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Numerical Investigation of Compact Heat Exchanger With Multi-louvered Plate Fin, Dimpled, Vortex Generator with Ceramic coating

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Abstract— **This Project presents the air side performance of fin and tube heat exchangers for multi-louvered plate fin with ceramic coating. This project focuses on heat and fluid flow analysis by various fin pitches and angle patterns. A steady –state three-dimensional numerical model is used to study the heat transfer and pressure drop characteristics of a multi-louvered plate fin heat exchanger with Reynolds number in the range of 1000-1600. A numerical study is performed on compact fin and tube heat exchanger having circular tube with plate fin dimple, vortex generator. The performance of heat exchanger in the air side with coating and without coating of the fin will be analyzed for various pitches such as 2, 2.5, 3, 3.5 mm and 4mm. By varying fin pitches, the overall heat transfer rate will increase in the system. In heat exchanger device the heat transfer analysis will be done by increasing number of tubes, rows, passes, and pitches.**

Index Terms— **Fin Pitch, Pressure drop, Heat Exchanger, Fin Thickness, Ceramic coating**

I. INTRODUCTION

The normal function of a multi-louvered plate fin and tube heat exchanger is to transfer heat from one fluid to another. The basic component of a multi-louvered plate fin-and-tube heat exchanger can be viewed as a tube with one fluid running through it and another fluid flowing by on the outside. There are thus two modes of heat transfer that need to be described: convective heat transfer from fluid to the inner wall of the tube, conductive heat transfer through the tube wall, and convective heat transfer from the outer tube wall to the outside fluid. multi louvered plate fin-and-tube heat exchangers are typically classified according to fin configurations and tube arrangements, as shown in Pongsoi et al . Generally for this kind of the multi-louvered plate fin-and-tube heat exchanger, the dominant thermal resistance is on the air-side. Decreasing air side thermal resistance can be done by increasing air speed, air turbulence, and heat transfer area. Moreover, a more efficient and compact heat exchanger of the multi-louvered plate fin-and-tube heat exchanger can be done via enhanced fin geometry. There have been many researches related to the experimental study of the multi louvered plate -finned tube heat exchangers. On the other hand, the only paper to describe the dimpled, Vortex generator with ceramic coating characteristics of the multi-louvered plate finned tube banks arrangement 1st report by K. Kawaguchi. They presented the influence of fin pitch on the heat transfer performance and friction characteristic for fin-and-tube heat exchangers by varying the fin pitches of 2,3,3.5 and 4 mm. It was confirmed that the fin pitch increases with decreasing heat transfer coefficients and pressure drops at the Reynolds number range 1000-1600. The experimental results given by Parinya Kiatpachai, the maximum heat transfer at a fin pitches of 2-3.5mm.

Over the years, most of the studies have focused on the flow characteristics of air flowing through the plate fins while the heat transfer performance has received comparatively little attention. Very few studies with heat transfer performance are available. However, although some information is currently available, there still remains room for further research. Up to now, there has been only one work, carried out by Parinya Kiatpachai , dealing with the effects of the fin pitch. However, their study focused only on multi-louvered plate fins dimpled, vortex generator at two different fin pitches. In real application, multi-louvered plate fins can be perforated with tubes. With this configuration, multi-louvered plate fins can reduce the thermal resistance between bases of fins with tube surfaces. In the present study, the effect of fin pitch of a plate fin-and-tube heat exchanger at high Reynolds number on heat transfer performance, which has never before appeared in open literature, is presented. Both frontal velocity and fin pitches used in the present study cover the range of real applications and real manufacturing.

II. DATA REDUCTION

In this study, the multi-louvered plate fin, dimpled, vortex generator with ceramic coating and-tube heat exchangers having Z shape tube arrangements and 2 tube rows are investigated by using experimental method to measuring the inlet and outlet water temperature using thermometer, flow rate, including the water flow loop, air flow supply, water suction pump and data acquisition system. The detailed geometrical parameters of the test section are shown according to table 1.The test samples are made from copper tube and Aluminum plate fin. The working fluids are ambient air and hot water for air-side and water side, respectively. The experimental conditions are shown in the table 2 and temperature and water flow rates are fixed while varying ambient air flow rate in range of 1000-1600 from Parinya kiatpachi

The present study's multi-louvered plate fin-and-tube heat exchanger is a type of finned tube heat exchanger. The dimensions of multi-louvered plate fin and tube heat exchanger shown in fig.1 and water flow arrangements shown in fig.2. The tests are performed under steady state conditions. And overall resistance can be obtained from the UA product of transfer units (ε-NTU). Yet total resistance is a sum of individual resistance as follows.

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Table 1
Detailed geometric parameters of the test samples

Fin type	d_i (mm)	d_o (mm)	d_f (mm)	p_L (mm)	p_T (mm)	f_t (mm)	n_t (mm)	N_{row} (mm)	W_s (mm)	h_s (mm)	f_p (mm)
Plate in	8	9.52	30	40	38	0.5	7	2	1	3	2.5,3 and 4

Remarks: d_f= outside diameter of fin; d_i = Tube inside diameter; d_o = Tube outside diameter; p_L = longitudinal p_T = Transverse tube pitch;
f_t = Fin thickness; n_t = no of tubes in row; N_{row} = number of tube row; W_s = segment width; h_s = segment hight f_p = Fin pitch

Table 2
Experimental conditions

Inlet air dry bulb temperature, ºC	=	31ºC
Inlet air frontal velocity, m/s	=	2-4
Inlet water temperature, ºC	=	46-50
Water flow rate, LPM	=	12-14

Fig.1.Multi-louvered plate fin dimpled, vortex generator

III. METHODOLOGY

The heat transfer and pressure drop characteristics are studied in the multi-louvered plate fin dimpled, vortex generator heat with and without ceramic coating. In the type of plate fin heat exchanger having two different cases viz. dimpled, vortex generator and without coating and with coating will be subjected to analysis.

The analysis will performed in three different patterns.

1. Multi-louvered plate fin heat exchanger without dimpled, vortex generator of fins.
2. Multi-louvered plate fin heat exchanger without dimpled, vortex generator of fins and with ceramic coating.
3. Multi-louvered plate fin heat exchanger with dimpled, vortex generator of fins and with ceramic coating.

3.1. Ceramic Coating

The multi-louvered plate fin and tube heat exchanger without ceramic coating in the previous experiments the condensate water may adhere as droplets on the fin surfaces without ceramic coating, and this phenomenon will cause bridging between the fins and increasing air pressure drop and the condensate water may corrode the aluminum fins and produce corrosion problems. So solving this problem the ceramic coating applied to the fin surface due to this increase the condensate water drainage and decrease pressure drop. The air side performance is different between multi-louvered plate fin and tube with coating and without coating.

3.2.Multi-louvered plate fins, dimpled

Dimples are used on the surface of internal flow passage because they produce substantial heat transfer augmentation. Heat transfer enhancement over surface results from the depression forming recesses rather than projections. Generically, such features are known as dimples, and may be formed in an infinite variation of geometries which results in various heats transfer and friction characteristics.

Fig 2 fabricated dimpled surface fin

3.3.Vortex generato

Vortex generator is a kind of passive heat transfer enhancing device which are attached to the duct walls or fin surfaces and protrude into the flow at an angle of attack to the flow direction. The basic principle of vortex generators (VGs) is to induce secondary flow, particularly longitudinal vortices, which disturb or cut off the thermal boundary layer developed along the wall and remove the heat from the wall to the core of the flow by means of large-scale turbulence.

IV. NUMERICAL CALCULATION

$$\frac{1}{UA} = \frac{1}{h_i A_i} + \frac{\ln\left(\frac{d_o}{d_i}\right)}{2\pi k_t L} + \frac{1}{\mu_o h_o A_o} \qquad (4.1)$$

The ε-NTU relations for multipass parallel cross-flow and multipass counter cross-flow configuration are available from (17-19),as shown in equations (2) and (3);

For multipass counter cross-flow with N_{row} = 2;

$$\varepsilon_c = 1 - \left(\frac{K}{2} + \left(1 - \frac{K}{2}\right) e^{2k/C_A}\right)^{-1}, K = 1 - e^{-NTU_A\left(C_A/2\right)}$$

For multipass parallel cross-flow with N_{row} = 2; (4.2)

$$\varepsilon_p = \left(1 - \frac{K}{2}\right)\left(1 - e^{-2k/C_A}\right), K = 1 - e^{-NTU_A\left(C_A/2\right)} \qquad (4.3)$$

Where C* = Cmin/Cmax is equal to Cc/Ch or Ch/Cc depending on the value of hot and cold fluid heat capacity rates. However, the multipass parallel and counter cross-flow used in this experiment is a combination of parallel cross-flow and counter cross-flow. Hence it may be reasonable to use the average value of the relationships shown in Eq. (4)as follows:

$\varepsilon_{pc} = \frac{\varepsilon_p+\varepsilon_c}{2}$For $N_{row} = 2$ (4.4)

The schematic diagram of circuitry arrangement (parallel, counter, cross) for Nrow = 2. Further details about the data reduction can be seen from Pongsoi et al. The efficiency of a radial fin with rectangular profile is based on the derivation of Gardner [20], i.e.,

$$\mu_f = \frac{2\Psi}{\phi(1+\Psi)}\frac{I_1(\phi R_o)K_1(\phi R_o)-I_1(\phi R_o)K_1(\phi R_o)}{I_o(\phi R_o)K_1(\phi R_o)+I_1(\phi R_o)K_o(\phi R_o)} \quad (4.5)$$

Where

$$\phi = (r_o - r_i)^{3/2}\left(\frac{2h_o}{k_f A_p}\right)^{1/2} \quad (4.6)$$

Accordingly, the air-side heat transfer coefficient (ho) can then be calculated from Eq. (1). The air-side heat transfer characteristics

of the heat exchanger are often in terms of dimensionless Colburn j factor:

$$j = \frac{Nu}{Re_{do}pr^{1/3}} = \frac{}{\rho_a V_{max} c_p}(pr)^{2/3} \quad (4.7)$$

The frictional characteristics are termed with f-fanning friction factor, as depicted by Kays and London [21]:

$$f = \left(\frac{A_{min}}{A_o}\right)\left(\frac{\rho_m}{\rho_1}\right)\left(\frac{2\Delta p\rho_1}{G_c^2}\right) - (1+\sigma^2)\left(\frac{\rho_1}{\rho_2}-1\right)$$

Where

(4.8)

A_{min} = minimum free flow area

A_o = Total heat transfer area

G_c = Maximum flux based on the free flow area

The heat transfer rate $q_v = m_f c_p (t_{out}-t_{in})/v$ (4.9)

The Power input per unit volume $e_v = m_f \Delta p/\rho_m \eta v$(4.10)

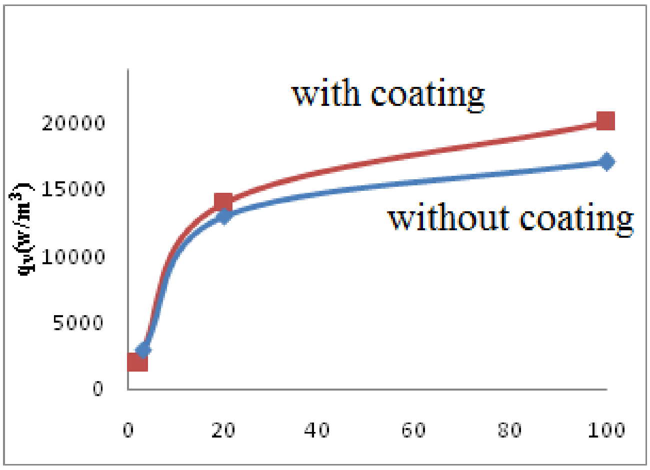
V. RESULTS AND DISCUSSION

The study focuses the effect of fin pitches (2, 2.5, and 4), multi-louvered plate of fins, dimpled, vortex generator of fins on air side performance of fins with ceramic coating perforated on 5 tube pass compact fin and tube heat exchanger, this type of heat exchangers used in wide applications like automobile radiator ,economizers, refrigeration's.

5.1Effect of multi-louvered plate fin

The performance plot for the three configurations investigated is depicted in Fig.3 for Reynolds numbers 1000, 1200 and 1600, respectively. It is clear that for the same heat transfer area, the case with multi-louvered plate fins delivers better performances than the case with full fins. The configuration with dimpled, vortex fins shows an about 9% better heat transfer rate for the same power input than the configuration with full fins having the same heat transfer area. For the same fin height, even though the model with full fins has a higher area than the reference model with coating fins, the performances of both configurations are close to each other. However, for a similar performance, the configuration with multi-louvered fins has the advantage of savings in material of 12.3% compared to the case with full fin.

The tube surface at the base of conventional plate fin is not covered by the fin, leading to tube corrosion and affect the heat transfer rate. So we need to find the alternate method, the multi-louvered plate dimpled, vortex fins have some distance from tube surface, this result no fouling in and increase heat transfer

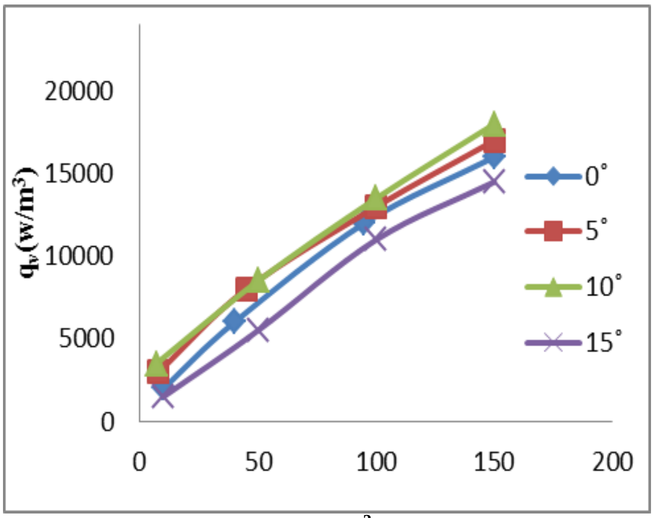


$E_v(w/m^3)$

Fig.3.Performance plot of cases with and without ceramic coating fin

5.2 Effect of dimpled, vortex generator fin

The effect of multi-louvered fin dimpled, vortex generator investigated for six different angles $\beta = 0°, 5°, 10°, 20°$.The multi-louvered plate fins on the dimpled surface fin increase the vortex generation due to this the natural convection heat transfer is increases. The angle of fins 5º-10º gives better heat transfer performance. The multi-louvered angles greater than 15˚result in a deterioration of the multi-louvered plate finned tube performance. Fig.4. shows the performance of configurations with different angles.



$E_v (w/m^3)$

Fig.4. Performance of configurations different angles

5.3 Effect of fin pitch

The experimental was carried out different fin pitches of 2, 2.5, 3, 3.5,4 from that fin pitches of 2.5,3 gives higher heat transfer rate and fin pitches affect heat transfer rate if fin pitch increases to increase pressure drop. The reduction of fin pitch increase heat transfer if fin pitch reduced more the is restricted to reduce the heat transfer rate. From the author Parinya Pongsoi, Somchai Wong wises gives the optimum fin pitches for better heat transfer rate (2.5, 3, and 3.5).

VI. CONCLUSIONS

The numerical investigation was carried out in this study show the advantage of multi-louvered plate fins in dimpled, vortex generator improving the performance of finned tubes or compact fin and tube heat exchanger. This is mainly due to the fact that the interruption of fins in these devices improves the re-build of the boundary layer close to heat transfer surfaces and increases the level of fluid mixing in the flow domain. The fin Pitches 2.5 to 3.5 gives better performance and also dimpled, vortex generator fins between the angle 5º-10º gives more heat transfer rate

The results obtained show that for the same heat transfer area, the multi-louvered plate fin tubes have better performances than the full fins. The ceramic coating gives better performance in under wet conditions, there no corrosion on the finned tube when used for number of days in practical Application. It is useful for manufacturing industries and power plants to increase performance in future days.

REFERENCES

[1]. A numerical study on the air-side heat transfer of perforated finned-tube heat exchangers with large fin pitches by Xiaoqin Liu, Jianlin Yu , Gang Yan(International Journal of Heat and Mass Transfer2016)

[2]. Numerical study of heat-transfer enhancement by punched winglet-type vortex generator arrays in fin-and-tube heat exchangers by Y.L. He a, H. Han [a*], W.Q. Tao [a], Y.W. Zhang [ab] (International Journal of Heat and Mass Transfer 2012)

[3]. Numerical investigation of fluid flow and heat transfer over louvered fins in compact heat exchanger by V.P.Malapure, Sushanta K. Mitra,A. Bhattacharya (International Journal of Thermal Sciences 2015)

[4]. Optimization of the angle of attack of delta-winglet vortex generators in a plate-fin-and-tube heat exchanger by A. Lemouedda [ab], M. Breuer [c], E. Franz [a*],T. Botsch [a], A. Delgado [b] (International Journal of Heat and Mass Transfer 2010)

[5]. Experimental and numerical investigation of the heat transfer augmentation and pressure drop in simple, dimpled and perforated dimpled louver fin banks with an in-line or staggered arrangement by Farhad Sangtarash [*], Hossein Shokuhmand (International *Applied Thermal Engineering* 2015)

[6]. Numerical study of fluid flow and heat transfer in a flat-plate channel with longitudinal vortex generators by applying field synergy principle analysis by Li-Ting Tian, Ya-Ling He[*], Yong-Gang Lei, Wen-Quan Tao (International Communications in Heat and Mass Transfer 2008)

[7]. Heat and mass transfer for plate fin-and-tube heat exchangers, with and without hydrophilic coating by Chi-Chuan Wang [a,*]: Chang-Tsair Chang [b] (International Journal of Heat and MassTransfer 2008)

[8]. An experimental study of the air-side performance of fin-and-tube heat exchangers having plain, louver, and semi-dimple vortex generator configuration by Chi-Chuan Wang [a*] , Kuan-Yu Chen [a], Jane-Sunn Liaw [b] Chih-Yung Tseng [b] (International Journal of Heat and Mass Transfer 2014)

[9]. Application Research on the Closed-Loop Heat-source-Tower Heat Pump Air Conditioning System in Hot-summer and Cold-winter Zone by Jianlin Chenga, Shenhua Zoua, and Shiqiang Chena (International journal on energy engineering, 2015)

[10]. An experimental study on performance during reverse cycle defrosting of an air source heat pump with a horizontal three circuit outdoor coilgions. By Song Mengjiea, Xu Xiangguob, Deng Shiminga, Mao Ning International journal on energy engineering, 2014)

[11]. A Numerical Investigation of Compact Spiral Fin Heat Exchanger for Circular Tubes with Hydrophilic Coating by P.Rajkumar[1] M. Ganesh karthikeyan[2] Dr.M.Prabhakar[3] S.Senthil Kumar[4] (*IJSRD - International Journal for Scientific Research & Development 2016)*