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Performance analysis of rectangular ducts with staggered square pin fins

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Abstract

This paper presents the heat transfer and friction characteristics and performance analysis of convective heat transfer through a rectangular channel with square cross-section pin fins attached over a flat surface. The pin fins were arranged in a staggered manner. Various clearance ratios (C/H) and interfin distance ratios (S_x/D) were used. The performance analysis was made under a constant pumping power constraint. The experimental results showed that the use of square cross-section pin fins may lead to an advantage on the basis of heat transfer enhancement. For higher thermal performance, lower interfin distance ratio and clearance ratio and comparatively lower Reynolds numbers should be preferred for the staggered arrangement. The results of the staggered configurations were also compared with the results of the inline arrangement.

Keywords: Pin fin; Heat transfer enhancement; Channel flow; Forced convection; Heat exchangers; Performance analysis

1. Introduction

Extended surfaces (fins) are frequently used in heat exchanging devices for the purpose of increasing the heat transfer between a primary surface and the surrounding fluid. Various types of heat exchanger fins, ranging from relatively simple shapes, such as rectangular, cylindrical, annular, tapered or pin fins, to a combination of different geometry, have been used. These fins may protrude from either a rectangular or cylindrical base.

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Nomenclature

A	cross-section area of duct, m^2
A	heat transfer area, m^2
C	clearance between upper surface of fin and ceiling of duct, m
D	thickness of fins, m
D_e	hydraulic diameter of channel, m
f	friction factor
H	height of fins, m
$\overline{h}$	average convective heat transfer coefficient, $W/m^2\,K$
k_{air}	thermal conductivity of air, W/m K
L	length of test surface, m
L_t	length of test section, m
N_f	number of pin fins
$\overline{Nu}$	average duct Nusselt number
$\overline{Nu}_D$	average pin Nusselt number
Pr	Prandtl number
$\dot{Q}$	heat transfer rate, W
Re	duct Reynolds number
Re_D	pin Reynolds number
S_x	distance between two fins in x direction, m
$\overline{T}$	mean temperature, K
U	mean bulk flow velocity, m/s
U_{max}	maximum flow velocity, m/s
W	width of base plate, m
ΔP	pressure drop, N/m^2
ρ	air density, kg/m^3
v	kinematic viscosity of air, m^2/s

Subscripts

in	conditions at inlet
out	conditions at outlet
s	smooth
w	conditions at surface

One of the commonly used heat exchanger fins is the pin fin. A pin fin is a cylinder or other shaped element attached perpendicular to a wall, with the transfer fluid passing in crossflow over the element. There are various parameters that characterize the pin fins, such as shape, height, diameter, height to diameter ratio etc. In addition, the pin fins may be positioned in arrays that are either staggered or inline with respect to the flow direction.

The heat transfer and friction characteristics of pin fin array systems have been the subject of extensive investigation because of its importance in a wide variety of engineering applications,