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Technical Note

An amendment of the generalized friction correlation for louver fin geometry

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Abstract

This study proposed an amendment to the previous correlation developed by Chang et al. [Y.J. Chang, K.C. Hsu, Y.T. Lin, C.C. Wang, A generalized friction correlation for louver fin geometry, Int. J. Heat Mass Transfer 43 (2000) 2237–2243] for the generalized frictional correlation for louver fin geometry. A total of 91 samples of louver fin heat exchangers are used in the regression analysis. The proposed amendment eliminates the discontinuity of the original correlation and gives a mean deviation of 9.11%, and it is shown that 83.91% of the frictional data can be correlated within ±15%.

Keywords: Louver fin; Friction factor; Heat exchanger

1. Introduction

This study proposed an amendment to the previous correlation developed by Chang et al. [1]. They had developed a general correlation for louver fin geometry based on 91 louvered fin heat exchangers having flat tube configuration (Fig. 1). The database of the 91 samples were collected from Davenport [2] (30 samples, Fig. 1, Type A, 529 data points), Tanaka et al. [3] (1 sample, Fig. 1, Type C, 6 data points), Achaichia and Cowell [4] (15 samples, Fig. 1, Type B, 193 data points), Webb [5] (5 samples, Fig. 1, Type C, 33 data points), Sunden and Svantesson [6] (6 sample, Fig. 1, Type C, 63 data points), Webb and Jung [7] (6 samples, Fig. 1, Type C and Type E, 36 data points), Rugh et al. [8] (1 sample, Fig. 1, Type D, 10 data points), and Chang and Wang [9] (27 samples, Fig. 1, Type C, 239 data points). The original correlation take the form:

$$f = f1 \times f2 \times f3 \tag{1}$$

where

$$f1 = \begin{cases} 14.39 Re_{\mathrm{Lp}}^{(-0.805F_{\mathrm{p}}/F_{\mathrm{l}})} \left(\log_{\mathrm{e}}(1.0 + (F_{\mathrm{p}}/L_{\mathrm{p}}))\right)^{3.04} \\ \quad Re_{\mathrm{Lp}} < 150 \\ 4.97 Re_{\mathrm{Lp}}^{0.6049-1.064/\theta^{0.2}} \left(\log_{\mathrm{e}}((F_{\mathrm{t}}/F_{\mathrm{p}})^{0.5} + 0.9)\right)^{-0.527} \\ \quad 150 < Re_{\mathrm{Lp}} < 5000 \end{cases} \tag{2}$$

$$f2 = \begin{cases} \left(\log_{\mathrm{e}}((F_{\mathrm{t}}/F_{\mathrm{p}})^{0.48} + 0.9)\right)^{-1.435} (D_{\mathrm{h}}/L_{\mathrm{p}})^{-3.01} \left(\log_{\mathrm{e}}(0.5 Re_{\mathrm{Lp}})\right)^{-3.01} \\ \quad Re_{\mathrm{Lp}} < 150 \\ ((D_{\mathrm{h}}/L_{\mathrm{p}})\log_{\mathrm{e}}(0.3 Re_{\mathrm{Lp}}))^{-2.966} (F_{\mathrm{p}}/L_{\mathrm{l}})^{-0.7931(T_{\mathrm{p}}/T_{\mathrm{h}})} \\ \quad 150 < Re_{\mathrm{Lp}} < 5000 \end{cases} \tag{3}$$

$$f3 = \begin{cases} (F_{\mathrm{p}}/L_{\mathrm{l}})^{-0.308} (F_{\mathrm{d}}/L_{\mathrm{l}})^{-0.308} (\mathrm{e}^{-0.1167 T_{\mathrm{p}}/D_{\mathrm{m}}}) \theta^{0.35} \\ \quad Re_{\mathrm{Lp}} < 150 \\ (T_{\mathrm{p}}/D_{\mathrm{m}})^{-0.0446} \left(\log_{\mathrm{e}}(1.2 + (L_{\mathrm{p}}/F_{\mathrm{p}})^{1.4})\right)^{-3.553} \theta^{-0.477} \\ \quad 150 < Re_{\mathrm{Lp}} < 5000 \end{cases} \tag{4}$$

Detailed geometric parameters are defined in Fig. 2. The developed correlation, including an earlier version reporting the heat transfer results (Chang and Wang [10]) had been included in several monographs (Hesselgreaves [11], Shah and Sekulic [12], and Webb and Kim [13]) and is

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Nomenclature

D_m major tube diameter (mm)
f Fanning friction factor dimensionless
$f1, f2, f3$ correlation parameter
F_d fin depth (mm)
F_l fin length (mm)
F_p fin pitch (mm)
F_t fin thickness (mm)
L_h louver height (mm)
L_l louver length (mm)
L_p louver pitch (mm)
M number of test data point
Re_{Lp} Reynolds number based on louver pitch, dimensionless
T_h $T_p - D_m$ (mm)
T_p tube pitch (mm)
T_d tube depth (mm)
V_c maximum velocity (m s^{-1})
w weighting factor
θ louver angle (°)

Subscripts
exp experimental value
pred prediction value by the proposed correlation

recognized as the most accurate correlation. The success of the developed correlations is associated with its wide-span database. For the proposed frictional correlation, despite the mean deviation is as low as 9.21%, the correlation suffered from discontinuity near $Re_{Lp} = 150$. This is because the original correlation is developed in two parts, one is applicable for $Re_{Lp} < 150$ and the other is applicable for $Re_{Lp} > 150$ (see Eqs. (2)–(4)). A typical plot of the test results against the correlation is shown in Fig. 3(a) in which one can see a sharp discontinuity at $Re_{Lp} = 150$. During

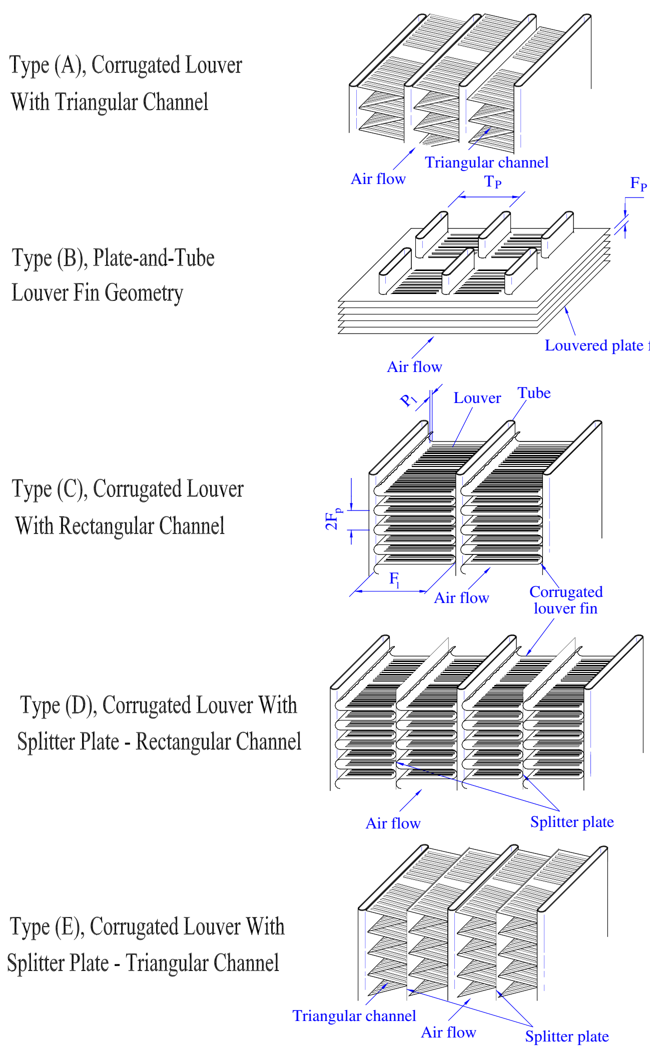

Fig. 1. Types of louvered fin heat exchangers.

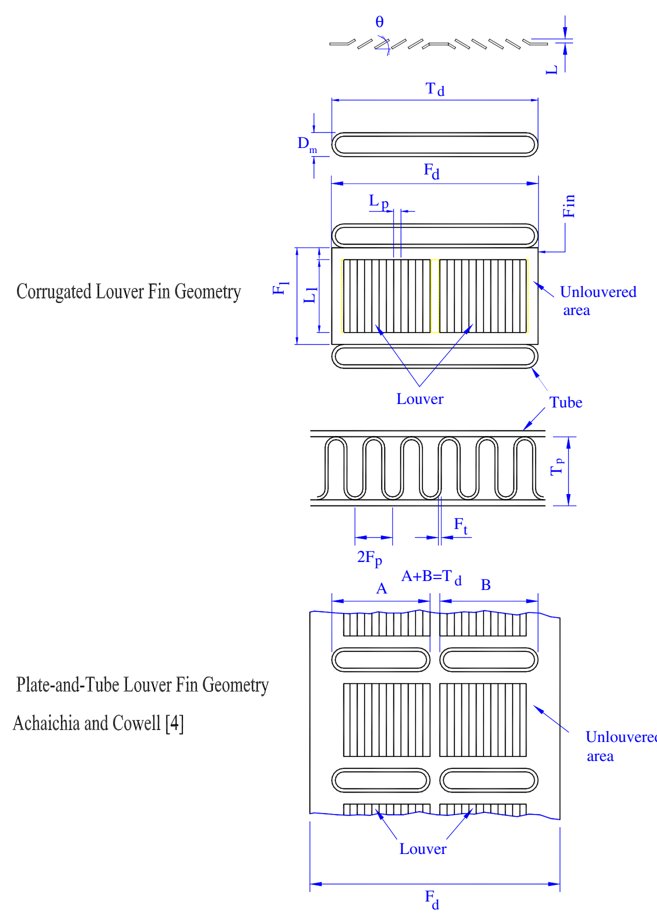

Fig. 2. Definition of various geometric parameters.

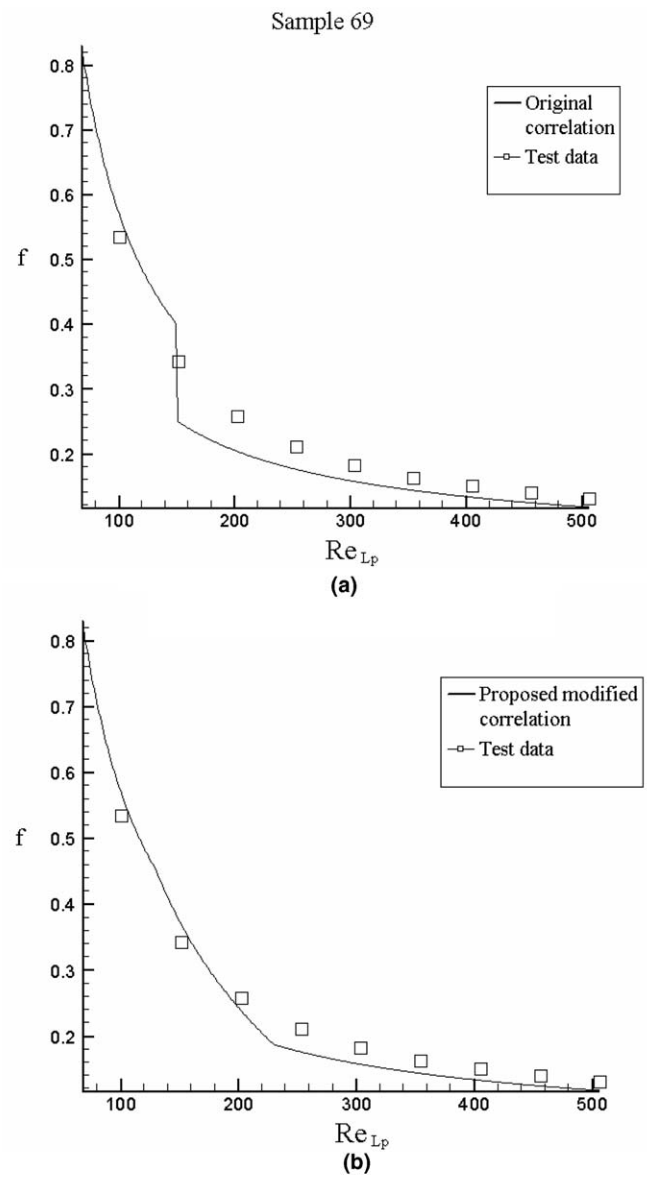

Fig. 3. Typical plot of experimental data and correlation for f vs. Re_{LP} (sample #69 from [1]): (a) Comparison between data and original correlation; (b) comparison between data and the proposed amendment.

the past several years, the authors had received many researchers from the world complaining about the inconsistent behaviors of this correlation near $Re_{Lp} = 150$. In that sense, the present authors feel it is necessary to develop an updated version of the correlation to eliminate the discontinuity of the correlation.

2. Proposed amendment and comparison with data and various correlations

To smooth the discontinuity of the proposed correlation, the applicable range of the original correlation is now changed into three regions. In the first ($Re_{Lp} \leqslant 130$) and third ($Re_{Lp} \geqslant 230$) region, the original equation is still applicable. The friction factor in the transition region

Table 1
Comparison of the correlation with all the experimental data

Deviation	Proposed modified correlation (%)	Original correlation [1] (%)	Davenport [2] (%)	Achaichia and Cowell [4] (%)
10%	68.97	68.35	45.49	14.97
15%	83.91	83.14	54.48	19.12
20%	89.66	90.89	64.05	21.73
25%	97.7	94.86	70.81	24.17
Average deviation	−0.52	0.027	−11.94	100.83
Mean deviation	9.11	9.21	17.50	102.48

Average deviation $= \frac{1}{M}\left(\sum_1^M \frac{f_{pred} - f_{exp}}{f_{exp}}\right) \times 100\%$.
Mean deviation $= \frac{1}{M}\left(\sum_1^M \frac{|f_{pred} - f_{exp}|}{f_{exp}}\right) \times 100\%$.
M: Number of data point.

($130 < Re_{Lp} < 230$) is calculated from the weighted values of the first and third region to ensure its smooth transition from the first to the third region. The proposed correlation in the transition region is as follows ($130 < Re_{Lp} < 230$):

$$\sqrt[2]{\frac{(1+w)f^2_{Re_{Lp}=130} + (1-w)f^2_{Re_{Lp}=230}}{2}} \tag{5}$$

where

$$w = 3.6 - 0.02Re_{Lp} \tag{6}$$

The proposed modification is then compared with the test data and with correlations from the original correlation [1], the Davenport correlation [2] and the Achaichia and Cowell correlation [4]. The results of the comparison to the database are shown in Table 1. As seen, the mean deviation of the present correlation is slightly improved from 9.21% to 9.11% while the deviations of the Davenport correlation and the Achaichia and Cowell [4] correlation are 17.5% and 102.5%, respectively. The most significant improvement of the amendment correlation is the removal of discontinuity as can be shown in Fig. 3(b).

3. Conclusions

An amendment of the generalized frictional correlation for louver fin geometry is developed in the present study. A total of 91 samples of louver fin heat exchangers are used in the regression analysis. The proposed amendment eliminates the discontinuity of the original correlation and gives a mean deviation of 9.11%, and it is shown that 83.91% of the frictional data can be correlated within ±15%.

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