Alexandria Engineering Journal (2015) 54, 905–915

HOSTED BY

ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Experimental and parametric studies of a louvered fin and flat tube compact heat exchanger using computational fluid dynamics

P. Karthik [a], **V. Kumaresan** [b], **R. Velraj** [b,*]

[a] *Department of Mechanical Engineering, RMK College of Engineering and Technology, India*
[b] *Department of Mechanical Engineering, Anna University, Chennai, India*

Received 26 March 2015; revised 3 August 2015; accepted 10 August 2015
Available online 29 August 2015

KEYWORDS

Goodness factor;
Computational fluid dynamics;
Louvered fin;
Louver pitch;
Thermo-hydraulic performance

Abstract The present study aimed to perform the parametric analysis on thermo-hydraulic performance of a compact heat exchanger using computational fluid dynamics (CFD). The analysis has been carried out at different frontal air velocities by varying the geometrical parameters such as fin pitch, transverse tube pitch, longitudinal tube pitch, louver pitch and louver angle. The air side performance of the heat exchanger has been evaluated by calculating Colburn factor (*j*) and Fanning friction factor (*f*). The comparison of CFD results with the experimental data exhibited a good agreement and the influence of various geometrical parameters for the selected range of values on the pressure drop, heat transfer coefficient and goodness factor was analyzed. The results obtained from the analysis will be very useful to optimize the louvered fin and flat tube compact heat exchanger for better thermo-hydraulic performance analysis without the need of time consuming and expensive experimentation.

1. Introduction

Due to inadequate thermal characteristics of the heat transfer fluid, the required heat transfer in a heat exchanger is achieved by increasing the temperature difference between the fluids (ΔT), increasing the area (A) and the convective heat transfer coefficient (h). A greater temperature difference can lead to an increase in the heat flow, but it is often limited by process or materials constraints. Also, the higher temperature difference requirement in the thermal devices for cooling/heating reduces the overall efficiency of the system. The heat transfer surface on the gas side of the heat exchanger needs to have a much larger surface area owing to its lower heat transfer coefficient than that for liquids. Increasing the surface area through fins is a common method to improve the heat transfer rate and this addition of fins results with increase in the surface area by 5 to 12 times [1–3] than that of the primary surface area. Among the various fins, the louvered fin geometry provides better enhancement compared to that of other fin geometries [4–8] by reducing thermal resistance on the gas

* Corresponding author at: Institute for Energy Studies, Anna University, Chennai 600025, India. Tel.: +91 44 22357600.
E-mail address: velrajr@gmail.com (R. Velraj).

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2015.08.003
1110-0168

Nomenclature

A	area (m^2)
c_p	isobaric specific heat capacity (J kg^{-1} K^{-1})
D_h	hydraulic diameter (m)
E	energy (J)
f	fanning friction factor
j	Colburn factor
g	body force
G	Mass flux or mass velocity (kg m^{-2} s^{-1})
h	heat transfer coefficient (W m^{-2} K^{-1})
h_e	specific enthalpy (J kg^{-1})
k	thermal conductivity (W m^{-1} K^{-1})
p	pressure (N m^{-2})
T	temperature (°C)
u	velocity of the fluid along × direction (m s^{-1})
v	velocity of the fluid along y direction (m s^{-1})
w	velocity of the fluid along z direction (m s^{-1})
Pr	Prandtl number (–)
Re	Reynolds number (–)
St	Stanton number (–)
VC	validation case (–)
Δp	pressure drop on air side (N m^{-2})
ΔT	temperature drop (K)

Greek symbols

θ	louver angle
ρ	density (kg m^{-3})
μ	dynamic viscosity (N s m^{-2})
τ	shear stress (N m^{-2})

Subscripts

a	air
i	inlet
f	frontal
o	outlet
s	surface
w	water
in	inlet
min	minimum

(air) side considerably in the compact heat exchangers. It is necessary to select the optimal shape and size of the louvered fins in effective design of the compact heat exchanger for better thermo-hydraulic performance. Intensive research works are being carried out by the researchers on various geometrical parameters such as the fin pitch, louver pitch, louver angle, flow length and inclination angle of the heat exchanger that influence the performance of the louvered fin heat exchanger.

Leu et al. [9] analyzed the performance of tube heat exchanger numerically and the results showed a decrease in pressure with respect to increase in louver angle. The effect of Reynolds number, fin pitch, louver thickness, and louver angle on flow efficiency in multi-louvered fins was reported by Zhang and Tafti [10]. Their results clearly revealed that the flow efficiency strongly depended on geometrical parameters, particularly at low Reynolds numbers. Vaisi et al. [11] experimentally investigated the heat transfer and pressure drop characteristics of air flow over louvered fins in compact heat exchangers with two different types of fin configurations (symmetrical and asymmetrical). They reported that the symmetrical arrangement of louvered fins provided an increase in the heat transfer performance of 9.3% and a decrease in the pressure drop of 18.2%, when compared to the asymmetrical arrangement of louvered fin due to the absence of the louvered region between two tubes. Yang et al. [12] studied the thermo-hydraulic performance of the heat sinks having plate, slit, and louver fin patterns. The enhanced fin patterns like louver or slit fin operated at a higher frontal velocity and at larger fin spacing were more beneficial than those of plain fin geometry. In addition to the fin parameters, the inclination angle of heat exchanger plays a vital role on the performance of the louvered fin and tube heat exchanger. Nuntaphan et al. [13] reported a considerable increase of heat transfer performance at an inclination of 30–45°, due to louver ducted phenomena on the air side. They proposed a correlation, considering the influence of inclination angle and this correlation predicted 71.4% of experimental data within ±10%. It is desirable to optimize the various parameters of louvered fin heat exchangers and explore the most influencing parameters on the thermal performance of the heat exchangers. The heat transfer and flow friction characteristics of a heat exchanger with corrugated louvered fins were analyzed by Qi et al. [14] using Taguchi method. Their results indicated that the flow depth, ratio of fin pitch to fin thickness and number of the louvers were the main factors that influence the thermal hydraulic performance of the heat exchanger. Similar methodology was also adopted by Hsieh and Jang [15] and interpreted the fin collar outside diameter, transverse tube pitch and fin pitch as the most influencing parameters. Recently, Sun and Zhang [16] evaluated overall thermo-hydraulic performance of elliptical finned tube heat exchanger using CFD approach and reported the influence of axis ratio on the overall performance of the heat exchanger under various flow conditions. The increase in axis ratio reduced the overall performance at lower air velocity and enhanced the performance at higher air velocity.

It is clear from the above literature that the geometrical parameters of the fins play a vital role in enhancing the heat transfer coefficient on the air side and these parameters are to be optimized for enhanced thermo-hydraulic performance of the louvered fin and tube heat exchanger. This necessitates several experiments to be conducted at various conditions that are not only time consuming, but also expensive. Considering the above pressing issues and recent developments in the CFD software, the present work aims to analyze the effects of the various parameters such as fin pitch, tube pitch, louver pitch and louver angle on the heat transfer and pressure drop characteristics of the compact heat exchanger with the louvered fins under different flow conditions.

2. Governing equations and boundary conditions

The problem under consideration is governed by three dimensional form of continuity, the Reynolds-Average Navier–Stokes equation (RANS), and the energy equation, along with