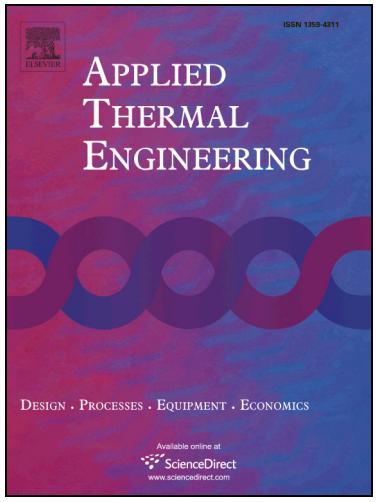

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Numerical Simulation of Double-Phase Coupled Heat Transfer Process of Horizontal-tube Falling Film Evaporation

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Abstract: The double-phase coupled heat transfer process plays an important role in the horizontal-tube falling film evaporation. The method of element sliced out of tube was presented and the continuous double-phase transformation was represented by the discrete mass fraction of steam in the tube. The model of the double-phase coupled heat transfer of the horizontal-tube falling film evaporation was built up to simulate the process of coupling heat-transfer process inside and outside tube. The Volume of Fluid (VOF) method was applied to investigate the influence of the spray density on the distributions of the film thickness and the circumferential and axial heat transfer coefficient of horizontal-tube. The computation results showed that the circumferential film thickness changed constantly. The minimum film thickness appeared approximately at the angular positions of 100° to 140°. And dry spot would form at the bottom of the horizontal-tube. The external film heat transfer coefficient of circumferential horizontal tube gradually decreased. In the axial direction the overall heat transfer coefficient was mainly impacted by the internal film heat transfer coefficient, which was improved with the increasing of water vapor condensation and not sensitive to the spray density.

Key words: horizontal-tube falling film evaporation; double-phase coupled heat transfer; film thickness; heat transfer coefficient; spray density

1 Introduction

The horizontal-tube falling film evaporation is common unit operation in process industry. It is important to improve the heat transfer performances of the horizontal-tube falling film evaporator in order to reduce equipment investment and energy consumption. The falling film evaporators are widely applied in sea water desalination and waste water treatment due to high heat transfer coefficients specially when the mass flow rates, temperature differences and heat exchange area are comparatively small. And there are lots of theoretical and experimental studies on the flow and heat transfer of falling film evaporation process [1-3].

Double-phase coupled heat transfer process, especially phase transformation inside and outside tube coupled with flow-tube correlatives, is a crucial problem in falling film evaporation. So the numerical simulation under such complicated conditions can be extremely helpful in an accurate thermal analysis and engineering design. Qi [4] compared the thickness of liquid film between elliptical tube and circular one and the performances of heat transfer by means of theoretical analysis, CFD numerical simulation and experiments. The results illustrated that the heat transfer performance of elliptical tube was better than circular one and preferred to falling-film evaporation. Luo et al. [5] studied the falling film flow and performance of heat transfer on circular tube, drop-shaped tube and oval-shaped tube outside the tube under the constant wall temperature conditions. The effects of spray density and spray heights on the liquid film and heat transfer coefficients were analyzed and the results showed that the un-circular tubes had higher heat transfer performance. Qiu [6,7] developed a 2-D multi-phase flow model for numerical simulation under adiabatic boundary condition which was the basis for the computation of circumferential film thickness distribution characteristics of horizontal-tube. The influence of mass flow rate and tube diameter parameters on the film thickness was investigated and the whole falling film flow along the horizontal-tube surface was considered as combination with the transient and steady process. The results showed that an obvious zone without liquid covered was formed very closely to the lower stagnation point, which would be enlarged with the increasing of Reynolds number.

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