: 600 mm
- Height: 400 mm
- 10°C subcooling at Condenser wall
- Left heat input: 2 W
- Heat flux can be increased to 20 W in steps

Steady-state temperature values at each measuring point（unit：K）

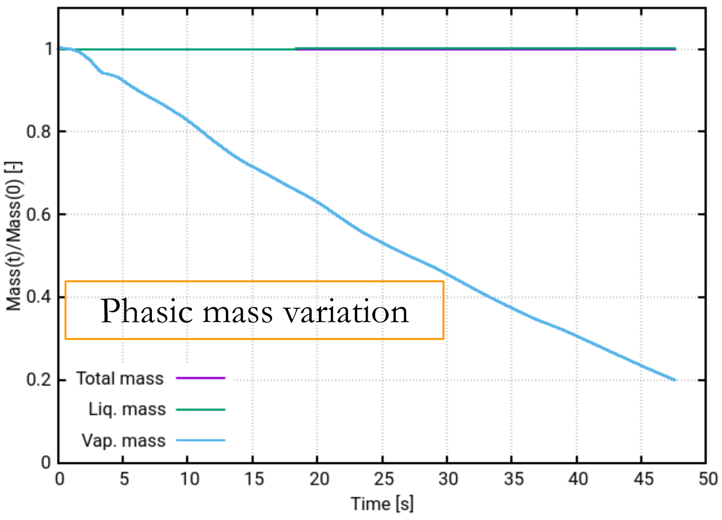
Working condition \ Point Number	101	102	103	104	105	106	107	109
20W	182.642	183.082	196.020	199.369	177.131	170.788	170.117	172.541
30W	189.734	190.219	198.894	202.552	186.277	182.581	182.620	183.640
40W	192.037	192.453	198.083	201.069	189.612	187.418	187.140	188.501

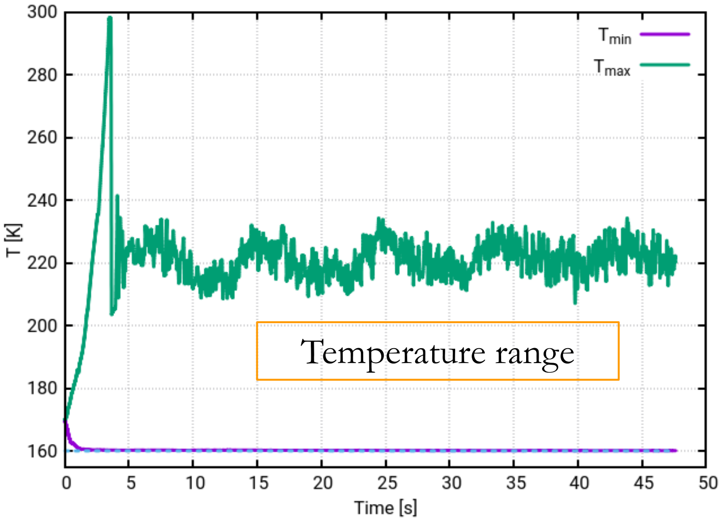
LHP SIMULATION WITH TRANSAT



LHP SIMULATION WITH TRANSAT

- Temperature range has equilibrated
- Pressure and average quality are still evolving
- TransAT can be used to simulate LHP designs with the view to improve designs.
- In the demonstration cases, evaporation and condensation is achieved using wall boundary conditions.
- Modeling of the Evaporator and condenser is required and can be achieved using UDFs.





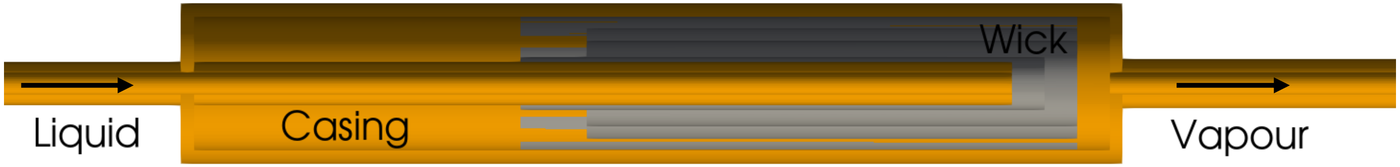
EVAPORATOR MODELLING WITH TRANSAT

Model

- Evaporator is modelled in detail separately
- Can be combined with the full loop to build a complete model

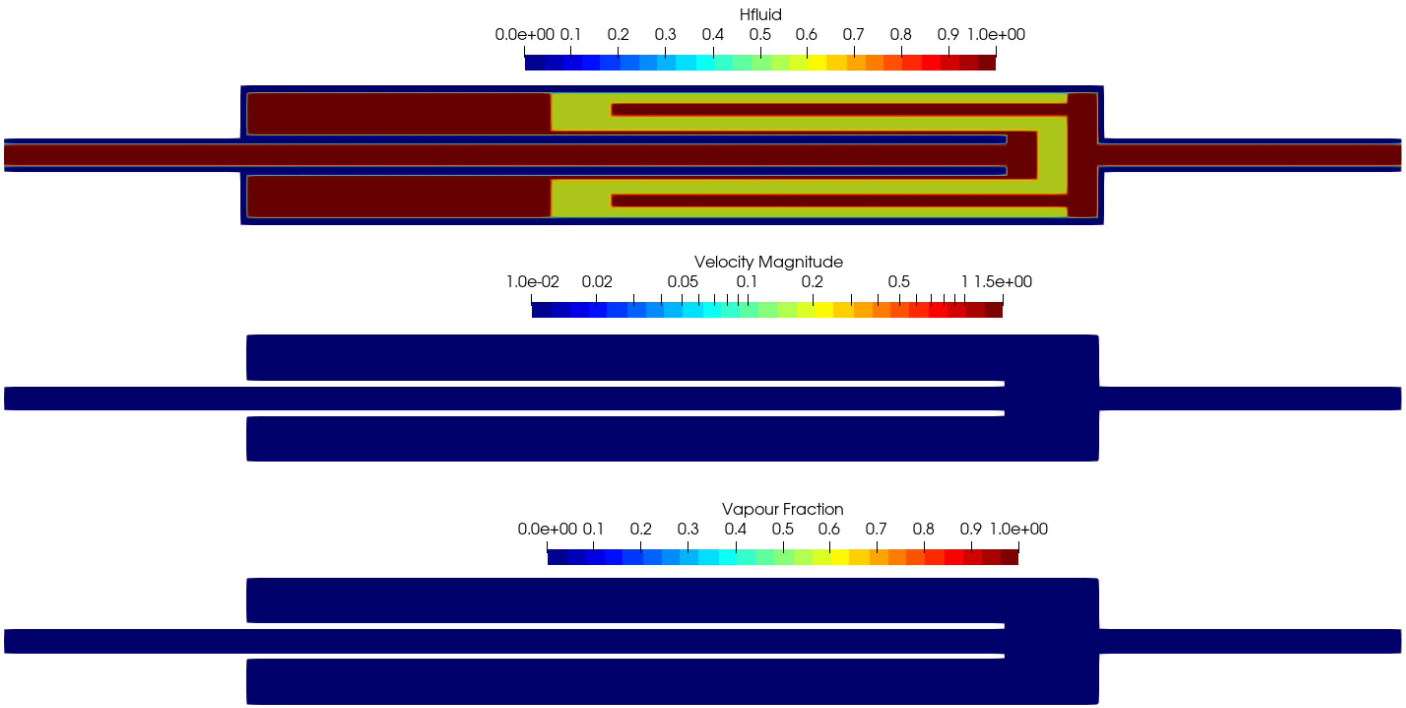
Conditions

- Wick has porosity of 0.6 and pore size of 1e-4 m
- Capillary pressure model has been used
- The wick has an internal heat source of 20 W
- To make the flow go in one direction an inflow velocity of 0.01 m/s is specified.



Evaporator geometry

EVAPORATOR SIMULATION WITH TRANSAT



- Result shows creation of vapor and exit of vapor from the right side.
- The evaporator model can be integrated with the loop to create a more complete model of an LHP.

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