ThermoCycle Moving Boundary Model

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Abstract

The authors present a new moving boundary model that was integrated into the ThermoCycle package written in the Modelica language. Focussing on a seamless integration with existing components, this new component allows to calculate dynamic heat transfer in an efficient and robust way covering the full range of possible operating points in the liquid, two-phase, gas and supercritical domain. A basic validation performed with heat transfer data from two different experiments with evaporators shows that the model is able to reliably predict heat exchanger performance. The flexible implementation allows to compare different heat transfer correlations, which are made freely available as part of the ThermoCycle library.

1 Introduction and Motivation

Moving boundary (MB) models are established tools to calculate heat exchanger performance in both steady-state and dynamic operation. A fictitious heat transfer channel is split up into different sections and with each section accounting for a different fluid state. In the case of an evaporator the maximum number of sections N is 3 for a) subcooled, b) two-phase and c) superheated state. At higher pressures, the fluid might enter the supercritical state. Hence, there are four different sections out of which a maximum of three can occur simultaneously. The name moving boundary is derived from the fact that the interfaces between these sections do not have a fixed spatial position but merely a fixed thermodynamic location depending on the presence of liquid and gaseous fluid, respectively. The actual existence of a certain section and its length are determined based on the fluid state resulting in variable sectioning. A fixed total length superimposes the required boundary condition to calculate the length of each section.

Moving boundary formulations are a good compromise between computational efficiency, robustness and accuracy[1].

2 Formulation

2.1 Assumptions

2.2 Equations

2.3 Heat Transfer

Based on Nusselt number (Nu) from Reynolds number (Re) and Prandtl number (Pr) for a characteristic length L. Angles are usually calculated in radians or π.

2.4 Pressure Drop

3 Results and Discussion

Compared to [2], the model ....
[3]
[4]

4 Conclusion

References

[1] Satyam Bendapudi, James E. Braun, and Eckhard A. Groll. A comparison of moving-boundary and finite-volume formulations for transients in centrifugal chillers. *International Journal of Refrigeration*, 31(8):1437–1452, 2008.

[2] Martin Ryhl Kærn. *Analysis of Flow Maldistribution in Fin-and-tube Evaporators for Residential Air-conditioning Systems.* Phd thesis, Technical University of Denmark, 2011.

[3] Wei-Jiang Zhang and Chun-Lu Zhang. A generalized moving-boundary model for transient simulation of dry-expansion evaporators under larger disturbances. *International Journal of Refrigeration*, 29(7):1119–1127, November 2006.

[4] Wei-Jiang Zhang, Chun-Lu Zhang, and Guo-Liang Ding. On three forms of momentum equation in transient modeling of residential refrigeration systems. *International Journal of Refrigeration*, 32(5):938–944, August 2009.

Glossary

c Specific heat capacity ($\mathrm{J\,kg^{-1}\,K^{-1}}$).

h Heat transfer coefficient ($\mathrm{W\,m^{-2}\,K^{-1}}$).

L Length (m).

N Number of sections (ND).

v Velocity ($\mathrm{m\,s^{-1}}$).

Acronyms

MB moving boundary.

Dimensionless Numbers

Nu Nusselt number: $\frac{\text{convection}}{\text{conduction}} = \frac{h\,L}{\lambda}$.

Pr Prandtl number: $\frac{\text{viscous diffusion}}{\text{thermal diffusion}} = \frac{c_p\,\mu}{\lambda}$.

Re Reynolds number: $\frac{\text{inertia}}{\text{viscosity}} = \frac{\rho\,v\,L}{\mu}$.

Greek Symbols

λ Thermal conductivity ($\mathrm{W\,m^{-1}\,K^{-1}}$).

μ Dynamic viscosity ($\mathrm{Pa\,s}$).

π ratio of circumference of circle to its diameter.

ρ Density of a material or medium ($\mathrm{kg\,m^{-3}}$).

Subscripts

p at constant pressure.