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Numerical investigation of refrigerant flow through non-adiabatic capillary tubes

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Abstract

A mathematical model is developed to study flow characteristics in non-adiabatic capillary tubes. The theoretical model is based on conservation of mass, energy and momentum of fluids in the capillary tube and suction line. The mathematical model is categorized into three different cases, depending on the position of the heat exchange process. The first case is considered when the heat exchange process starts in the single-phase flow region, the second case is determined when the heat exchange process starts at the end of the single-phase flow region, and the last case is considered when the heat exchange process takes place in the two-phase flow region. A set of differential equations is solved by the explicit method of finite-difference scheme. The model is validated by comparing with the experimental data obtained from previous works. The results obtained from the present model show reasonable agreement with the experimental data. The present non-adiabatic capillary tube model can be used to integrate with system models working with alternative refrigerants for design and optimization.

Keywords: Two-phase flow; Refrigerant; Non-adiabatic capillary tube; Suction line; Heat exchanger

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Nomenclature

A	cross-sectional area (m^2)
c_p	specific heat ($J\,kg^{-1}\,K^{-1}$)
C_r	heat capacity ratio
D_c	capillary tube diameter (m)
D_s	suction line diameter (m)
f	friction factor
g	gravitational acceleration ($m\,s^{-2}$)
G	mass flux ($kg\,s^{-1}\,m^{-2}$)
h	specific enthalpy ($J\,kg^{-1}$)
Nu	Nusselt number
P	pressure (Pa)
Pr	Prandtl number
Q	heat transfer rate (W)
Re	Reynolds number
s	specific entropy ($J\,kg^{-1}\,K^{-1}$)
T	temperature (K)
U	overall heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
V	velocity ($m\,s^{-1}$)
h_c	heat transfer coefficient in capillary tube ($W\,m^{-2}\,K^{-1}$)
h_s	heat transfer coefficient in suction line ($W\,m^{-2}\,K^{-1}$)
K	entrance loss coefficient
L	length (m)
L_f	final length of capillary tube (m)
L_{hx}	heat exchange region length (m)
L_{in}	initial length of capillary tube (m)
L_{sp}	single-phase flow length (m)
L_{tp}	two-phase flow length (m)
m	mass flow rate ($kg\,s^{-1}$)
NTU	number of transfer unit
x	vapour quality
z	position (m)
ϵ	surface roughness (m)
μ	dynamic viscosity ($kg\,m^{-1}\,s^{-1}$)
ρ	density ($kg\,m^{-3}$)
τ	shear stress ($N\,m^{-2}$)
υ	specific volume ($m^3\,kg^{-1}$)
ϕ	effectiveness

Subscripts

c	capillary tube
cond	condenser