RESEARCH ARTICLE OPEN ACCESS

Performance of Louver Fin Pattern as Extended Surface Used To Enhance Heat Transfer - A Review

Vinayak S. Powar*, Prof. M. M. Mirza**
*(Department of Mechanical Engineering, RIT, Islampur, India)
** (Department of Mechanical Engineering, RIT, Islampur, India)

ABSTRACT
Enhancing heat transfer surfaces are used in many engineering applications such as heat exchangers, refrigeration and air conditioning systems, chemical reactors and automobile radiators. Hence many enhancing extended fin patterns are developed and used. Louver fin pattern is one of the advanced extended fin surface which used to enhance heat transfer coefficient with decrease in size, weight and cost of heat exchanger. This paper reviews experimental and numerical work brought by researchers on louver fin pattern to augments the overall thermal-hydraulic airside performance of heat exchangers. Numerous works are available for louver fin pattern to visualize flow, optimizing geometrical parameters of louvers, comparison study with different extended surfaces. The available work is in experimental form as well as numerical form performed by computational fluid dynamics. Researchers have given thermal-hydraulic performance of louver fin heat exchangers with different correlation techniques.
***Keywords* –** Correlation, Louver Fin, Thermal-Hydraulic Performance.

I. INTRODUCTION

Researches are carried out for improving performance of heat exchangers having high degree of surface compactness and optimum overall thermal-hydraulic performance. In a gas to fluid heat exchanger the thermal resistance is dominant on gas side and is up to 80% [5] to that of total thermal resistance in a heat exchanger. The main reason of lower thermal performance on gas side is due to 10 to 50 [5] times smaller heat transfer coefficient of gas than that of fluid. Hence a wide scope is available to enhance gas side heat transfer coefficient by some techniques.

1.1 Enhancement Techniques

The heat transfer enhancement techniques can separate into two categories. One is “Active Technique” which requires external power source to enhance heat transfer like application of electromagnetic field and surface vibration. The other one is “Passive Technique” which requires no direct application of external power. It employs special surface geometries or fluid additives to enhance heat transfer. Passive technique is economical and widely used heat transfer enhancement technique. The heat transfer rate in heat exchanger is given by equation as

$$Q = h\,A\,\theta_m \qquad \text{………..(1)}$$

Where h is heat transfer coefficient, A is effective heat transfer surface area and θ_m is mean value of temperature difference.

The use of passive technique to enhance heat transfer with considering the heat transfer equation (1) is in following manners.

1. Increase the effective heat transfer surface area A per unit volume without appreciably changing heat transfer coefficient h e.g. uses of plain fin surface.
2. Increase heat transfer coefficient h without appreciable changing area A by using special shapes like wavy or corrugated fins. That fin provides mixing due to secondary flows and boundary layer separation within channel.
3. Increase both h and A e.g. interrupting fins like louvers. These surfaces increase effective surface area and enhance heat transfer by repeated growth and destruction of boundary layers.

1.2 Louver Fin Pattern

Louver fin pattern is one of the most advanced enhanced extended surfaces which are essentially formed by cutting the sheet metal of the fin at intervals and rotating the strips of metal so formed out of the fin. Fig.1 shows geometrical definition of heat exchanger with louver fins.

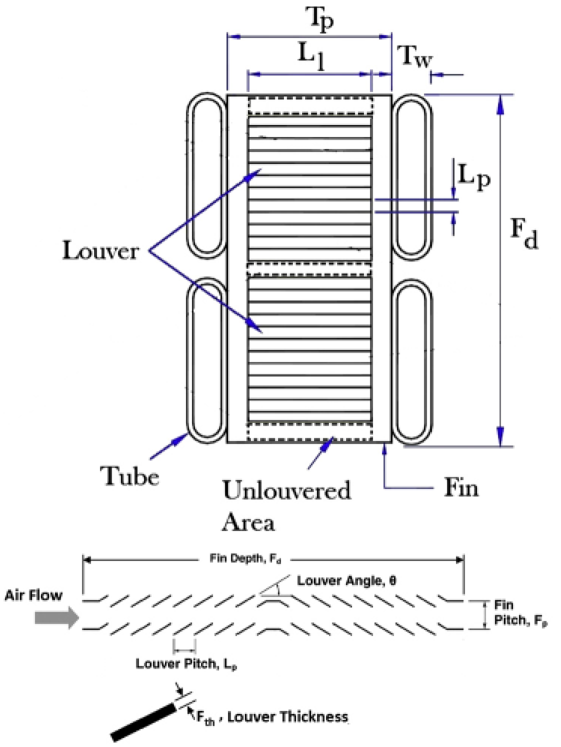

Figure 1: Typical louver fin pattern [7]

Louver fin has geometrical parameters like louver pitch, louver height, louver depth, louver angle, number of louvers, number of louver regions. By customizing that parameters different combinations of louver patterns can be developed such as symmetric, asymmetric, multi region, inclined, convex shaped and so many. The enhancing heat transfer is depends on geometrical parameters of louver fins hence researches are going on optimizing thermo-hydraulic performance of heat exchanger with respect geometrical parameters of louver.

II. RELATED WORK

The work available to examine performance of louver pattern is in experimental as well as numerical form performed by computational fluid dynamics. Due to involvement of large geometrical parameters experimental studies are time consuming and costly for testing and optimize performance of louver fin at various combinations of its geometrical and flow parameters so the trend is to use numerical studies for the same. Here both experimental and numerical studies are explained with result evaluation techniques.

2.1 Wei-Mon Yan et al. [1] have performed an experimental study to investigate the heat transfer and pressure drop characteristics of Fin and tube exchangers with plate, wavy and louvered fin surfaces. He has tested 12 plate fins, 12 wavy fin and 12 louvered fin geometries and results are presented as plots of friction factor f and Colburn factor j against Reynolds number in the range 300-2000. Both f and j factors decrease with increasing Reynolds number based on outer tube diameter, also larger f and j factors are found for the louver fin heat exchangers than others. For plate fin heat exchangers, the f and j factors increase with the decrease in the fin pitch. But for louver fin heat exchangers, the effects of fin pitch on the f and j factors do not show a trend. A larger pressure drop has found for a heat exchanger with a greater tube row number, also pressure drop decreases with the increase in the fin pitch. But for heat transfer coefficient h, the effects of the tube row number on h shows an insignificant influence. At a fixed fan power, a better heat transfer coefficient h is found for a heat exchanger with a lower tube row number. In addition, the louver fin surface shows the largest h among various fin surfaces. This means the louver fin is relatively most advantageous when used at the same operating condition.

2.2 Jin-Sheng Leu et al. [2] have numerically investigated the air side performance of fin and tube heat exchangers having circular and oval tube configuration. The geometrical parameters of louver angle, louver pitch and louver length have tested. Fig. 2 shows a tested louver fin pattern having circular tubes.

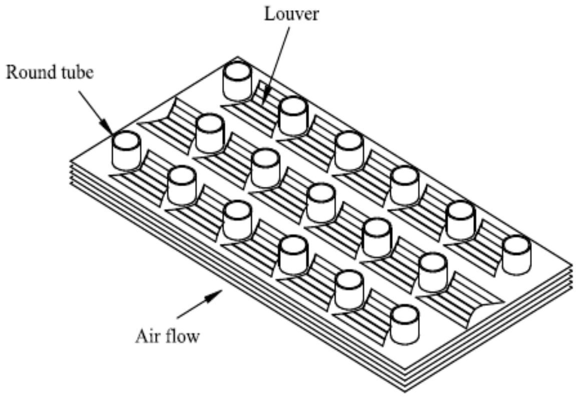

Figure 2: Circular tube louver fin pattern

The validation of numerical results has done with experimental results obtained from literature of louver tube geometry having circular tube. It is found that the average Nusselt number and heat transfer coefficient overestimated by 20% than experimental results. The numerical results have compared between circular tube and oval tube with both have same perimeter. It is found that the heat transfer coefficient for oval tube is less than its circular tube counterpart by approximately by 10 % and the pressure drop for circular tube exceeds by 41% than oval tube configuration. It is seen that pressure drop increase with louver angle for all three louver pitches (L_p=3.75, 2.68, 2.08 mm) at Reynolds number 149.4 and smaller louver pitch results in better heat transfer. It is seen that both average nusselt number and pressure drop for three different louver length (6.25, 7.34, 8.37mm), louver angle 14º and Reynolds number 149.9 increases with increase of louver length.

2.3 Man-Hoe Kim et al. [3] have performed experimental study on the air-side heat transfer and pressure drop characteristics for multi-louvered fin and flat tube heat exchangers. He has tested 45 heat exchangers with different louver angles (15º to 29º), fin pitches (1.0, 1.2, 1.4 mm) and flow depths (16, 20, 24 mm), for the air-side Reynolds numbers of 100–600. The air-side thermal performance data has analyzed using effectiveness- NTU method for cross-flow heat exchanger. The heat transfer coefficient and pressure drop data for heat exchangers with different geometrical configurations has reported in terms of Colburn j-factor and Fanning friction factor f, as functions of Reynolds number based on louver pitch. Pressure drops increase with flow depth and air velocity, while the heat transfer coefficients decrease with flow depth and increase with face velocity. Pressure drops for all flow depths increase with louver angle, while the effect of louver angle on the heat transfer coefficients depends on flow depth.
For 16 mm flow depth, heat transfer coefficients do not change much with louver angle. On the other hand, for 24 mm flow depth, heat transfer coefficients increase with louver angle and maximum at 27º, and again decrease with louver angle. Friction factors increase with louver angle, the j factor increases with louver angle, but its effect on the j factor varies with flow depth.

2.4 Ching-Tsun Hsieh et al. [4] have performed 3-D thermal-hydraulic analysis of louver fin heat exchangers with variable louver angle. He has tested five models (A-E) having successively increased or decreased louver angle patterns. Fig. 3 shows case models of tested heat exchangers. The heat transfer and pressure drop characteristics for different models interpreted by Colburn factor j and friction factor f.

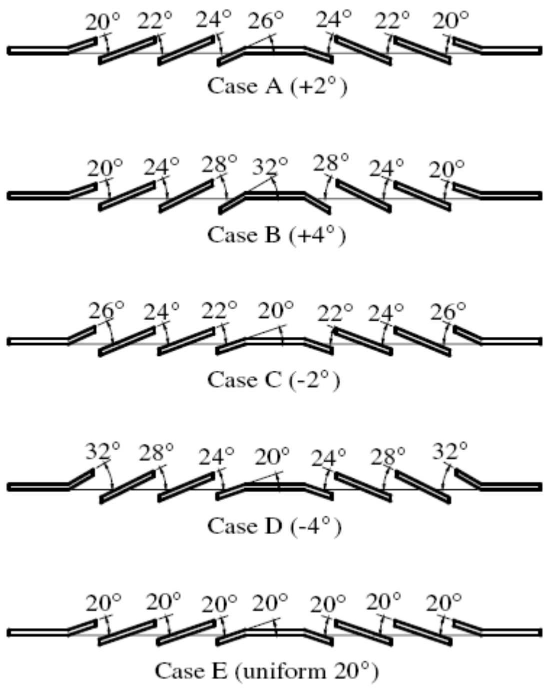

Figure 3: Different case models of heat exchanger

It is found that at Reynolds number 1075, the temperature gradient is more pronounced for larger louver angle that is the higher heat transfer performance for large louver angle. However, a larger louver angle would also contribute to the increase in the pressure drop. It is also found that the temperature gradient is higher for successively variable louver angles than uniform angle. It is also seen that both Nusselt number Nu and pressure drop coefficient Cp for successively variable louver angles (cases A–D) are higher than those for the uniform louver angle (case E). It is seen that boundary layers exist on both the upper and lower surfaces of the louvers at Reynolds number 1075. The relevant heat transfer enhancement is due to thinner boundary layers that form at the leading edge of each louver. The present results indicated the successively variable louver angle patterns applied in heat exchangers could effectively enhance the heat transfer performance.

2.5 V. P. Malapure et al. [5] has performed numerical simulation of single and double row tubes with louvered fins. The air side performance of heat exchanger is evaluated by calculating Stanton number and friction factor for different geometries with varying louver pitch, louver angle, fin pitch and tube pitch with different Reynolds number. Fig. 4 shows computational domain used in numerical study.

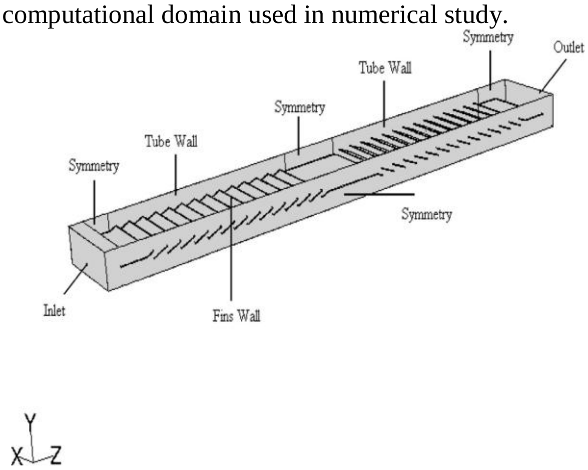

Figure 4: Computational domain louver fins

He has found that at low Reynolds number most of air flows through gap between the fins rather than through the louvers. The reason is that at low Reynolds number air has low kinetic energy so air finds path of least resistance so flow becomes duct directed rather louver directed and the heat transfer performance of fin is poor at low Reynolds number. At higher Reynolds numbers, the boundary layers around the louvers are thinner and the flow is nearly aligned with the louvers. Hence the heat transfer rate is increased with Reynolds number. By observing temperature variation across the middle of the upstream and downstream of the fin it is found that the temperature of the fin decreases with the distance from the tube surface, increasing tube pitch and increasing Reynolds number. Heat transfer and pressure drop

characteristics are presented in terms of non-dimensional parameters, Stanton number (*St*) and friction factor (*f*) as functions of Reynolds number. There is Close agreement is found between the computational results and experimental data at intermediate and high Reynolds number. However, at low Reynolds number there is a large deviation. The local Nusselt number on the top surface of each louver in the flow direction along the length of fin for Reynolds number *Red* = 1000 is obtained, high Nusselt number is obtained at the tip of the fin, leading edge and trailing edge of each louver. He has found that heat transfer coefficient increases with louver angle and reaches maximum value at 28–29◦ and then again decreases with the increase in louver angle for fin pitch 2.17 mm also higher heat transfer coefficient is obtained at smaller louver pitch, i.e., L_p = 0.81 mm at optimum louver angle. By decreasing the fin pitch from 3.33 mm to 2.11 mm, heat transfer rate increases. However further reduction in fin pitch
does not result in any additional improvement in heat transfer

2.6 Wei Li et al. [6] have performed an experimental study on air-side heat transfer and pressure drop characteristics of heat exchangers with multi-region louver fins and flat tubes with Reynolds numbers of 400–1600 based on the louver pitch. Fig. 5 shows seven kinds of samples of heat exchangers with different number of louver regions (0 to 6) and fin louver heights were tested. The performance data were analyzed by using the effectiveness-NTU method also thermal-hydraulic characteristics of heat exchanger presented in terms of the Colburn j factor and Fanning friction f factor as function of the Reynolds number.

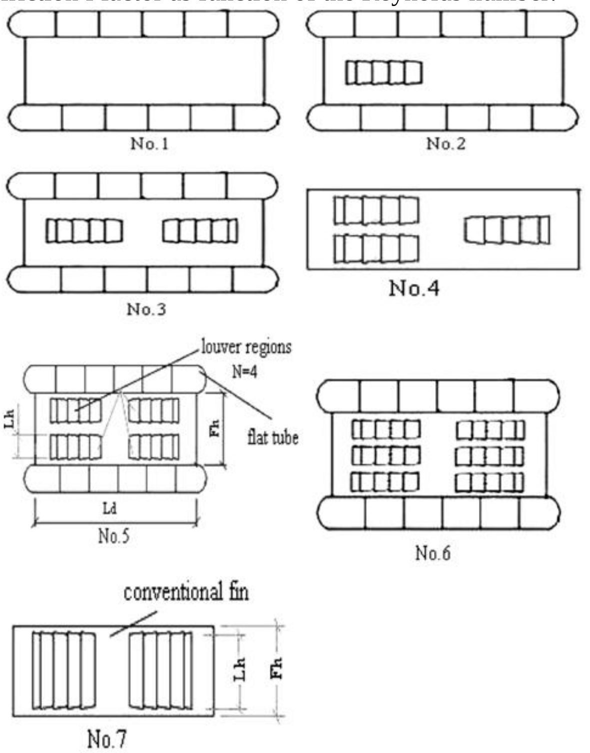

Figure 5: Multi region louver fin patterns

The j factor and f factor tend to decrease with an increasing Reynolds number and tend to increase with the increased number of louver regions. The cause is that with the increased number of louver regions, the louver area of the fin increases. The results show that the 4-region louver fin and the 6-region louver fin are better than the traditional fin in overall thermal hydraulic performance and that the 6- region louver fin is even better than the 4-region louver fin

2.7 A. Vaisi et al. [7] have performed experimental study on automobile radiator to investigate air side heat transfer and pressure drop characteristics of flow over louvered fins. He performed tests for asymmetrical and symmetrical arrangements of louvers which shown in Fig. 6 and 7 respectively. A thermal-hydraulic performance of radiator has examined for various geometrical and flow parameters and experimental results compared with effectiveness-NTU results.

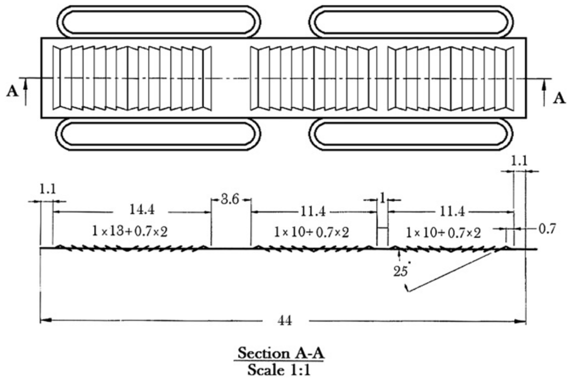

Figure 6: Asymmetrical arrangement of louvers

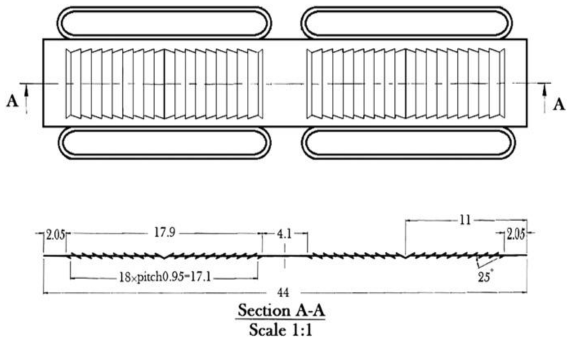

Figure 7: Symmetrical arrangement of louvers

He has used seven different inlet air velocities on both louver arrangements. He found that heat transfer rate tends to increase with an increasing inlet air velocity but at same velocity the symmetrical pattern has the higher heat transfer rate than asymmetrical. The reason is that symmetrical pattern has more louvers per tube and more the number of louvers with short pitch are the more the common areas between the fluid flows. By increasing air velocity the pressure drop in air side will be increased but the symmetrical pattern louvered fin behaves better in pressure drop performance. In the same conditions of temperature and mass flow rates for inlet air and water, the cooling rate of outlet water and heating rate of outlet air temperature of symmetrical pattern is greater than asymmetrical one. The overall conclusion obtained from above work is that symmetrical louver fin arrangement found best in thermal-hydraulic performance than asymmetrical arrangement hence it is essential to consider geometrical parameters and physical structure of heat exchanger in order optimize performance.

2.8 Hui Han et al. [8] have numerically investigated fluid flow and heat transfer characteristics of finned tube heat exchanger. He has tested six models of heat exchanger containing oval tube having major axis 11.01 mm and minor axis 4.94 mm, big circular tube having same perimeter that of oval tube and diameter of 8.8 mm, and small circular tube having same hydraulic diameter that of oval tube and diameter of 6.18 mm. the fin patterns used are louver and wavy. Fig. 8 shows tested models.

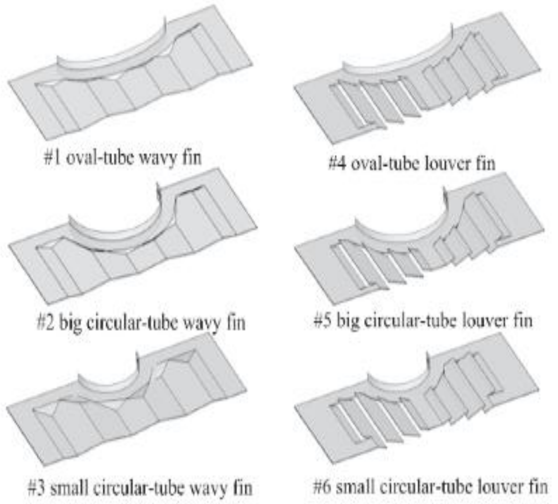

Figure 8: Test models

The results shows that oval tube fins shows better heat transfer and lower pressure drop compared to big and small circular tube fins. The heat transfer coefficient of louver fin and oval tube increased by 3.2-6.6% and 26.0-28.4% also pressure drop decreased by 22.0% to 31.8% and 1.8% to 3.5% compared to big and small circular tubes. It is seen that Oval tubes can significantly improve the fin surface temperature distribution along the flow direction, making the temperature distribution more uniform, thereby improving the fin efficiency.

III. CONCLUSION

Different kinds of louver patterns have tested by researchers through its experimental and numerical studies. The heat transfer coefficient and pressure drop are two important characteristics used to optimize thermal-hydraulic performance of louver fin heat exchanger. Optimum heat exchanger bears maximum heat transfer coefficient and minimum pressure drop characteristics. The effects of various geometrical parameters such as louver pitch, louver regions, louver angle, louver numbers, louver height and flow parameters like air velocities are studied on performance of louver fin heat exchanger. Although
To find an optimum louver fin heat exchanger for suitable application considering various parameters is cumbersome.

REFERENCES

[1] Wei-Mon Yan and Pay-Jen Sheen, Heat transfer and friction characteristics of fin and tube heat exchangers, *International Journal of Heat and Mass Transfer, 43*, 2000, 1651-1659.

[2] Jin-Sheng Leu, Min-Sheng Liu, Jane-Sunn Lia and Chi-Chuan Wang, A numerical investigation of louvered fin and tube heat exchangers having circular and oval tube configurations, *International Journal of Heat and Mass Transfer, 44,* 2001, 4235-4243.

[3] Man-Hoe Kim and Clark W Bullard, Air-side thermal hydraulic performance of multi louvered fin aluminum heat exchangers, *International Journal of Refrigeration, 25,* 2002, 390-400.

[4] Ching-Tsun Hsieh and Jiin-Yuh Jang, 3-D thermal- hydraulic analysis for louver fin heat exchangers with variable louver angle, *Applied Thermal Engineering, 26,* 2006, 1629-1639.

[5] V P Malapure, Sushanta K Mitra, A Bhattacharya, Numerical investigation of fluid flow and heat transfer over louvered fins in compact heat exchanger, *International Journal of Thermal Sciences, 46,* 2007, 199–211.

[6] Wei Li and Xialing Wang, Heat transfer and pressure drop correlations for compact heat exchangers with multi-region louver fins, *International Journal of Heat and Mass Transfer, 53*, 2010, 2955-2962.

[7] A Vaisi, M Esmaeilpour and H. Taheria, Experimental investigation of geometry effects on the performance of a compact louvered heat exchanger, *Applied Thermal Engineering 31*, 2011, 3337-3346.

[8] Hui Han, Ya-Ling He, Yin-Shin Li, Yu Wang and Ming Wu, A numerical study on compact enhanced fin and tube heat exchangers with oval and circular tube configurations, *International Journal of Heat and Mass Transfer, 65*, 2013, 686-695.