Pergamon

Int. J. Heat Mass Transfer. Vol. 41, Nos 4–5, pp. 817–822, 1998

0017-9310/98 $19.00+0.00

PII: S0017-9310(97)00154-3

An experimental study of heat transfer and friction characteristics of typical louver fin-and-tube heat exchangers

CHI-CHUAN WANG, KUAN-YU CHI and YU-JUEI CHANG
Energy and Resources Laboratories, Industrial Technology Research Institute, Hsinchu, Taiwan

and

YEON-PUN CHANG
Department of Mechanical Engineering, Chung Yuan Christian University, Chung Li, Taiwan

(*Received* 6 *September* 1996 *and in final form* 14 *March* 1997)

INTRODUCTION

The louvered fin surface is widely used in both automotive and residential air conditioning systems. 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 serpentine or a parallel flow geometry. For residential air-conditioning systems, the configurations of fin-and-tube heat exchangers consist of mechanically or hydraulically expanded round tubes in a block of parallel continuous fins (Fig. 1). The louver surface can break and renew the boundary layer of the air flow. Consequently, higher heat transfer performance is expected as compared to plain fin surface. During the past few decades, there have been numbers of experimental efforts devoted to the louver fin having flat tube configurations. Recently, a general heat transfer correlation for automotive heat exchangers that compiled more than 90 samples was proposed by Chang and Wang [1]. Compared to the flat tube heat exchangers, there were relatively few experimental data available for round tube configurations. The only experimental data were reported by Chang *et al.* [2], they had reported 7 louver fin surface having a 9.52 mm tube diameter. Therefore, the main purpose of the present study is to present extensive experimental results of the louver fin configuration for the commercially available louver fin geometry. The effects of the number of tube row, fin pitch, and the tube size for the present fin geometry are investigated.

The sample coils are of the louver fin configuration are shown in Fig. 2. Their detailed geometric parameters are tabulated in Table 1. all tests were conducted in a wind tunnel. Detailed description of the test facility and the corresponding reduction method can be found from previous study [3].

RESULTS AND DISCUSSION

The effect of the number of tube rows on the heat transfer and friction characteristics is shown in Fig. 3. The number

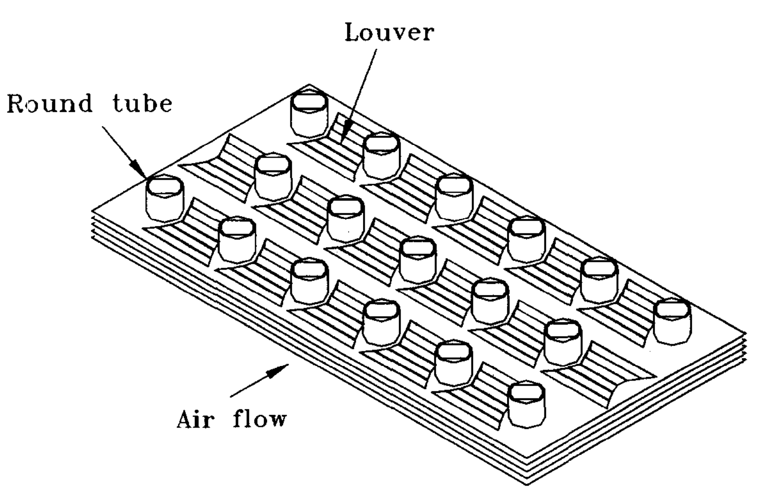

Fig. 1. Typical louver fin geometry with round tube configuration.

NOMENCLATURE

A_o	total surface area [m^2]
D_c	fin collar outside diameter ($D_o + 2\delta_f$) [mm]
D_o	outside tube diameter [mm]
f	friction factor
F_p	fin pitch [mm]
h	heat transfer coefficient [W m^{-2} K^{-1}]
j	the Colburn factor
ΔP	pressure drop [Pa]
P_l	longitudinal tube pitch [mm]
P_t	transverse tube pitch [mm]
Re_{Dc}	Reynolds number based on tube collar diameter ($\rho V_c D_c/\mu$)
V_c	air velocity at minimum flow area [m s^{-1}]
V_{fr}	frontal velocity [m s^{-1}].

Greek symbols

δ_f	fin thickness [mm]
η_o	surface efficiency
ρ	mean air density [kg m^{-3}].

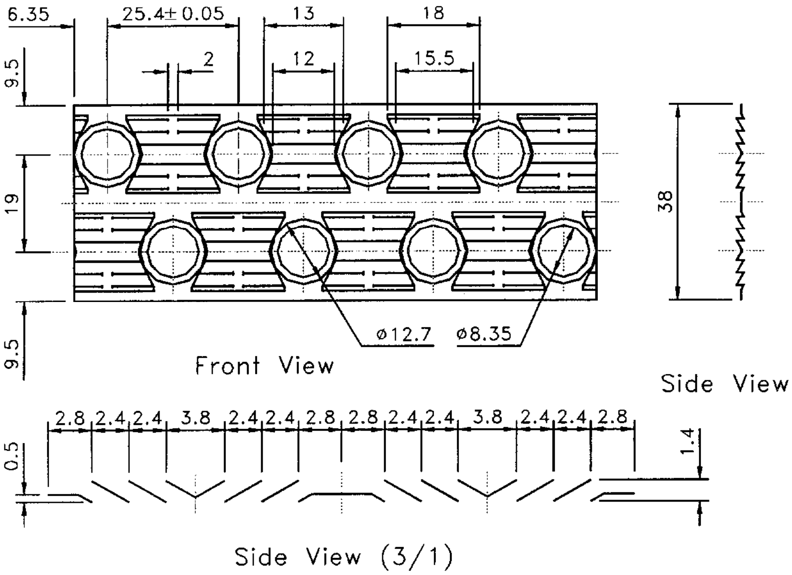

Fig. 2. Details of the present louver fin configuration.

of tube rows are 1, 2, 4 and 6, respectively, and the corresponding fin pitches for the samples are between 2.05 and 2.1 mm. As seen, the Colburn j factors decrease with increase of the number of tube rows for $Re_{Dc} < 2000$, and are relatively independent of the number of tube row for $Re_{Dc} > 2000$ and $N > 1$. This phenomenon is very similar to the plain fin data reported by Rich [4], and Wang *et al.* [3]. As the Reynolds number decreases, the downstream turbulence tends to diminish, and the ineffective vortices behind the tube cylinder come into effect. As a result, the number of tube rows shows a significant effect on the heat transfer characteristics for $Re_{Dc} < 2000$. The six-row coil shows a tremendous reduction of heat transfer coefficient.

The effect of the number of tube rows on the heat transfer characteristics vanishes $Re_{Dc} > 2000$ as seen in Fig. 3. This is because the downstream turbulence eddies shed from the tubes that cause good mixing in the downstream fin region. The 'level-off' phenomenon of the Colburn j factors for the four- and six-row coils is very similar to those of six-row data for plain fin configuration as reported by Rich [4] and Wang *et al.* [3]. Wang *et al.* [3] had interpreted the 'level-off' phenomenon of j factors for plain fin configuration. According to the experimental evidence of Chen and Ren [5], Wang *et al.* [3] suggests two possible explanations about this phenomenon, that is the effect of the standing vortices from behind the tube and the effect of fin spacing. However, converse to the test results of the present louver fin, there is no 'level-off' phenomenon for the plain fin geometry having four-row configuration. Therefore, there might be other explanations for the 'level-off' phenomenon for the present enhanced fin geometry. Another possible reason is that the bulk mean fluid change more from the inlet fluid temperature at downstream position. However, as pointed out by Suzuki *et al.* [7] and later proven by Xi *et al.* [8], this is only a minor reason. Suzuki *et al.* [7] had numerically investigated the heat transfer characteristics of a parallel louver fin, and found at low Reynolds number the thermal wakes of fins can not develop completely within the spatial interval between the two successive fins (wake-unrecovery-effect). This effect may become larger for the downstream fins due to superposition. Eventually, larger suppressions of heat transfer coefficients were encountered at low Reynolds number. The experimental data by Xi *et al.* [8] supported the findings of Suzuki *et al.* [7]. Accordingly, the 'wake-unrecovery-effect' may also

Table 1. Geometric dimensions of the sample louver fin heat exchangers

No.	Fin pitch [mm]	D_c [mm]	P_t [mm]	P_l [mm]	Row no.
1	1.50	10.42	25.4	19.05	1
2	2.05	10.42	25.4	19.05	1
3	1.50	10.42	25.4	19.05	2
4	2.05	10.42	25.4	19.05	2
5	1.30	10.42	25.4	19.05	3
6	1.81	10.42	25.4	19.05	3
7	1.29	10.42	25.4	19.05	4
8	1.49	10.42	25.4	19.05	4
9	1.79	10.42	25.4	19.05	4
10	2.08	10.42	25.4	19.05	4
11	1.51	10.42	25.4	19.05	6
12	2.07	10.42	25.4	19.05	6
13	1.50	8.71	25.4	19.05	1
14	2.07	8.71	25.4	19.05	1
15	1.52	8.71	25.4	19.05	2
16	2.08	8.71	25.4	19.05	2
17	1.53	8.71	25.4	19.05	4

Tube wall thickness: 0.35 mm.
Fin thickness: 0.115 mm.
D_c is the outer tube diameter plus 2 fin thickness ($D_o + 2\delta_f$).
F_p is the distance between fins (including one fin thickness).

contribute to the reduction of heat transfer performances for the present multi-row louver fin configuration at low Reynolds number. Excluding one-row configuration, Fig. 3 also indicates that the friction factors are relatively independent of the number of tube rows. This phenomenon is very similar to other plain fin-and-tube heat exchangers as shown by Rich [4] and Wang *et al.* [3].

As shown in Fig. 3, the Colburn *j* factor for the one-row coil is higher than those of multi-row coils at low Reynolds number, and became less than those of the multi-row coils for higher Reynolds number. A 25% lower heat transfer performance was seen for a Reynolds number of 7000. Higher heat transfer performance at low Reynolds number of the one-row coil is due to the air flow which is normal to most of the louvers, and lower heat transfer performance at higher Reynolds number is because there is no effect of the downstream turbulence eddies that shed from the tube. As seen, the heat transfer characteristics for the one-row coil is quite different from those of multi-row coils. Basically, the heat transfer characteristics of the one-row is similar to the flat tube heat exchanger.

Figure 4 depicts the effect of fin pitches on the heat transfer and friction characteristics. For plain fin configuration, Rich [9] and Wang *et al.* [3] concluded that the heat transfer performance is essentially independent of fin spacing. For the present louver fin geometry ($F_p = 1.29 \sim 2.08$ mm), it seems that the effect of fin pitch is very small for $Re_{Dc} > 1000$. The experimental data show the Coburn *j* factors decrease with fin pitch for $Re_{Dc} < 1000$. This may be due to the 'channel flow' effect. The results agree with those of Chang *et al.* [2]. For the results of friction factors, the effect of fin pitch on the friction factors is again very small compared to plain fin configuration. The plain fin pattern shows a detectable cross-over vs. the Reynolds number. However, the louver fin geometry does not show such kind of behaviour. The experimental data reported by Chang *et al.* [2] for louver fin geometry also reveals similar results.

For the same fin configuration, the effect of using smaller heat transfer tube for one-row and four-row configuration is shown in Fig. 5. As seen, for $F_p = 1.5$ mm and four-row configuration, the heat transfer coefficients for the 8.71 mm tube is higher than those of 10.42 mm tube. Further, the 8.71 mm tube shows an approximately 10% lower pressure drop. The improvement of heat transfer coefficient is especially pronounced for $V_{fr} < 1.5$ m s^{-1}. This is because the ineffective region behind the tube for larger tube may significantly reduce heat transfer on downstream fin. This phenomenon can be further illustrated by the test results of the one-row coil. It is obvious that the one-row coil has no downstream fin area to influence it, therefore the effect of tube size on the heat transfer performance for the one-row coil is negligible. For multi-row coil, as air velocity increases further, the downstream turbulence may cause good mixing, and the improvements due to the use of smaller tube eventually diminish. It is expected that the fin efficiency may be smaller for the 8.71 mm due to its larger fin length. Therefore, Fig. 5 also presents the direct comparison of the overall thermal conductance (evaluated as $\eta_o h_o A_o$). As seen, similar results for using smaller tube were also shown.

CONCLUSIONS

Extensive experiments on the heat transfer and pressure drop characteristics of louver fin-and-tube heat exchangers were carried out. In the present study, 17 samples of commercially available louver fin-and-tube heat exchangers with different geometrical parameters, including the number of tube row, fin pitch, and tube size, are reported. On the basis of previous discussions, the following conclusions are made:

- The experimental data indicate that the number of tube row does not affect the friction factors, the effect of the number of the tube row is negligible for $Re_{Dc} > 2000$, and a significant reduction of the heat transfer performance is found for Reynolds number less than 2000 for the six-row coil.
- Fin pitch has negligible effect on the heat transfer characteristics for $Re_{Dc} > 1000$, and the heat transfer performances decrease with decrease of fin pitch for $Re_{Dc} < 1000$. The cross-over phenomena of the friction factors are much less pronounced as compared to the plain fin configuration.
- For the present louver fin configuration, the heat transfer characteristics for multi-row coils may benefit from using smaller heat transfer tube especially for $V_{fr} < 1.5$ m s^{-1}. However, for one-row configuration, there is no improvement of the heat transfer coefficients. A 10% reduction of pressure drops due to the tube size reduction was reported in the present study.

Acknowledgement—The authors would like to express gratitude for the Energy R&D foundation funding from the Energy Commission of the Ministry of Economic Affairs, which provides final support of the current study.

REFERENCES

1. Chang, Y. J. and Wang, C. C., A generalized heat transfer correlation for louver fin geometry. *International Journal of Heat and Mass Transfer*, 1997, **40**(3), 533–544.
2. Chang, W. R, Wang, C. C., Tsi, W. C. and Shyu, R. J., Air side performance of louver fin heat exchanger. In *Proceedings of the 4th ASME/JSME Thermal Engineering Joint Conference*, 1995, **4**, 367–372.
3. Wang, C. C., Chang, Y. J., Hsieh, Y. C. and Lin, Y. T., Sensible heat and friction characteristics of plate fin-and-tube heat exchangers having plane fins. *International Journal of Refrigeration*, 1996, **19**(4), 223–230.
4. Rich, D. G., The effect of the number of tube rows on the heat transfer performance of smooth plate fin-and-tube heat exchangers. *ASHRAE Transaction*, 1975, **81**(1), 307–317.
6. Chen, Z. Q. and Ren, J. X., Effect of fin spacing on the

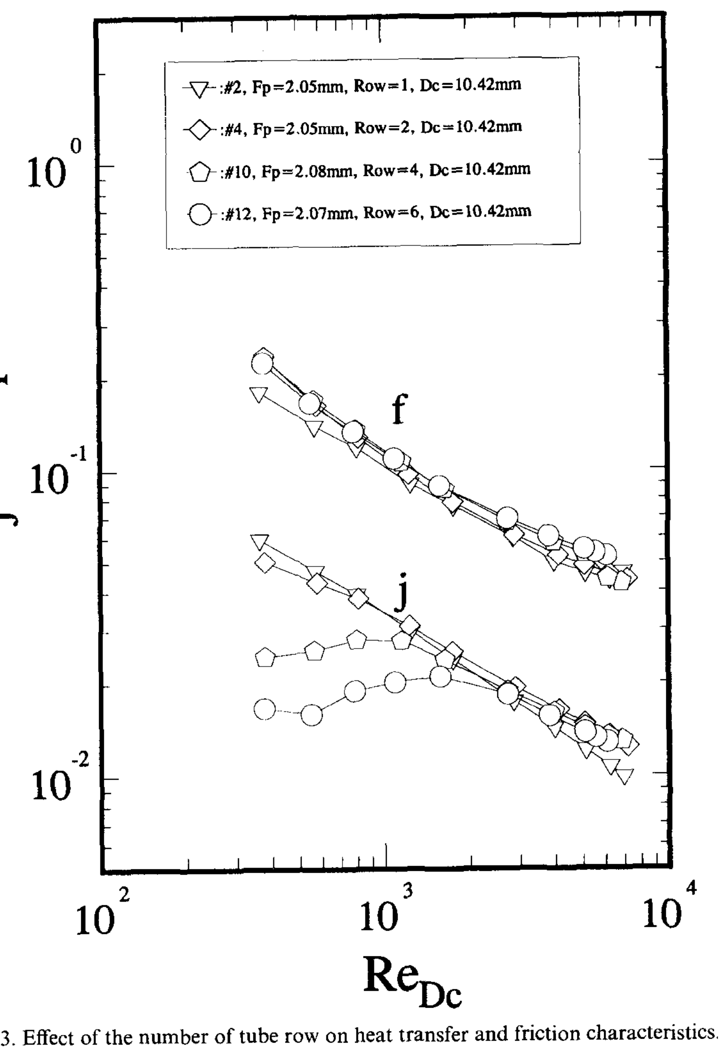

Fig. 3. Effect of the number of tube row on heat transfer and friction characteristics.

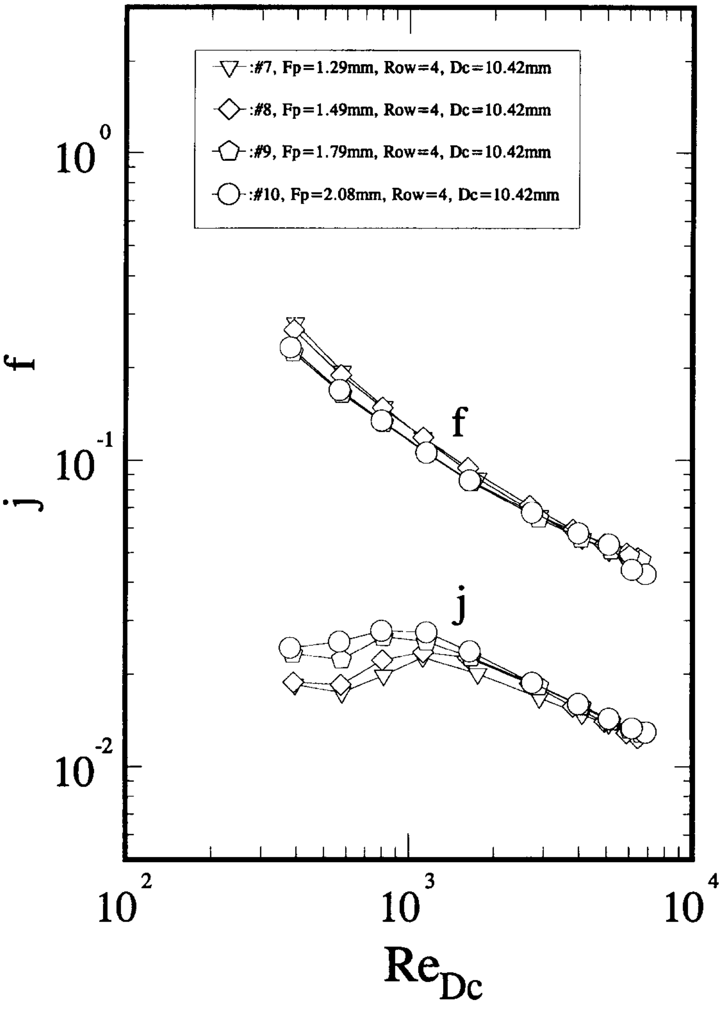

Fig. 4. Effect of fin pitch on the heat transfer and friction characteristics.

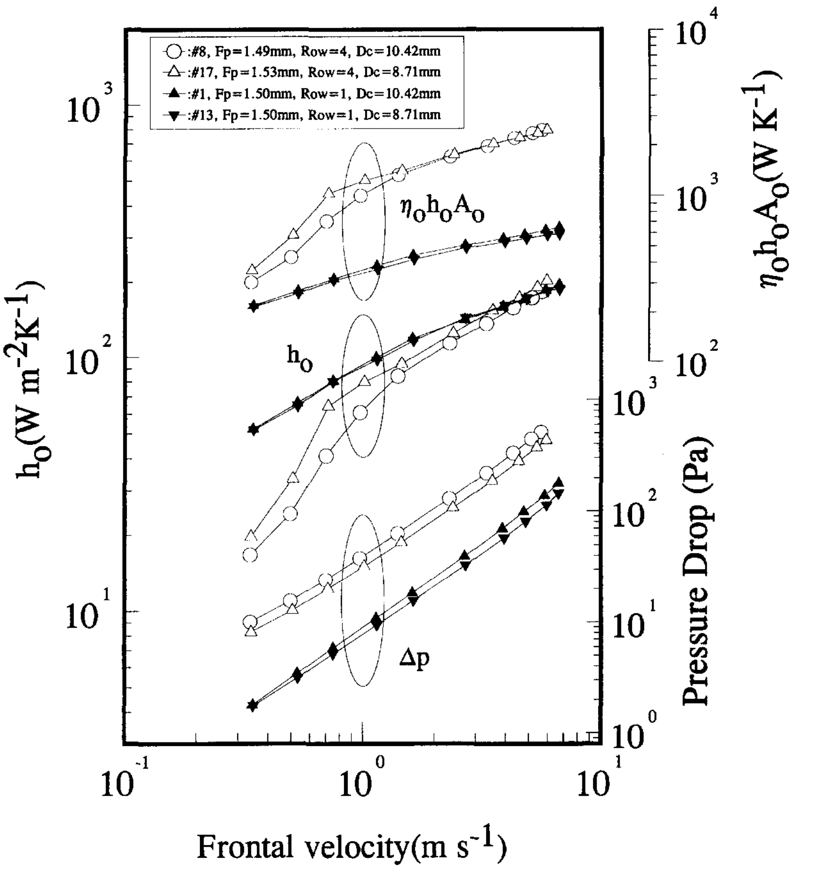

Fig. 5. Effect of using smaller heat transfer tube on the heat transfer and friction characteristics.

heat transfer and pressure drop of a two-row plate fin and tube heat exchanger. *International Journal of Refrigeration*, 1988, **11,** 360–456.

7. Suzuki, K., Nishihara, A., Hayashi, T., Schuerger, M. J. and Hayashi, M., Heat-transfer characteristics of a two-dimensional model of a parallel louver fin. *Heat Transfer—Japanese Research*, 1990, 654–669, originally published in *Transactions of JSME*, 1989, **55**(516), 2475–2464.
8. Xi, G. N., Suzuki, K., Hagiwara, Y. and Murata, T., Experimental study on heat transfer characteristics of offset fin arrays-effect of fin thickness in low and middle ranges of Reynolds numbers. *9th International Heat Transfer Conference*, 1990, 10-EH-14, pp. 81–86.
9. Rich, D. G., The effect of fin spacing on the heat transfer and friction performance of multi-row, plate fin-and-tube heat exchangers. *ASHRAE Transactions*, 1973, **79**(2), 137–145.