Experimental Investigation of Single-Phase Friction Factor and Heat Transfer inside the Horizontal Internally Micro-Fin Tubes

by

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Master of Science in Electromechanical Engineering

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Abstract

EXPERIMENTAL INVESTIGATION OF SINGLE-PHASE FRICTION FACTOR AND HEAT TRANSFER IN HORIZONTAL INTERNALLY MICRO-FIN TUBES

by Sun Cheong

Thesis Supervisor:
Prof. Lap Mou Tam
Master of Science in Electromechanical Engineering

A simultaneous pressure drop and heat transfer experiment for single-phase flow in a plain and three micro-fin tubes was conducted in this study. The micro-fin tubes have the same fin height to inner diameter ratio of 0.0336, the same number of starts of 25, but different fin spiral angle of 18°, 25° and 35°. The transition of friction factor and heat transfer from laminar to turbulent were established and shown to be inlet dependent and fin spiral angle dependent. The results showed that the friction factor and heat transfer characteristics of the micro-fin tubes in the transition region were different compared to the plain tube. The friction factor and heat transfer data could not be easily correlated by the traditional regression method. Therefore, the logistic dose response curve fitting method, which has recently been used by other researchers in correlating the friction factor in plain tube, was proposed in this study for correlating the micro-fin tubes friction factor and heat transfer data. All the fully developed friction factor data for the entire flow regime can be predicted accurately by a composite logistic dose response function within ±18% deviation. The majority of the data (80%) was predicted with less than ±5% deviation. The fully developed

heat transfer data for the entire flow regime were predicted by a composite logistic dose response function within ±28% deviation. The majority of the data (78%) was predicted with less than ±10% deviation.

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NOMENCLATURE

C_f	fully developed friction factor coefficient (fanning friction factor), [$=\Delta P \cdot D_i/(2 \cdot L \cdot \rho \cdot V^2)$], dimensionless
c_p	specific heat of the test fluid evaluated at T_b, J/(kg·K)
D_i	inside diameter of the test section (tube), m
D_o	outside diameter of the test section (tube), m
e	internal fin height, mm
f_a, f_b, f_c, f_d	functions for each line segment in Figures 4.8 to 4.11 and Figures 4.17 to 4.20, dimensionless
F	composite logistic dose response function in Equation 4.1, dimensionless
F_1, F_2	composite logistic dose response functions in Equations 4.2 and 4.3, dimensionless
h	fully developed peripheral heat transfer coefficient, W/(m^2·K)
h_b	local peripheral heat transfer coefficient at the bottom of the tube, W/(m^2·K)
h_t	local peripheral heat transfer coefficient at the top of the tube, W/(m^2·K)
j	Colburn-j factor [$=St \cdot Pr^{0.67}$], dimensionless
k	thermal conductivity of the test fluid evaluated at T_b, W/(m·K)
L	length of the test section (tube), m
N_s	number of starts/ fins inside the cross-section area, dimensionless
Nu	local average or fully developed peripheral Nusselt number (= $h \cdot D_i/k$), dimensionless
p	axial fin pitch, [$=\pi \cdot D_i/(N_s \cdot \tan \alpha)$], m
Pr	local bulk Prandtl number ($=c_p \cdot \mu_b/k$), dimensionless

Re	local bulk Reynolds number (=$\rho \cdot V \cdot D_i / \mu_b$), dimensionless
St	local average or fully developed peripheral Stanton number [=Nu/(Pr·Re)], dimensionless
T_b	local bulk temperature of the test fluid, ºC
T_w	local inside wall temperature, ºC
V	average velocity in the test section, m/s
x	local axial distance along the test section from the inlet, m

Greek letters

α	spiral angle, degree
ΔP	pressure difference, Pa
μ_b	local bulk dynamic viscosity of the test fluid evaluated at T_b, Pa·s
μ_w	local bulk dynamic viscosity of the test fluid evaluated at T_w, Pa·s
ρ	density of the test fluid evaluated at T_b, kg/m^3

Subscripts

b	bulk
cal	refers to calculated value
exp	refers to experimental value
l	laminar
t	turbulent
tr	transition
w	wall

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