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A Numerical Investigation of Multi-Louvered Compact Plate Fin Heat Exchanger Having Circular Tube Configuration with and without Hydrophilic Coating

P. Bharathidasan[1] | K. Mahadevan[2] | N. Azhaguvel[3]

[1,2,3]Department of Mechanical Engineering, Dhanalakshmi Srinivasan Institute of Research and Technology, Perambalur-621212, Tamil Nadu, India

ABSTRACT

This study presents the airside performance of fin-and-tube heat exchangers for plain fin and multi-louvered fin with hydrophilic coating. In this research focuses on heat and fluid flow analysis by various louvers angle patterns. 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 with Reynolds number in the range of 200 to 1600. A numerical study was performed on compact fin-and-tube heat exchangers having circular tube with multi-louvered fins. Air side performance for heat exchanger with and without hydrophilic coating has been studied. The pressure drops of 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 26°, 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.

KEYWORDS: Fin-and-tube heat exchanger; Heat transfer Co-efficient; Pressure drop; Hydrophilic coating

I. Introduction

Plate fin heat exchanger is a kind of compact heat exchanger which changes upon its competition in automobile radiators, air conditioning evaporators and condensers, charge air coolers, electronic cooling devices and cryogenic exchangers to meet the demand for saving energy and resources. To curtail the size and weight of heat exchangers assorted augmented surfaces have been evolved to enhance the air side heat transfer performances. [1]. Orthodox fin geometries are plain fins, wavy fins, offset fins, perforated fins, pin fins and louvered fins. For these complex geometries, which are customarily set up in a cross flow arrangement, Multi-louvered fin have a higher degree of surface compactness and high efficiency [2]. The Plate fin heat exchanger core is crafted with layers of plate and fins. Fluid will be streaming in the passage created between the plate and the fins. Hot and cold fluids flow alternatively in each plate fin assembly and heat transfer takes place between them. 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. [4] With 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. In numerically investigated 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. [7] 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. METHODOLOGY

The heat transfer and pressure drop characteristics are studied in the multi-louvered plate fin heat exchangers, with and without hydrophilic coating. In the type of multi-louvered plate fin heat exchanger having two different cases viz. without louver, with louver and without coating, with coating are subject to analysis. The analysis is performed in three different patterns. (1) Plain plate fin heat exchanger without louver pattern I. (2) multi-louvered plate fin heat exchanger with louver and without hydrophilic coating pattern II. (3) multi-louvered plate fin heat exchanger with louver and with hydrophilic coating. 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.[4]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.

The round tube having an internal diameter of 6mm.This ensures the heat transfer and pressure drop are influenced by the shape only. 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 in CFX tool.

III. SPECIFICATIONS OF PLATE FIN MODEL

TABLE I. THE PLATE FIN ARRANGEMENTS ARE MODELED AS PER THE STANDARD SPECIFICATIONS

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

IV. NUMERICAL SIMULATION

To obtain the heat transfer and pressure loss characteristics of the multi-louvered plate fin from the experimental data, the ε-NTU method is applied to determine the UA product in the analysis.[5] The total heat transfer used in the calculation is the mathematical average of the air side and the water side heat transfer, namely,

$Q_{air} = m_{air} C_{P,\, air} \Delta T_{air}$

$Q_{water} = m_{water} c_{p,\, water} \Delta T_{water}$

In the ε-NTU method, the number of heat transfer units (NTU) is defends as

$Q_{ave} = (Q_{water} + Q_{air}) / 2$

$NTU = UA / C_{min}$

The UA product was calculated using the ε-NTU relationship accounting the effect of the number of tube rows from. Definitions of C* and e is given as follows:

$$c^* = \frac{c_{\min}}{c_{\max}} = \frac{m_{air} c_{p,air}}{m_{water} c_{p,water}}$$

$$e = \frac{Q_{ave}}{Q_{\max}} = \frac{Q_{ave}}{C_{\min}(T_{in,water} - T_{in,air})}$$

V. BOUNDARY CONDITIONS

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

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. [4] 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.

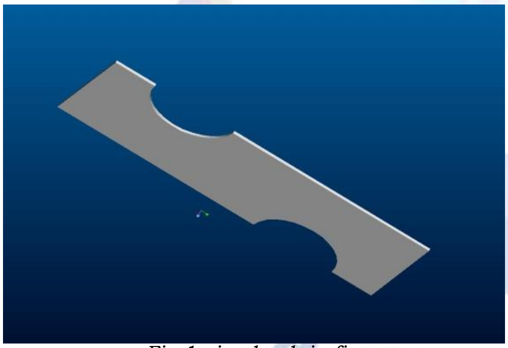

Fig.1.simple plain fin

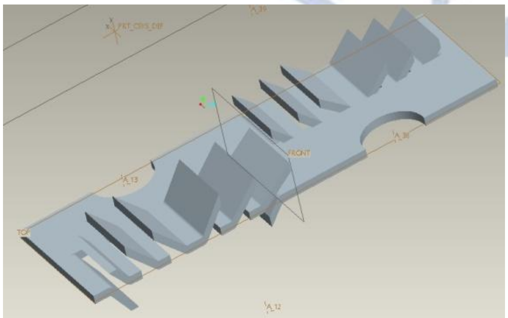

Fig.2.schematic of multi-louvered fin

VI. RESULTS AND DISCUSSION

Three dimensional computational fluid dynamics analyses have been done for a plain fin and tube heat exchanger with circular tube arrangement. Steady state analysis is affected 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.3 and 4respectively.

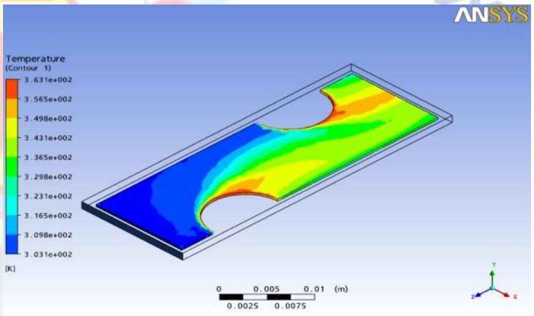

Fig.3.Temperature distribution

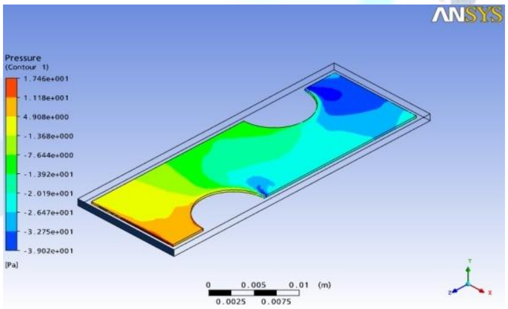

Fig.4.Pressure distribution

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.6 and 4respectively.

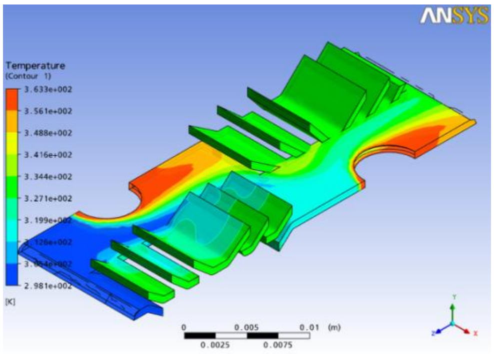

Fig.5.Temperature distribution

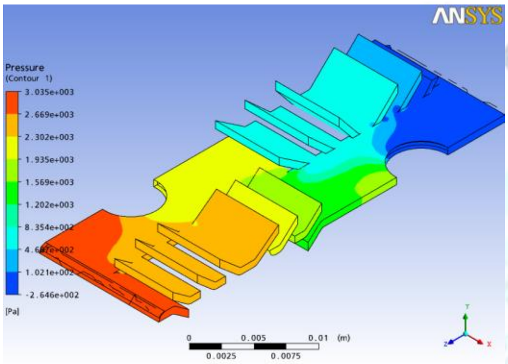

Fig.6.Pressure distribution

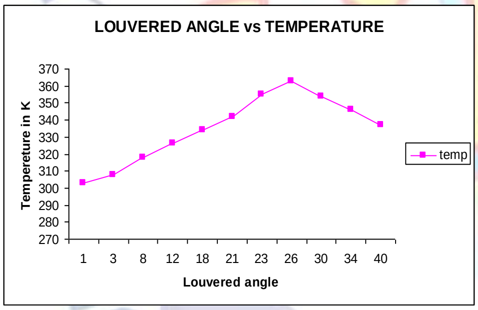

Fig.7.various temperature with louver angle

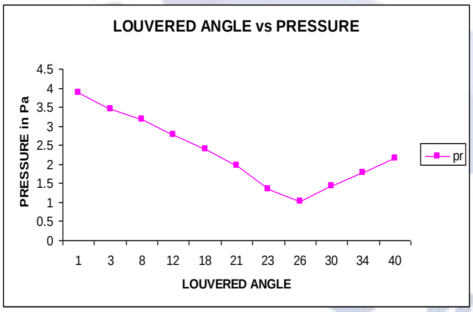

Fig.8.various pressure with louver angle

The figure.7 shows the various temperatures with louver angle. When the louver angle increases correspondingly temperature also increases up to an angle of 26° due to fin contact area increases, after that the temperature decreases when increase the louver angle. The figure.8 shows the various pressures with louver angle. When the louver angle increases correspondingly pressure decreases up to an angle of 26° due to fin contact area increases, after that the pressure increases when increase the louver angle.

VII. 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. [8]. 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 co-efficients 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.

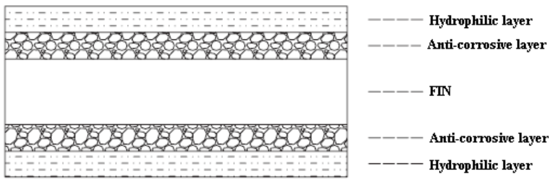

Fig.9.coating structure of fin surface

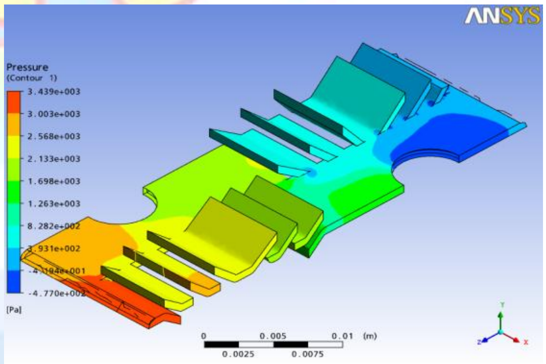

Fig.10.Temperature distribution

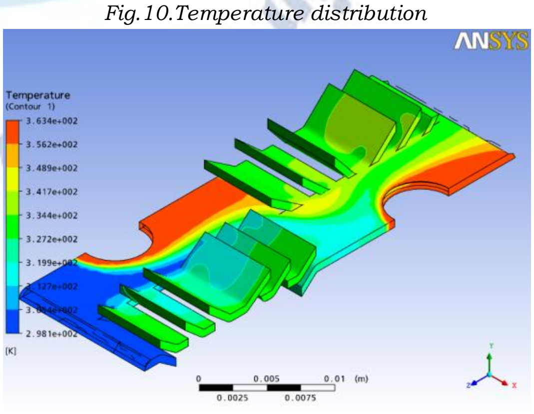

Fig.11.Pressure distribution

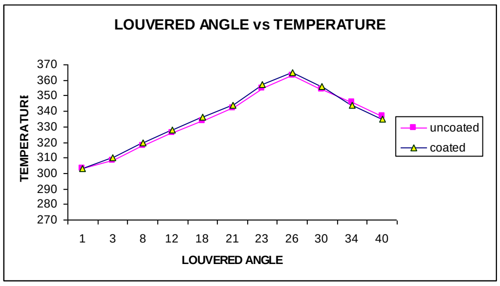

Fig.12.various temperature with louver angle

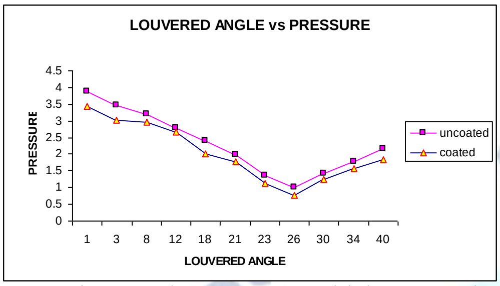

Fig.13.various pressure with louver angle

The figure.12 shows that various temperature with various louver angles and with and without hydrophilic coating, from the graph air outlet temperature increase up to an angle of 26° and then it seens to be decreasing. This may be due to reduction in the contact area. The figure.13 shows that various pressures with a various louver angle and with and without hydrophilic coating, from the graph the pressure is found to be minimum for a louver angle 26°.

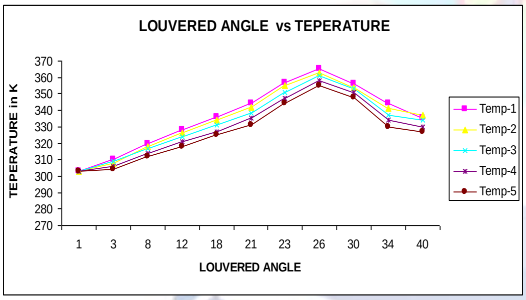

Fig.14.various temperature with louver angle

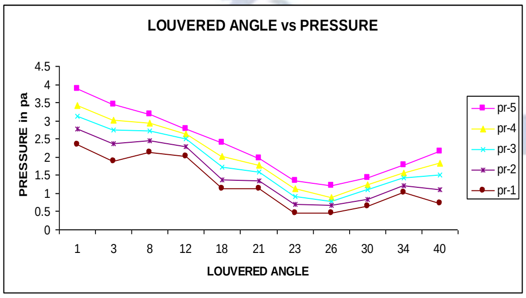

Fig.15.various pressure with louver angle

The figure.14 shows the various temperatures with louver angle and with different hydrophilic coating. When the louver angle increases correspondingly temperature also increases up to an angle of 26° due to fin contact area increases, after that the temperature decreases when increase the louver angle. The figure.15 shows the various pressures with louver angle and with different hydrophilic coating. When the louver angle increases correspondingly pressure decreases up to an angle of 26° due to fin contact area increases, after that the pressure increases when increase the louver angle

VIII. 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. [6] 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.

REFERENCES

[1] Junqi Dong, Jiangping Chen, Zhijiu Chen, Wenfeng Zhang, Yimin Zhou. "*Heat transfer and pressure drop correlations for the multi-louvered fin compact heat exchangers*", Energy Conversion and Management 48 (2007) 1506–1515.

[2] Ching-Tsun Hsieh, Jiin-Yun Jang. "*3-D thermal-hydraulic for louver fin heat exchangers with variable louver angle*". Applied Thermal Engineering 26 (2006) 1629-1639.

[3] C.-C. Wang, C.-J. Lee, C.-T. Chang, S.-P. Lin "*Heat transfer and friction correlation for compact louvered fin and tube heat exchangers*" International Journal of Heat and Mass Transfer 42(1999) 1945-1956.

[4] Chi-Chuan Wang, Kuan-Yu Chi, "*Heat transfer and friction characteristics of plain fin and tube heat exchangers*" International Journal of Heat and Mass Transfer 43 (2000) 2681-2691.
[5] Chi-Chuan Wang, Kuan-Yu Chi And Yu-Juei Chang, "*An experimental study of heat transfer and friction characteristics of typical louver fin-and-tube heat exchangers*" PII:S0017-9310(97)00154-35
[6] Dohoy Jung and Dennis N. Assanis, "*Numerical modeling of cross flow compact heat exchanger with louvered fins using thermal resistance concept*" SAE paper 2006-01-0726, 2006.
[7] Thomas Perrotin and Denis Clodic, "*Thermal hydraulic CFD study in louvered fin-and-flat-tube heat exchangers*" International Journal of Refrigeration 27 (2004) 422-432.
[8] Xiaokui Ma, Guoliang Ding, Yuanming Zhang and Kaijian Wang," *Airside heat transfer and friction characteristics for enhanced fin-and-tube heat exchanger with hydrophilic coating under wet conditions.*