Experimental Investigation of Single-Phase Heat Transfer in a Horizontal Internally Micro-Fin Tube with Three Different Inlet Configurations

by

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Abstract

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To increase heat transfer, internally micro-fin tubes are widely used in commercial HVAC applications. It is commonly understood that the micro-fin enhances heat transfer in the turbulent region. There are only a few works that fundamentally studied the continuous change in the characteristic behavior of heat transfer from laminar to transition and eventually the turbulent regions. Furthermore, it is difficult to find the information about the effect of inlet configuration on the micro-fin tube heat transfer in the open literature. Therefore, more in-depth study for the micro-fin tube heat transfer characteristics is necessary.

In this study, heat transfer was measured in a single test section fitted with a micro-fin tube and compared with the data of a plain tube. Both of the tubes with the same internal diameter of 14.9 mm were tested under the uniform wall heat flux boundary condition. Three inlet configurations, re-entrant, square-edged, and bell-mouth, were used in this study. The entire experiment covered the Reynolds number range between 1,100 and 23,000.

From the heat transfer results, the transition from laminar to turbulent region for the plain and micro-fin tubes was clearly established. For both of the plain and micro-fin tubes in the laminar region, buoyancy effects and heat transfer magnitudes were comparable. It was also observed that for the micro-fin tube heat transfer enhancement initiated in the transition region and lasted through the turbulent region.

For both of the plain and micro-fin tubes, the transition from laminar to turbulent region was found to be inlet dependent. For bell-mouth inlet, it was obvious that the micro-fin tube had an earlier transition than the plain tube. Furthermore, for both of the plain and micro-fin tubes with bell-mouth inlet, an unusual behavior of the local heat transfer coefficient was observed in the transition and turbulent regions.

Finally, the heat transfer correlations for laminar, transition and turbulent regions, and different inlets were developed based on the experimental data. The micro-fin tube correlations for different inlets can help to design the thermal engineering equipments such as heat exchangers.

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NOMENCLATURE

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
h	fully developed peripheral heat transfer coefficient, W/(m^2·K)
h_b	local peripheral heat transfer coefficient at the bottom of tube, W/(m^2·K)
h_t	local peripheral heat transfer coefficient at the top of tube, W/(m^2·K)
j	Colburn-j factor [=St $Pr^{0.67}$], dimensionless
k	thermal conductivity, evaluated at T_b, W/(m·K)
N_s	Number of starts/fins inside the cross-section area, dimensionless
N_u	local average or fully developed peripheral Nusselt number (= h·Di /k), dimensionless
p	axial fin pitch, [= $\pi \cdot$ Di / (Ns · tan α)], 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
V	average velocity in the test section, m/s
x	local axial distance along the test section from the inlet, m

Greek Symbols

α Spiral angle, degree

μ_b absolute viscosity of the test fluid evaluated at T_b, Pa·s

μ_w absolute 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

l laminar

t turbulent

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