

Effects of Geometrical Parameters to the Performance of Louvered Fin Heat Exchangers

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Abstract. Numerical study using ANSYS Fluent is conducted to investigate the effects of louver angle on pressure drop and heat transfer of a heat exchanger. Flow simulations are conducted on 3D modeling of multi stacks louvered fins at three different parameters of louver angles which are 22.0°, 25.5° and 29.0° with Reynolds number ranging from 200 to 1000. These Reynolds numbers are based on louver pitch and fin pitch. The flow temperature is set at 300K which is the room temperature, while temperature of louver fin is set at 400K. The results show that Reynolds number based on fin pitch 2.02 mm and louver angle of 22.0° generate higher performance of heat exchanger compared to louver pitch of 1.40 mm and the other louver angles. Therefore, configuration of Reynolds number based on fin pitch 2.02 mm and louver angle 22.0° is preferred to be adopted in the design process of heat exchanger.

Introduction

Nowadays, compact heat exchangers are widely used in automotive radiator, oil cooler, refrigeration and residential air conditioning application. There are numerous newer surfaces of heat exchanger evolved in the recent development. However, louvered fins are the mostly used in automotive application among the variety types of fins such as strip fin, offset fin and wavy fin. That is due to the fact that it can be accommodated in a small space unlike other types that gives high heat duty but larger size, which is more advantageous for the limited space of the automobile application. As suggested by Lawson, reducing the size of a compact heat exchanger is important to reduce fuel consumption besides giving better performance [1]. By reducing the size of heat exchanger, it will reduce the weight and also the pressure drop caused by larger surface contact area against the air flow. Moreover, louvered fins are often used in automotive application because of their continuous fins design that channel air flow better to reduce the resistance of air flow. All of these above mentioned advantages are making it important to have a compact and lightweight heat exchanger [2, 3, 4].

The heat transferred to outside air in car radiator provide stability and efficiency of the operation. Therefore, louvered fins are generally used to increase heat transfer area in order to increase heat transfer rate significantly. Consequently, Zhang *et al.* found in his multi louvered fins study that the heat transfer capacity is strongly affected by flow efficiency. In addition, the flow efficiency is found to be strongly dependent on geometrical parameters such as louver angle, louver pitch and fin pitch especially at low Reynolds numbers. Reynolds number and louver angle leads to increase flow efficiency while decreasing with fin pitch and thickness ratio. However, louver angle has a stronger effect compared to fin pitch. It is also worth to mention that a high Reynolds number play important role in air ventilation trapped by the louvered fin in the radiator to obtain excellent result, but the pumping power required is significant [5, 6].

On the other hand, louvered fin heat exchangers are usually designed to increase the surface contact between fins and air flow to produce better heat transfer rate and to reduce the resistance of flow to gain better efficiency which is another advantage of using louvered fin heat exchanger. Since heat transfer increases with the increase of the area, the performance of heat exchanger can be improved by adding more fins to increase the surface area contact with air flow and further channel

the air flow better to reduce pressure drop and increase heat transfer rate. In addition, Hussein *et al.* suggested that, the conduction in the wall will be important for micro channel heat exchanger. Thus, increasing the surface area of the side wall can improve the performance of heat exchanger [7, 8].

In this study, analysis of different louver angles at constant louver pitch and fin pitch are performed using ANSYS Fluent. Results of other parameters such as different louver pitch and fin pitch had been published in different paper [2]. This study intends to determine the effects of louver angle on the performance of louvered fin heat exchangers numerically by using two types of Reynolds number definition; based on louver pitch and fin pitch.

The rest of this paper presents the methodology including geometrical dimension, boundary conditions and governing equations. The results are presented which consists of grid independence study and the relations between pressure drop and heat transfer to the louver angle, louver pitch and fin pitch. Finally, the last section summarised the findings of this investigation.

METHODOLOGY

Numerical experiments on the analysis of louvered fins were carried out by using ANSYS Fluent. Ten different cases of velocity were used in this simulation. Half of them were obtained based on louver pitch which was set at 1.4 mm and the other half were based on fin pitch which was set at 2.02 mm. The velocity was obtained using the equation of Reynolds number. The Reynolds number was set at 200, 400, 600, 800, and 1000. Table 1 lists the adopted velocities in this simulation. The best meshing size of the louvered fin is happened to be 0.25 mm while the periodic wall, side wall, inlet and outlet of the louvered fins are set at 0.31 mm.

Fig. 1 shows side view of a 2D geometry for one stack louvered fins and the geometrical details adopted in this study for one case. The rest of the cases are shown in Table 2.

Table 1: Velocity adopted in accordance with the Reynolds number

| No | Louver pitch = 1.40 mm | | Fin pitch = 2.02 mm | |
|----|-------------------------------|----------------|-------------------------------|----------------|
| | Reynolds number (Re_{LP}) | Velocity (m/s) | Reynolds number (Re_{FP}) | Velocity (m/s) |
| 1 | 200 | 2.26 | 200 | 1.57 |
| 2 | 400 | 4.51 | 400 | 3.13 |
| 3 | 600 | 6.77 | 600 | 4.69 |
| 4 | 800 | 9.03 | 800 | 6.26 |
| 5 | 1000 | 11.28 | 1000 | 7.82 |

Table 2: Dimensions of variant models used in the experiments

| Model | Fin pitch (mm) | Louver pitch (mm) | Louver angle (°) | Reynolds number |
|-------|----------------|-------------------|------------------|--------------------------------------|
| A | 2.02 | 1.40 | 22.0 | Based on louver pitch, (Re_{LP}) |
| B | 2.02 | 1.40 | 25.5 | |
| C | 2.02 | 1.40 | 29.0 | |
| D | 2.02 | 1.40 | 22.0 | Based on fin pitch, (Re_{FP}) |
| E | 2.02 | 1.40 | 25.5 | |
| F | 2.02 | 1.40 | 29.0 | |

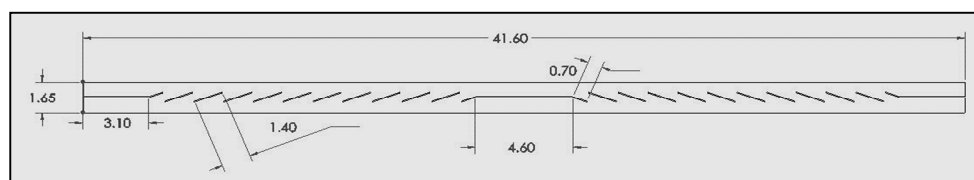


Figure 1: 2-D geometry of one stack louvered fins from side view (unit in mm)

Boundary conditions. The numerical work involved 3-dimensional, steady simulation of air enters across the heat exchanger. Uniform velocity was set at the inlet with ambient temperature at 27°C and zero pressure outlet. Symmetrical boundary conditions was applied to the side planes (Y-Z planes) with zero normal gradients. Non-slip conditions and constant wall temperature were specified at the louvered fin surface. On the upper and lower X-Z planes, periodic boundary conditions were imposed.

Results and discussion

Grid independence study. Grid sensitivity tests are conducted to improve grid simulation stability. It is very important to determine the most appropriate grid size and compare the calculated results to the experiment. Processing time during simulation also plays an important role to obtaining accurate results. Good balance between processing time and appropriate grid size is needed to optimize the analysis by obtaining accurate of data value compared to correlation data. Fig. 2 indicates the calculated pressure drop for eleven different numbers of elements. The number of elements is ranging from 308022 to 506025. The calculated results are compared to the values obtained from the correlation of the experiment [4, 8]. Small difference from the experiment indicates the meshing scheme can be used for further analysis. However, the best fit of predicted pressure drop to the correlation data is selected from the preferred mesh density. Therefore, the lowest mean difference is selected to be used in the further simulation. The lowest mean difference selected is 12.02% while the mesh density is 506,025 numbers of elements.

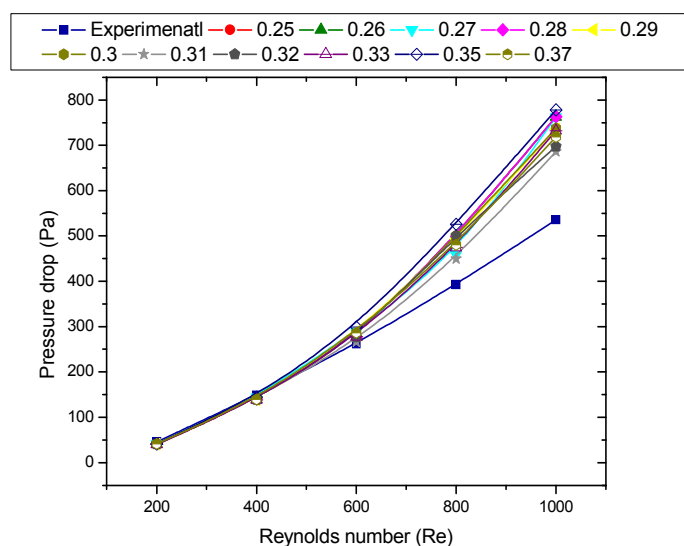


Figure 2: Pressure drop for different number of elements

Relationship between pressure drop with louver angle, louver pitch and fin pitch. This study examines the relationship between pressure drop with louver angle, louver pitch and fin pitch. The results show that the pressure drop occurred at louver pitch of 1.4 mm is relatively higher than fin pitch at 2.02 mm. Fig. 3 shows the variation of pressure drop against Reynolds number at fin pitch 2.02 mm and louver pitch 1.4 mm with louver angle of 22.0°, 25.5° and 29.0°. The results suggest that pressure drop will increase when the angle of louver is increased. It is also noticed that the pressure drop of air velocity based on louver pitch 1.4 mm is slightly higher than the air velocity based on fin pitch 2.02 mm. Consequently, that makes the result of fin pitch, 2.02 mm (Model A, Model B and Model C) better than that of the louver pitch, 1.4 mm (Model D, Model E and Model F) which means they are the optimum for the design purposes.

Relationship between heat transfer coefficient with louver angle, louver fin and louver pitch. Fig. 4 shows the value of heat transfer coefficient against Reynolds number at louver pitch of 0.7 mm and fin pitch 2.02 mm with louver angle of 22.0°, 25.5° and 29.0°. It's observed that, unlike the result of the pressure drop, the heat transfer at louver pitch 1.4 mm (Model D, Model E and Model F) is higher than that of fin pitch 2.02 mm (Model A, Model B and Model C). In addition, it is also been suggested that the heat transfer coefficient will increase from louver angle of 22.0° to

25.5° while the heat transfer coefficient decrease from louver angle 25.5° to 29.0°. This indicates that the best configurations is at louver angle of 25.5°.

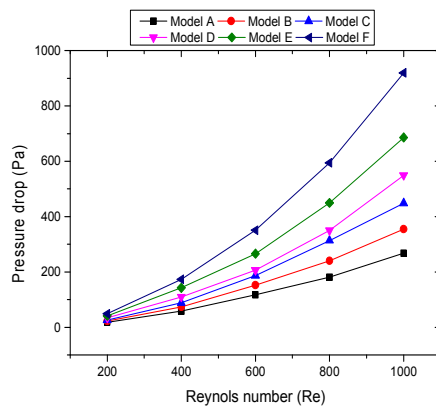


Figure 3: Pressure drop against Reynolds number for all of the models

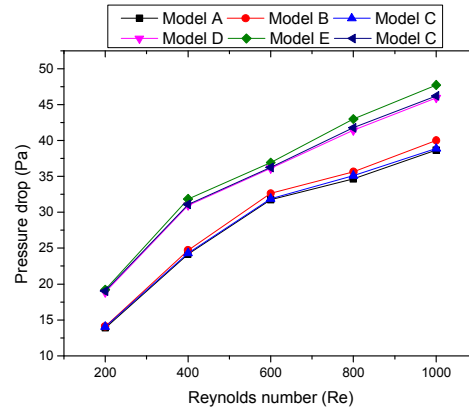


Figure 4: Heat transfer coefficient against Reynolds or number for all of the models

Relationship between the ratio of Nusselt number over Euler number with louver angle.

Fig. 5 shows the relationship between mean values of Nusselt number over Euler number at three different louver angle. The Nusselt number is divided by Euler number to gain the heat exchanger efficiency in terms of heat transfer coefficient and pressure drop. It is observed that for a constant louver pitch and fin pitch, the mean values of Nusselt number over Euler number decreases from 22.0° to 29.0°. These values suggested that an increase in louver angle will not improve the performance of heat exchanger. However, in terms of fin size, it is also noticed that Reynolds number based on fin pitch is higher than louver pitch in the performance of the heat exchanger.

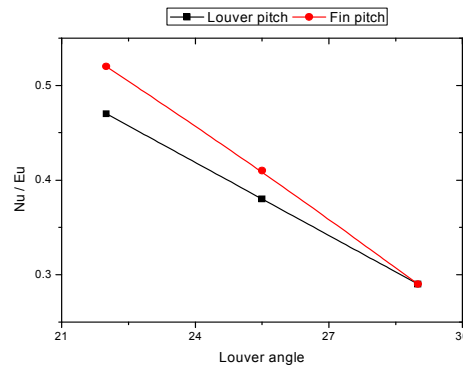


Figure 5: The relationship between mean values of Nusselt number over Euler number at different louver angle

Conclusion

Based on this study, it can be concluded that pressure drop is directly proportional to the Reynolds number. In other words, higher Reynolds number will draw higher pressure drop on louvered fin. It is also noticed that there is higher pressure drop occurred at Reynolds number based on louver pitch 1.40 mm (Model D, Model E and Model F) compared to fin pitch 2.02 mm (Model A, Model B and Model C). Louver pitch has larger pressure drop compared to fin pitch because the air flows between the louvers which is known as louver directed flow, while in the latter case the air flows between the fins, also known as fin directed flow. Louver directed flow will have larger pressure drop due to the flow is only following the direction of every single fins while air flow with fin

directed flow through the gap between the stacks of louver fin. Therefore, Reynolds number based on fin pitch is more suitable to be selected in terms of lower pressure drop consideration.

In terms of heat transfer analysis, it is observed that the heat transfer coefficient increases with louver angle and reaches maximum value at an angle of 25.5° and then decreases with the increase in louver angle. This is because the air flow is aligned with the louver at louver angle after 25.5° . Moreover, by comparing the effect of fin pitch and louver pitch, the louver pitch has the higher heat transfer rate. This happened because the flows of louver pitch is aligned to the fins in which effectively transfer heat from fins to flow. However, for better heat transfer rate, configuration of Reynolds number based on louver pitch with louver angle of 25.5° is selected as the better performance on heat transfer coefficient. For both louver pitch 1.4 mm and fin pitch 2.02 mm, louver angle of 29° have the highest value of Euler number due to the higher pressure drop occurred.

The ratio of Nusselt number and Euler number is obtained in order to measure the efficiency of heat exchanger performance. As a result, for a good balance, the louver angle of 22.0° and Reynolds number based on fin pitch (Model A) has been chosen as the best configurations for this study due to the highest balance in terms heat transfer coefficient and pressure drop.

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