Analysis of steam condensation in the presence of noncondensable gases using MARS-KS code

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Introduction

❖ Condensation

- One of the important phenomena in the heat transfer process
  - The steam condensation is used as a heat removal process in safety systems such as the PCCS.
- In the presence of a noncondensable gas
  - Disturb the condensation of the steam
- Several experimental studies have been performed
  - Dehbi performed experiment to determine the dependence of the condensation heat transfer, pressure, wall temperature subcooling, tube length, and the noncondensable gas ratio of the mixture.

❖ Objective

- Simulate the experiment of Dehbi by MARS-KS code
- To verify the condensation model of MARS-KS code

Condensation Model of MARS-KS

❖ Heat flux due to condensation of steam toward the interface of liquid-steam

$$q_v'' = h_m h_{fgb} \rho_{vb} \ln \left(\frac{1-\frac{P_{vi}}{P}}{1-\frac{P_{vb}}{P}} \right)$$

❖ Heat flux from the liquid film to the wall

$$q_l'' = h_c \left(T_{vi} - T_w \right)$$

❖ Assuming the initial wall temperature, iterate the calculation to satisfy following equation

$$q_v'' = q_l''$$

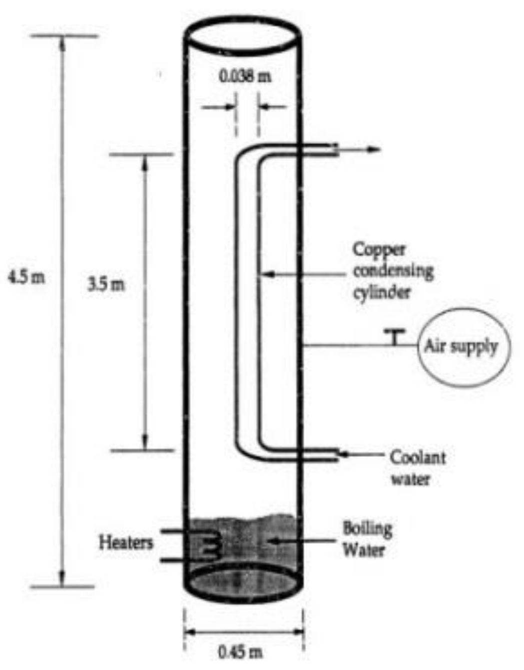
❖ Obtained by iterative calculation heat flux is

$$q'' = h_c \left(T_{wall} - T_{vb} \right)$$

❖ In this study, heat transfer coefficient is calculated by using the control variable as :

$$h_c = \frac{q''}{\left(T_{wall} - T_{vb} \right)}$$

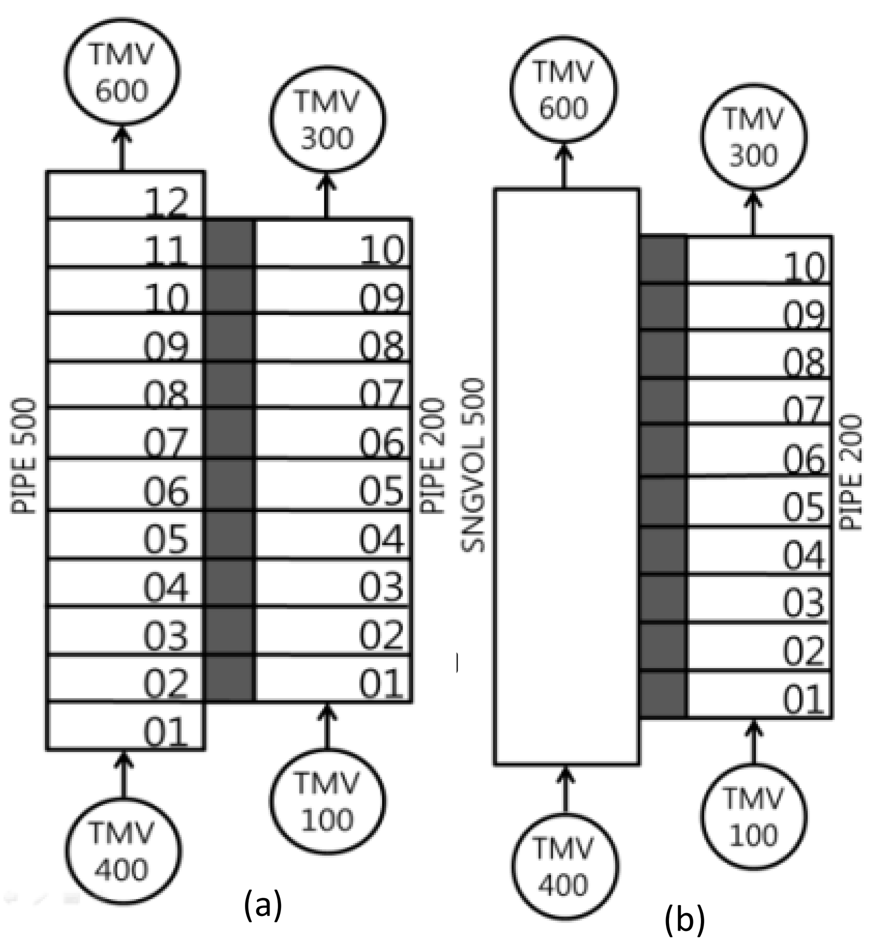
Condensation experimental apparatus by Dehbi



Schematic of the steam condensation experiment.

- Stainless steel vessel
  - Height : 4.5 m
  - Diameter : 0.45 m
  - Maintain constant steam pressure & temperature
- Cooper pipe (heat transfer tube)
  - Height : 3.5 m
  - Diameter : 0.038 m
  - Coolant : supplied into the bottom

MARS-KS code nodalization

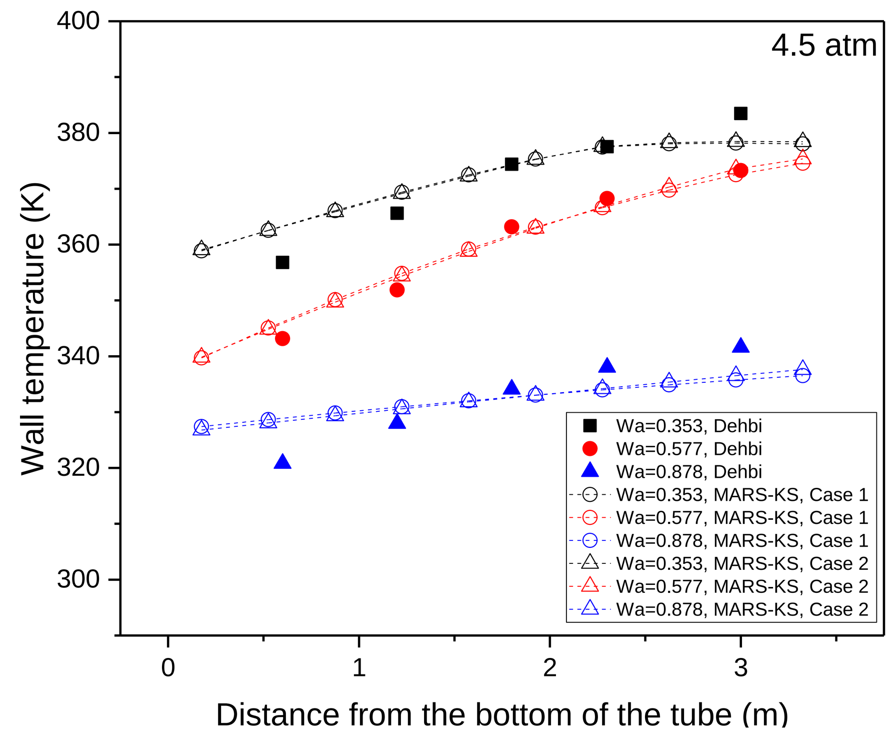


MARS-KS nodalization of the steam condensation experiment.

- Heat structure
  - Consists of 10 volumes
  - Heat transfer occurs only
- Boundary conditions
  - Steam mass flow rate
    – $\dot{m} = Q\left(h_g - h_f\right)$
    by time-dependent junction
  - Coolant mass flow rate
    – experiment
    : Reynolds number < 1500
  - Air mass fraction
    – Modified the boundary conditions
    – Setting to be similar Air mass fraction

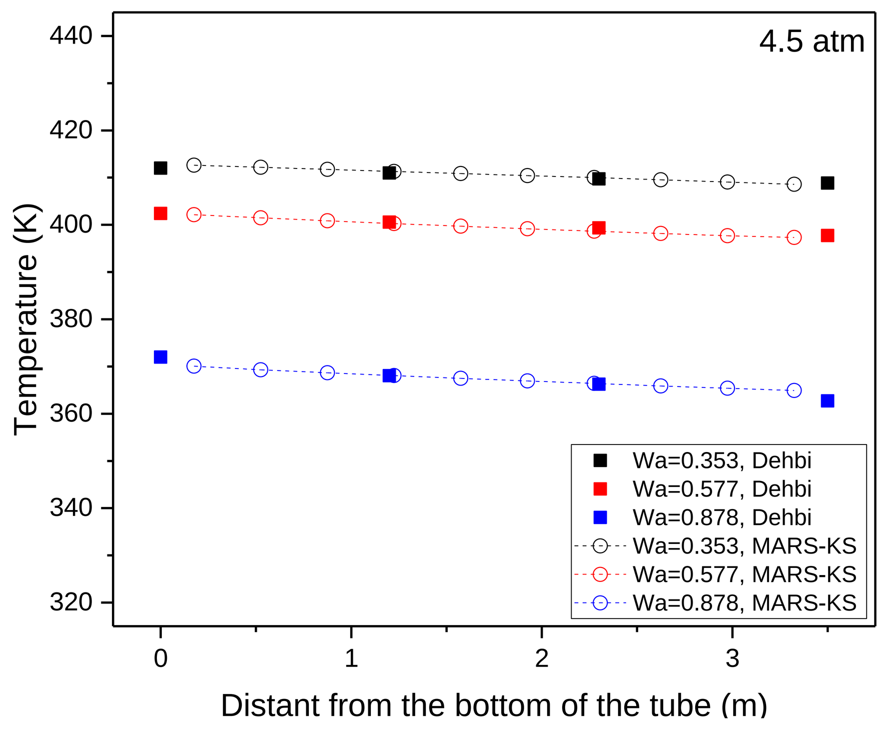
Results

❖ Wall temperature for 4.5-atm vessel pressure



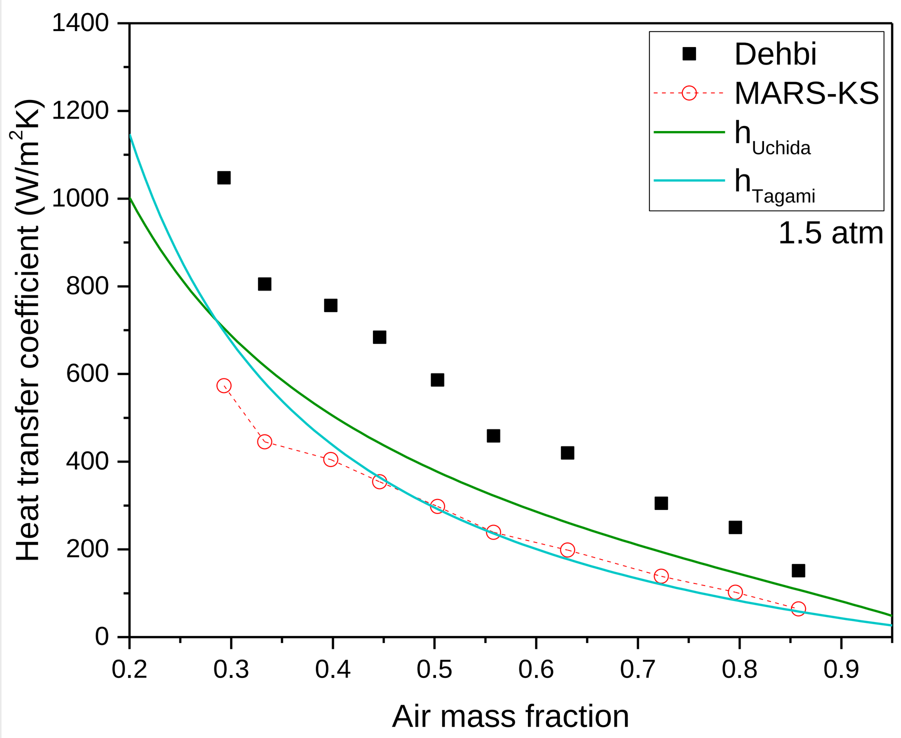
- Difference of case (a) and (b)
  - Wall temperature : 0.1 K
  - Heat transfer coefficient : 1%
- Case (a) is able to compare with the experiment of Dehbi for bulk temperature and air mass fraction along the tube, unlike the case (b).
- Take the case (a) to compare data of Dehbi's experiment with result of calculation

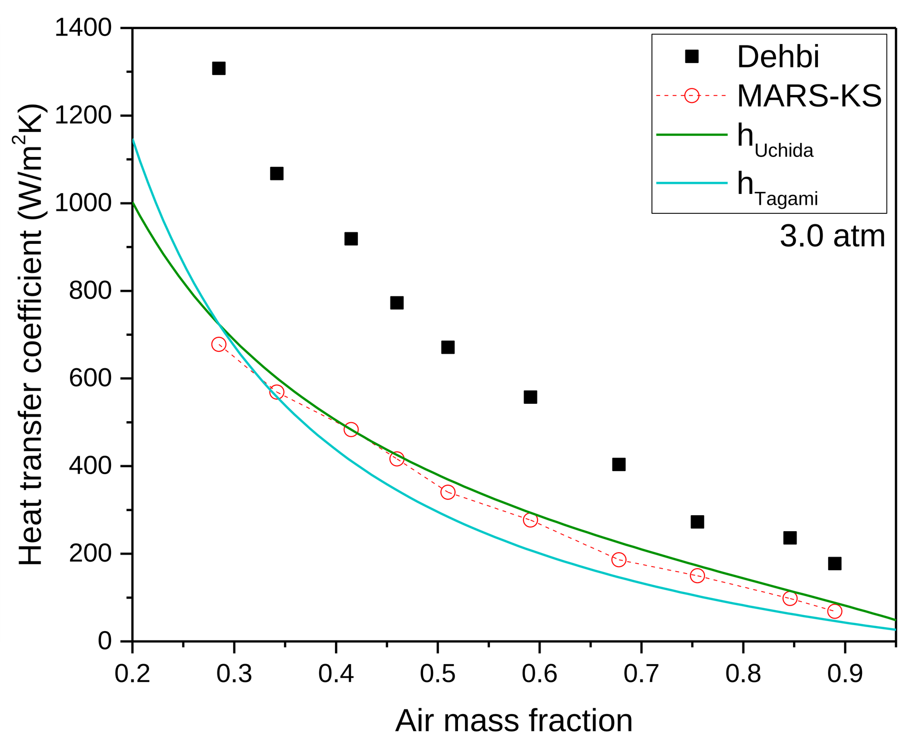
❖ Bulk temperature for 4.5-atm vessel pressure

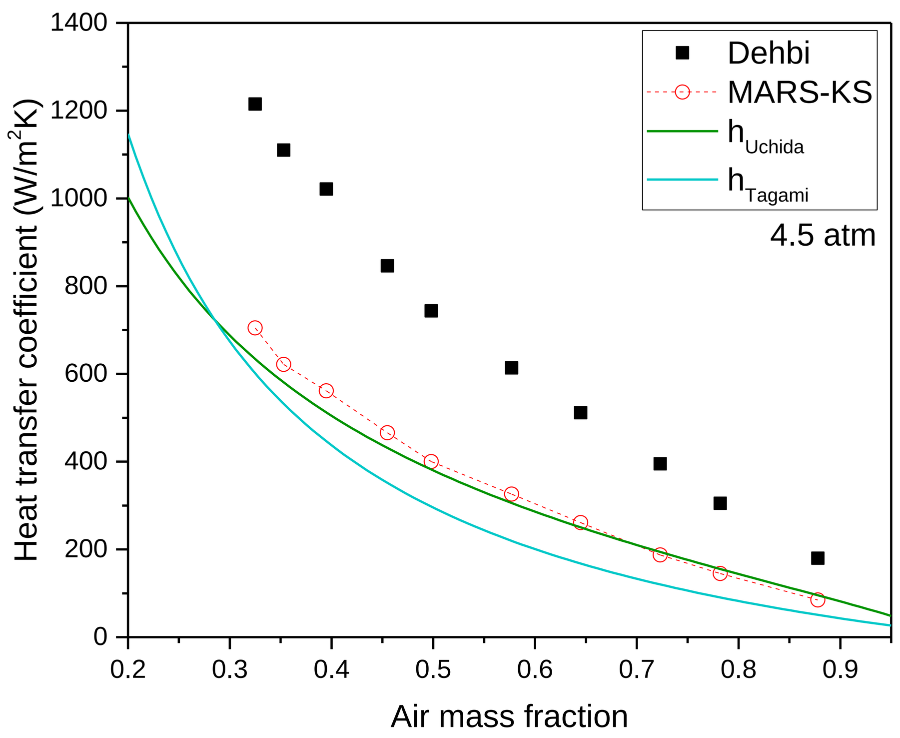


- Adjusting the boundary conditions
  → to be similar wall temperature of calculation with data of Dehbi's experiment
  → calculate the heat transfer coefficient

❖ Heat transfer coefficient







- Heat transfer coefficient
  - Pressure ↑
    → Heat transfer coefficient ↑
  - Air mass fraction ↑
    → Heat transfer coefficient ↓
- Difference of heat transfer coefficient between the Dehbi's data and result of MARS-KS code
  - result of MARS-KS : 50 % lower
- Condensation heat transfer model of MARS-KS code is should be modified.

Conclusion and Further works

❖ Heat transfer coefficient

- Heat transfer coefficient of MARS-KS calculation increases along the pressure increment, however, is lower than Dehbi's experiment.
- Result of MARS-KS is more conservative than data of Dehbi.
- Condensation heat transfer Model of MARS-KS code should be modified.

❖ Further works

- Implement the modified condensation heat transfer model for the accuracy of MARS-KS code
- Simulate the experiment of JNU by MARS-KS code