Design, Fabrication and Numerical Investigation of Multi- Louvered Compact Plate Fin Heat Exchanger

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Abstract— Heat exchanger is a thrust area, which required constant improvement in the performance. Recently multi-louvered plate fin heat exchangers, a kind of compact heat exchanger, have been the subject of vast research. Multi-louvered plate heat exchanger has unique advantage, in that it is easy to control fluid temperature beside the general peculiarity of compact heat exchanger; so a large number multi-louvered plate fin heat exchanger, especially plate fin heat exchanger, are used in chemical industry. In the present study, successively increased or decreased louver angle patterns are proposed and 3-D numerical analysis on heat and fluid flow are carried out. A steady-state three-dimensional numerical model was used to study the heat transfer and pressure drop characteristics of a multi-louvered compact plate fin heat exchanger. Air was the heat transfer medium, and the Reynolds number ranged from 200 to 1600. A numerical study was performed on compact fin-and-tube heat exchangers having circular tube with multilouvered fins. Air side performance for heat exchanger with and without hydrophilic coating has been studied. The pressure drops for the hydrophilic coated surface were lower than the corresponding un-coated surfaces. The heat transfer performance for the hydrophilic coating surface was found to be lower than the corresponding un-coated surface tested at the same condition. Moreover, the increase in the heat transfer performance was found to be 20% for louver angle 26º, fin pitches of 1.2 mm with hydrophilic coating. The effects of number of tube rows, fin pitch and louver angle on airside performance were analyzed.

Key words: Heat Transfer Coefficient; Pressure Drop; Hydrophilic Coating

I. Introduction

Multi-louvered fin and flat tube heat exchangers have a higher degree of surface compactness, and substantial heat transfer enhancement is obtained due to the periodic starting and development of the laminar boundary layer over the interrupted channels formed by the louvered fins and their dissipation in the fin wakes. The flow pattern could be characterized in terms of duct directed or louver directed flows, depending on the Reynolds number. At low Reynolds number, the boundary layers are so thick that the gap between adjacent louvers is blocked, and the flow is duct directed in the direction of the fin. At higher Reynolds numbers, the boundary layers are thinner, and the flow is almost aligned with the louvers. The characteristics of the heat transfer and pressure drop for heat exchangers with the different geometrical configurations are reported in terms of the Colburn j-factor and Fanning friction factor f as a function of Reynolds number based on the louver pitch. The test was performed in a range of Reynolds number of 200–1600 based on louver pitch and maximum air velocity with a water flow rate maintained at 3m/s.The inlet water temperature was maintained at 90 ˚C.

Chang et al. and Chang and Wang presented 27 samples of corrugated louvered fin heat exchangers with different geometrical parameters, including louver length, louver pitch, fin height and fin pitch. Jang et al. numerically investigated a three-dimensional convex louver finned-tube heat exchangers. The effects of different geometrical parameters, including louver angles, louver pitch and fin pitch are investigated in detail for the Reynolds number (based on the fin spacing and the frontal velocity) ranging from 100 to 1100. It was shown that, for equal louver pitch, both the average Nusselt number and pressure drop coefficient are increased as the louver angle is increased; while for equal louver angles, they are decreased as the louver pitch is increased.

Finned tube heat exchangers are widely used in a variety of applications such as air-conditioning, refrigeration and in the process industry. Generally, the heat exchangers consist of a plurality of spaced parallel tubes through which a heat transfer medium such as water, oil or refrigerant is forced to flow while a second heat transfer fluid like air is directed across the tubes. For automotive application, such as radiators, condensers and evaporators, the louver fins are generally brazed (or soldered, mechanically expanded) to a flat, extruded tube, with a cross section of several independent passages, and formed into a serpentine or a parallel flow geometry. For applications to residential air-conditioning systems, the fin-and-tube heat exchangers are consisted of mechanically or hydraulically expanded round tubes in a block of parallel continuous fins.

II. Multi-louvered plate fin heat exchanger

The multi-louvered plate fin heat exchanger are preferred to conventional heat exchanger due to their high surface area available, compactness and capability to have multi-louvered fin.(Chi-Chuan Wang.et al,2000) Heat exchangers are employed virtually in all industrial sectors and domestic appliances. Nowadays the applications of compact heat exchanger are expanding expeditiously. The principal parts of these plate fin heat exchangers is the secondary heat transfer surface called fin.

A. Methodology

- The various fin types are modeled for the standard specifications using the modeling software (pro-E).
- Each fin configurations are investigated for heat transfer and pressure drop for the specified boundary conditions using CFD analysis CFX.
- The numerically obtained heat transfer and pressure drop characteristics of the fin arrangement will be validated experimentally.

B. Specifications of Plate Fin Model

S.N	Multi-louvered fin		Tube	Tube
1	Material	Aluminium	Material	Copper
2	Louver Length	6.25mm	Outer Diameter	9.5mm
3	Louver Pitch	2.4mm	Inner Diameter	6mm
4	Louver Height	1.4mm	Wall Thickness	3.5mm
5	Louver Angle	26^o	No. of row in tube	2
6	Fin Pitch	2mm	Longitudinal Pitch	19.05mm
7	Fin thickness	0.3mm	Transverse pitch	25.4mm

Table 1: The Plate Fin Arrangements are modeled as per the Standard Specifications. (CC.Wang.et.al, 1999)

C. Boundary Conditions

Plate temperature	:	90°C
Air inlet temperature	:	30°C
Air velocity	:	$3ms^{-1}$
Air density	:	$1.19kgm^{-3}$
Fin material	:	Aluminium ($k=204Wm^{-1}K^{-1}$

III. NUMERICAL SIMULATION

A. Plate Fin & Multi-Louver Fin Model

The plate fin models are a small representation of the plate fin heat exchanger. A single passage alone is taken into consideration. (Chi-Chuan Wang.et.al, 1997) The various fin configurations are plain fin, multi-louvered fin as shown in figure.1 and fig.2.respectively. A simple fin and multi-louvered fin model is analyzed.

Fig.1

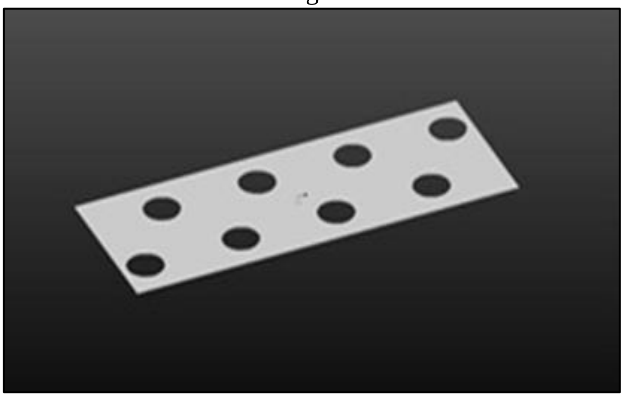

Fig. 1 & 2: Simple Plain Fin

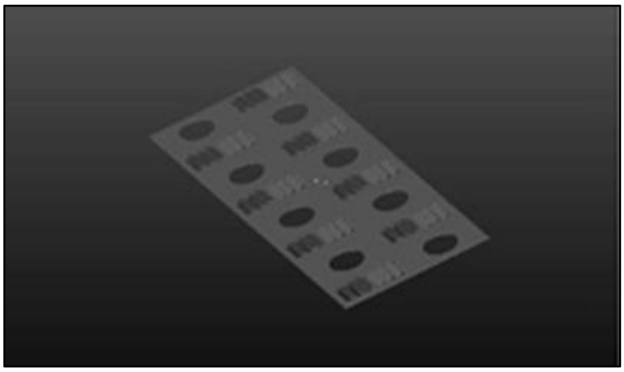

Fig. 3:

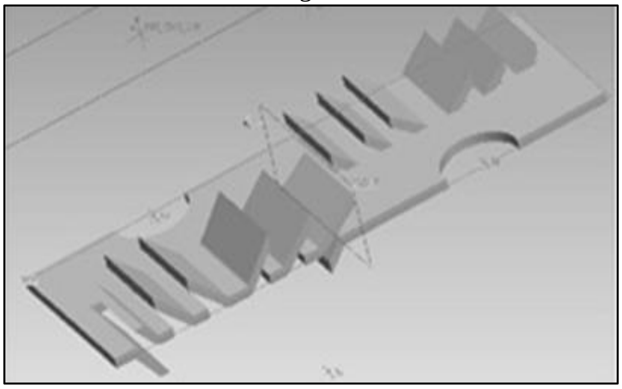

Fig. 3 & 4: Schematic of Multi-Louvered Fin

IV. RESULTS AND DISCUSSION

Three dimensional computational fluid dynamics analysis has been done for a plain fin and tube heat exchanger with circular tube arrangement. Steady state analysis is effected to detect the temperature, pressure fluctuations inside the plate fin model. Steady state analysis is performed for simple fin and louvered fin to find the time required for the fin arrangement for a particular temperature drop to arrive at the more efficient fin. The fin arrangement which takes minimal time for transferring heat is the best fin arrangement.

A. Steady State Condition of Plain Fin

The temperature diversification is more in the surface of the fin. It takes 3.900 seconds for the fin to drop from 363K to 323K. The fin temperature drops down linearly along the length of the plate fin model. The pressure distribution is shown in the figure.3.The profiles representing the temperature distribution of the plain fin are shown in figure.5 and 6respectively.

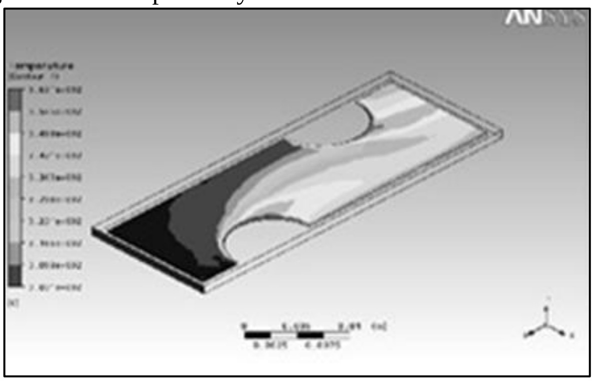

Fig. 5: Temperature distribution

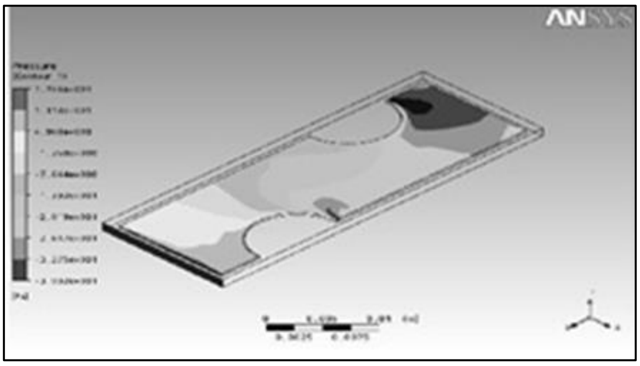

Fig. 6: Pressure Distribution

B. Steady State Analyses of Multi-Louvered Fin

Multi louvered fin takes 3.900 seconds for the fin to drop from 363K to 323K. The fin temperature drops down linearly along the length of the plate fin model. The pressure variation is shown in the figure.5.The profiles showing the temperature distribution of the plain fin are shown in figure.7 and 8respectively.

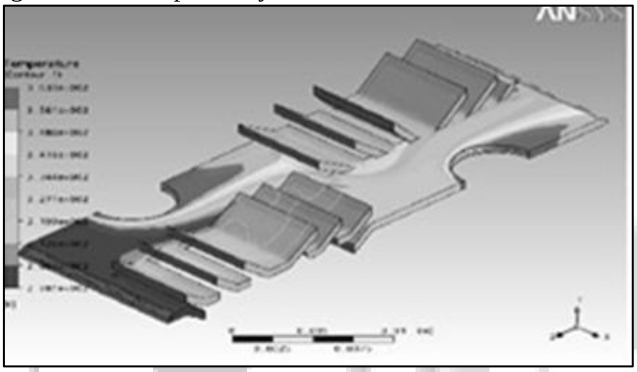

Fig. 7: Temperature Distribution

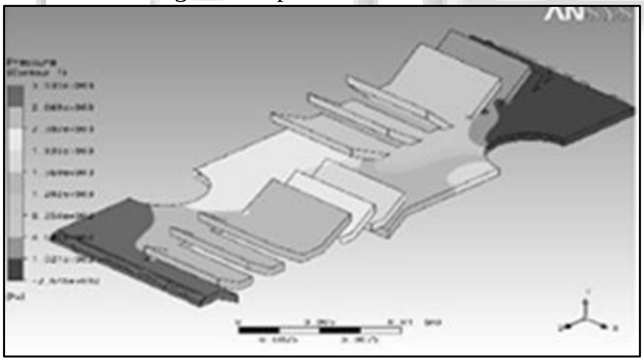

Fig. 8: Pressure Distribution

C. Multi-Louvered Fin with Hydrophilic Coating

The pre-coated design is a two-layer surface with anti-corrosion layer above the base aluminum material and hydrophilic toping above the anti-corrosion layer. (Xiaokui Ma.et.al, 2007). The major ingredients of the hydrophilic coating are polyethylene, polypropylene, polyisobutylene, and polyvinyl alcohol, polystyrene. The presence of condensate may act as a roughening mechanism and thus increase in heat transfer is accomplished. By decimating the fin pitch the roughness effect can be amplified significantly. For the Fin pitch of 2 mm the drop of heat transfer coefficients for hydrophilic surfaces can be enhanced to 20%. In addition to the heat transfer performance, the effect of hydrophilic coating can considerably curtail the associated pressure drops.

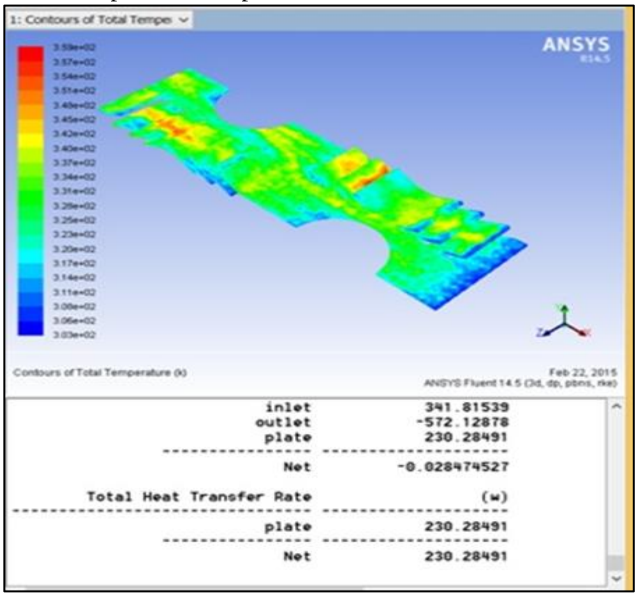

Fig. 9: Coating Structure of Fin Surface

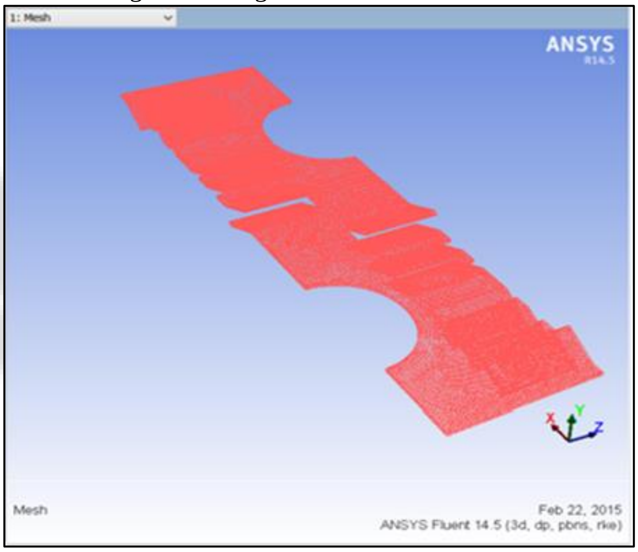

Fig. 10: Meshing

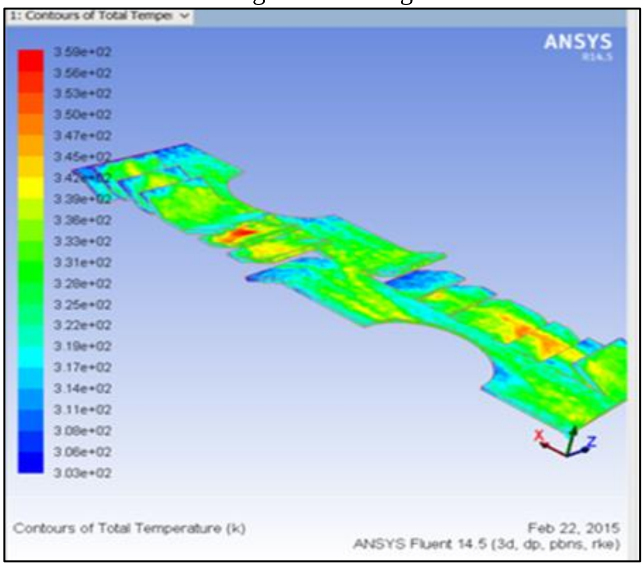

Fig. 11: Temperature Distribution

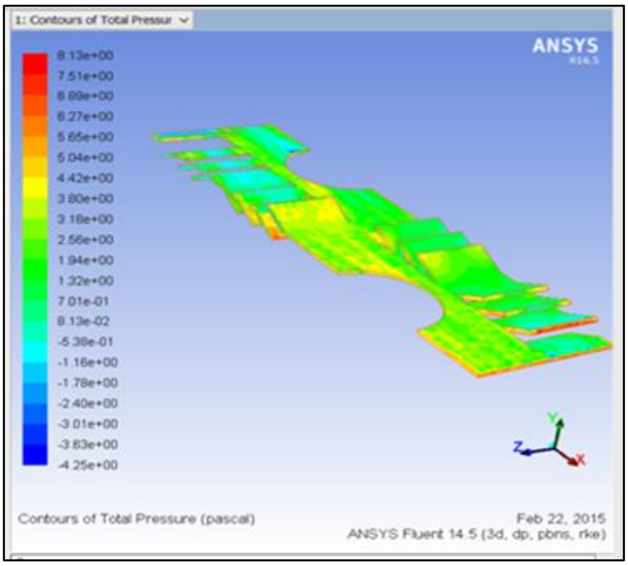

Fig. 12: Pressure Distribution

V. CONCLUSION

The numerical investigation carried out in the plate fin and multi-louvered fin models the following conclusions. It was found that there was no appreciable heat interaction between the plate fin and the air flow through the large surface contact area available. This is due to the fact that velocity of air is high. (Dohoy Jung.et.al, 2006) At high velocity residence time of the air inside the plate fin arrangement is less, leads to less heat interaction between the plate fin and air. There is a gradual decrease in the pressure from the inlet to the exit whereas the velocity of airflow slightly increases from the inlet to the exit. This is due to the very small dimension of the plate fin arrangement. The contact area between the plate and the fin is also responsible for heat transfer enhancement. To improve the heat transfer characteristics of the plate fin model, the contact area between the plate and fin should be increased. (Thomas Perrotin.et.al, 2004) Increase in the surface area of both plate and fin leads to better heat transfer characteristics. If the fin configuration is denser, heat transfer characteristics will be enhanced, but care must be taken to avoid excessive pressure drop. As per the analyses performed with the effects of fin pitch, fin length and fin height in the plain plate fin and the effects of louver angle, louver pitch and louver length in the multi-louvered fin, the multi-louvered fin has a better heat transfer coefficient with an increase in pressure drop, which is at an acceptable level.

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