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DEVELOPMENT OF OBLIQUE WAVY FIN HEAT EXCHANGER

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ABSTRACT

Heat transfer and pressure drop characteristics of oblique wavy fin heat exchanger are evaluated experimentally. It is found that the heat transfer coefficient of the optimal oblique wavy fin is more than twice larger than that of the plate fin, which is slightly smaller than the conventional louvered fin. On the other hand, the increase of pressure drop was nearly three times larger, which was much smaller than the louvered fin. Present result proves that oblique wavy fin is competitive against louvered fin, and oblique wavy fin heat exchanger can be expected as a promising heat transfer enhancement device for single phase laminar flows.

1. INTRODUCTION

Louvered fins or interrupted fins are widely used as heat transfer enhancement devices for low Reynolds number single phase laminar flows (Webb, 1994). Those interrupted fins can theoretically achieve very high heat transfer augmentation even at very low velocity conditions. However, further improvements for the louvered fins are difficult because those fins can be easily stuck by dust, drainage and frost etc. In addition, machining processes of very fine louvers are reaching the limit because of machinability problems. Moreover, pressure drop penalty often exceeds the merit of heat transfer enhancement. Recently, a novel heat transfer enhancement technique, i.e. oblique wavy surface, is proposed by Suzue et al. (2006), Fukuda & Shikazono (2007) and Shikazono et al. (2010). Periodically mirrored oblique waves which are created on both sides of the channel produces secondary flow without resulting any separation of the flow. From numerical analyses, it is shown that oblique wavy surface can achieve very high heat transfer enhancement even at laminar flow regimes. Fukuda & Shikazono (2007) carried out a set of numerical simulation for the developing laminar flow heat transfer inside oblique wavy fins as shown in Fig. 1. Oblique wavy fin consists of oblique waves of wavelength w and amplitude a witch are placed at an angle θ from the main flow direction and are mirrored at a pitch r in the spanwise direction. From the parametric numerical study, it is shown that the heat transfer coefficient of oblique wavy fins can be enhanced nearly five times compared to plate fins at an optimal condition. In addition, *j/f* factor of oblique wavy fin, which is a ratio of heat transfer to pressure drop, showed larger value than that of the plate fins. In general, most of the known heat transfer enhancement techniques for single phase flows including louvered fins show deterioration of *j/f* factor compared to plate fins. Thus, it can be expected that oblique wavy fin has a potential to exceed the performance of louvered fins. However, experimental validation must be required to confidently demonstrate its performance.

In the present study, prototypes of corrugated fin heat exchangers are fabricated and tested by hot water experiment. Heat transfer coefficient and pressure drop are measured for various parameters to demonstrate the effectiveness of the oblique wavy fin heat exchanger.

2. EXPERIMENT

2.1 Oblique wavy fin heat exchanger

Prototype samples of oblique wavy fins as shown in Table 1 are fabricated. The height of the prototype heat exchanger is 100 mm, the width is 102.5 mm and the depth is 50 mm. The fin pitch is p = 1.3 mm, wave length is w = 2.5 mm, mirroring pitch is r = 2.35 mm, amplitudes are a = 0.4, 0.5 mm, wave angles are θ = 15, 30, 40°, respectively. Plate fin and louvered fin heat exchangers are fabricated as well for comparison. All the fins were made by press molding and heat exchangers are fabricated by furnace brazing.

2.2 Experimental setup

Figure 2 shows the experimental setup. Hot water is provided by the pump to the test sample. Heat exchange rate was measured by the water side temperature difference and the flow rate. Overall heat transfer coefficient is calculated by the ε-NTU method. Air side pressure drop was measured by a differential pressure gauge.

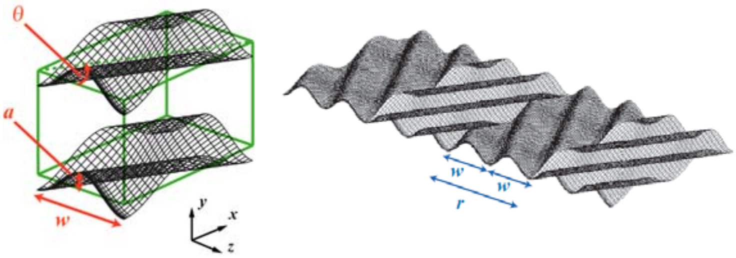

Fig. 1 Oblique wavy fin configuration

Table 1 Dimensions of prototype heat exchangers.

	Parameter Levels		
HEX Height [mm]	100.0	-	-
HEX Width [mm]	102.5	-	-
HEX Thickness [mm]	50.0	-	-
Fin height h [mm]	4.7	-	-
Fin pitch p [mm]	1.3	-	-
Return pitch r [mm]	2.35	-	-
Wave length w [mm]	2.50	-	-
Wave amplitude a [mm]	0.4	0.5	-
Wave angle θ [°]	15	30	40

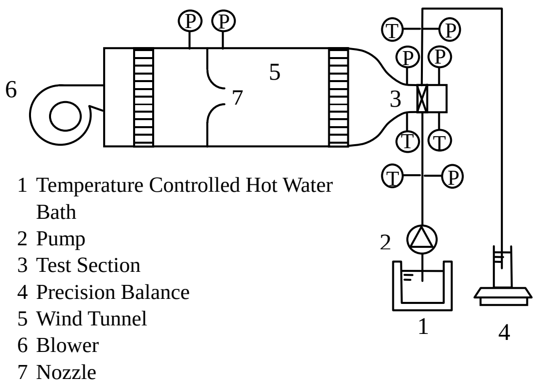

Fig. 2 Experimental setup

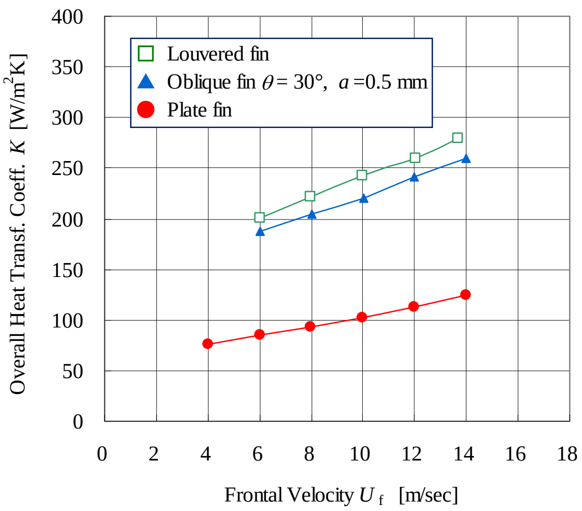

Fig. 3 Measured overall heat transfer coefficient.

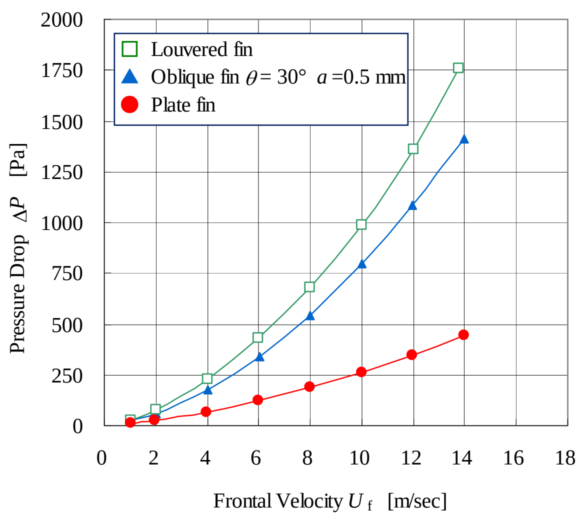

Fig. 4 Measured pressure drop.

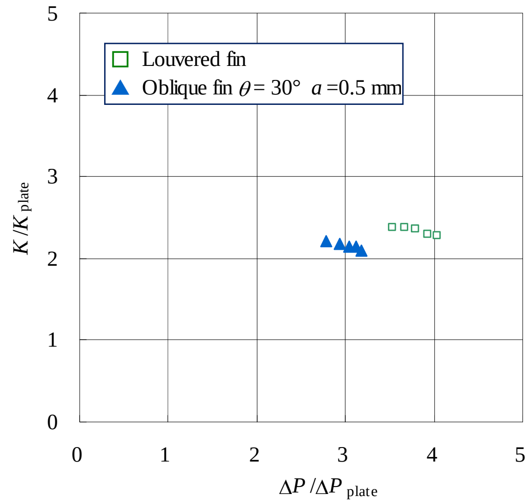

Fig. 5 Heat transfer and ΔP increase compared to the plate fin.

3. RESULTS

Figure 3 shows the comparison of measured overall heat transfer coefficients of oblique wavy fin (wave angle θ=30°, wave amplitude a = 0.5 mm), louvered fin and plate fin heat exchangers. The overall heat transfer coefficient of oblique wavy fin shows approximately 10% smaller value than that of the louvered fin. However, it still shows more than twice larger value than the plate fin heat exchanger. Figure 4 shows the comparison of airside pressure drop of the three fins. The air side pressure drop of oblique wavy fin is nearly three times larger than that of the plate fin. However, it is nearly 20% smaller than that of louvered fin. Figure 5 shows the heat transfer and pressure drop increase of oblique wavy and louvered fins compared to the plate fin. As can be seen from the figure, oblique wavy fin shows much more favorable *j/f* characteristics than the louvered fin.

CONCLUSION

Prototype samples of oblique wavy fins are fabricated and their heat transfer and pressured drop characteristics are measured by the hot water experiment. Measured overall heat transfer coefficient of oblique wavy fin (wave angle θ=30°, wave amplitude a = 0.5 mm) was more than twice larger than that of the plate fin heat exchanger. On the other hand, the air side pressure drop of oblique wavy fin was nearly three times larger than that of the plate fin. However, oblique wavy fin showed much more favorable *j/f* characteristics than the louvered fin. It is thus expected that oblique wavy fin has a potential for a new heat transfer enhancement device for applications in which louvered fins are not preferable.

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