Assessment of Modified Wall Condensation Models of MARS-KS and SPACE Codes using Reflux Condensation Test

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1. Introduction

The wall condensation models of MARS-KS and SPACE codes adopt the Colburn-Hougen diffusion method to solve for the liquid-gas interface temperature in the presence of noncondensable (NC) gases [1].

Recent studies reported that there was an error in the vapor mass flux term when the models were implemented in the codes [2,3]. This error causes the codes to underestimate the steam condensation rate. This tendency becomes more noticeable with the increase in the mole fraction of NC gases.

In this study, we assess the modified condensation model of MARS-KS and SPACE codes. The calculation results of modified version of the codes (MARS-KS 1.3r1 and SPACE 2.16r1) are compared to those of the original version (MARS-KS 1.3 and SPACE 2.14) and the experimental data. The KAIST reflux condensation test [4] with NC gases are used in this assessment.

2. Facility and Model Description

The experimental equipment and test procedure are well described in ref. 4. The MARS-KS nodalization is shown in Fig. 2. The upflow side of U-tube, the condenser tube, is modeled using the vertical pipe component (150) with 15 volumes. The nodalization of the condenser tube is set so that the cell centers are aligned with the thermocouple elevations.

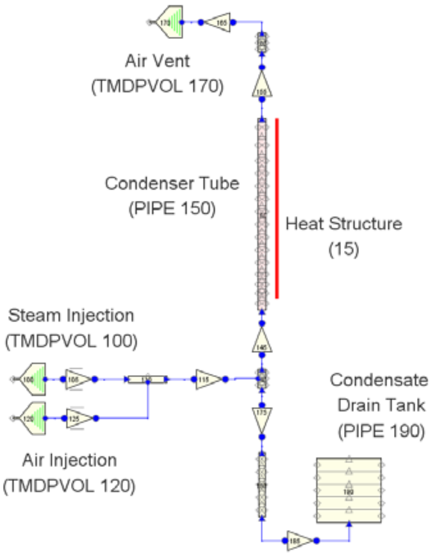

Fig. 1 MARS-KS model

Two time dependent junction components (105 and 125) are used to model the steam and air injections, respectively. The time dependent volume component (170) is used for the air vent line. The condensate drain tank is modeled using pipe component (190). The heat structure (15) is connected to condenser tube to model the condenser wall. The constant surface temperature are used as the right boundary conditions of the heat structure.

The input model for SPACE codes has the same nodalization used to develop the MARS-KS input. The same heat structure thermal properties, initial and boundary conditions are also used in both input models. The transient calculations were run for 100 seconds with the maximum timestep size of 0.01s. The predicted values are taken at the end of calculation.

3. Results and Discussion

A total of two cases with different inlet air mass fraction ($W_{air,in}$) are analyzed. Figures 2 and 3 show comparisons of the calculated values of gas-steam mixture temperature (T_b), tube inner wall surface temperature ($T_{w,i}$), heat fluxes at inner wall (q”), and local heat transfer coefficients (HTCs) with the experimental data.

As both codes use the same condensation model, overall results are similar except the gas-steam temperature of small inlet air mass fraction test.

Figures 2(a) and 3(a) show the gas-steam temperature results. As the air mass fraction increases along the tube axial direction, the modified condensation model predicts lower gas-steam temperature than the original model. At low inlet air mass fraction test, the MARS-KS code predicts lower gas-steam temperatures than SPACE code. At the high inlet air mass fraction test, the modified model provides a reasonable estimate of gas-steam temperatures.

The results of Figs. 2(b) and 3(b) demonstrate that the inner wall temperature are well predicted by both of code versions. At high inlet air mass fraction test, the modified models slightly increase the inner wall temperature.

The local heat fluxes at tube inner wall are plotted in Figs. 2(c) and 3(c). As shown in the results, there is little difference between models at low inlet air mass fraction. However, the modified model predicts higher heat fluxes than the original model at relatively high inlet air mass fraction.

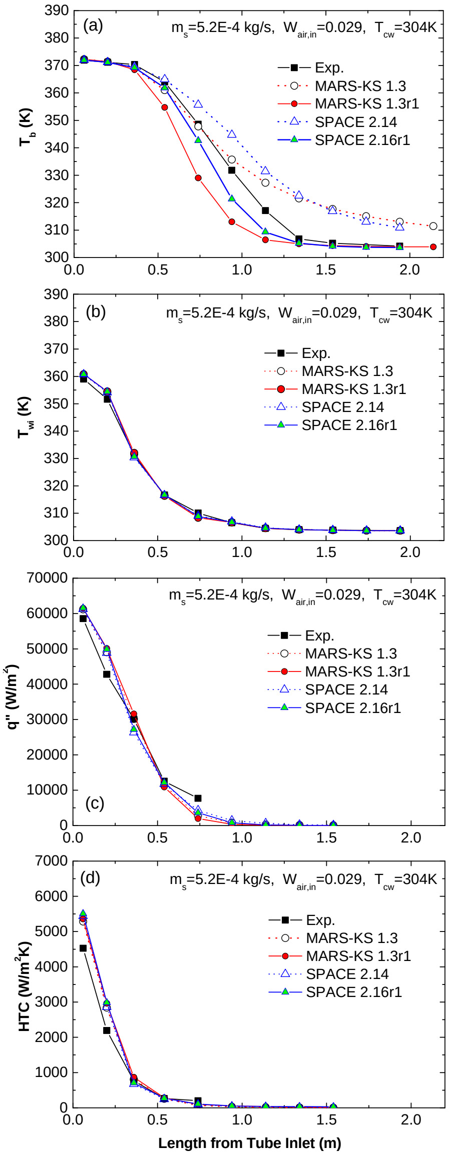

Fig. 2. Comparison of calculated values with exp. data ($m_s = 5.2 \times 10^{-4}$ kg/s, $W_{air,in} = 0.029$)

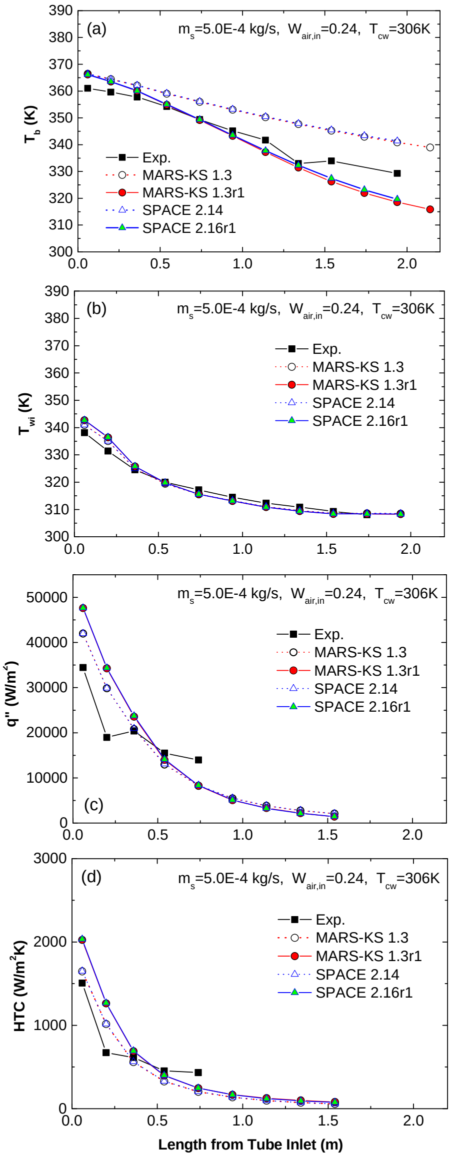

Fig. 3. Comparison of calculated values with exp. data ($m_s = 5.0 \times 10^{-4}$ kg/s and $W_{air,in} = 0.24$)

Figures 2(d) and 3(d) shows the local heat transfer coefficients (HTC). In the calculation, the definition of predicted HTC was consistent with that of experimental data. At low air mass fraction, there are no significant difference. At high air mass fraction, the modified model predicts about 24% higher HTC than the original model at the tube entrance region. When compared with the experimental data, the modified condensation model increase the discrepancy.

4. Conclusions

The modified wall condensation model provides a reasonable estimate of gas-steam mixture temperature. The modified model predicts higher heat fluxes and HTCs than the original model due to the increase in the steam condensation rate. At relatively high air mass fraction, the modified model increases the discrepancy between the measured data and calculated values.

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