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Experimental Study of Heat Transfer Characteristics of Condensed Flow on The Vertical Wave Plates

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Abstract. Studies on the heat transfer characteristics of vertical wave plate subjected to the condensed steam had been done. This research was done to know temperature distribution profiles and heat transfer coefficient on wave plates in vertical position. Temperature profiles were obtained by measuring directly the temperature of test section. On the other hand, determination of heat transfer coefficient was done by using Von Karman's equation that based on temperature profile. The results show that temperature distribution profile is: $\frac{T-T_s}{T_\infty-T_s}=2.23\left(\frac{y}{\delta_{th}}\right)-1.32\left(\frac{y}{\delta_{th}}\right)^2$ and average heat transfer coefficient and average Nusselt number are respectively, $\bar{h}_L=0.888\left(\frac{k}{L}\right)Re_L^{1/2}Pr^{1/3}$;and $Nu_L=0.888Re_L^{1/2}Pr^{1/3}$.

Introduction

Heat transfer rate of condensation depends on the film thickness of condensate and on the rate of condensation. Condensate that forms will cause thermal resistance on the surface of the plate. The thicker the film, greater the thermal resistance that occurs between the vapor and cooling surface which also lead to the smaller its condensation heat transfer coefficient. On the other hand, the rate of condensation will influence the amount of the latent heat of condensation that transferred through the film to the plate surface.

Condensate that occurs in the process of condensation can form in layers (filmwise) or dew points (dropwise) shape. Both types of condensate have been observed by several researchers, among them are Eckert [1] and Nusselt [2,3]. They observe how the condensation that occurs on the surface of a flat plate in a vertical position and tilt as well as the tube bundles compacted . Condensation in the form of granules was first studied by Schmidt [4] on a flat-plate positioned vertically, and then was followed by fatica and Katz [4], Welch and Westwater [4], Jian-Jun SHU [5] with various model promoters.

So far, studies on the condensation of steam on a wavy surface have been carried out only the tube bundle shape. It was conducted by Gregorig (1953) [2] which was followed later by Lusterader et al [2], Nabavian [2] on the horizontal tube bundle of the condenser, Thomas [2] on the vertical tube bundle of the preheater and evaporator, and Markowitz et al [2] on electronic cooling equipment.

Application of steam condensation on the surface of the wavy plate can be found on the cooling towers. Some researcher of heat transfer on wavy plates in natural convection have been done, among others by Yao [6], Chiu and Chou [6]. They observed by experimental a convection heat transfer while research by J.Huan Jang and W.Mon Yan [6] is limited to the numerical study. However, research on the wavy plate surface has not been clearly span the 'hierarchy, especially in the calculation of the value of transfer coefficient that has great influence to the process of condensation.

Because of the lack of information on the temperature profiles and heat transfer coefficient, especially the condensed heat transfer on wavy plate, so this research has been undertaken to enrich the information about heat transfer in a vertical wavy plate.

Experimental Method and Formulation

Objects in this study is steam from a boiler that flows toward the test section (experimental setup is shown in Figure 1). In the test section, the steam flowed to the surface of the test plate, wherein the other side of the test plate surface in direct contact with cooling water (water + ice). As a result of the cooling process, steam in contact with the surface of the test plate experiencing condensation.

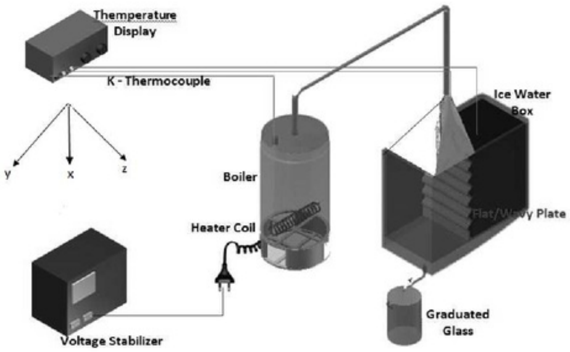

Fig.1 Experimental set up

Test plate used is made of steel with a wavy surface with an amplitude of 5 mm. The length of the test plate 220 mm (x-axis) with a width of 100 mm (z-axis). Temperature measurement starts from the surface of the plate up to 50 mm in the direction of the y axis. The results of temperature measurements are displayed in form of the dimension and non-dimension temperature.

Based on the temperature equation and assuming that the velocity profile is identical to the temperature profile as well as using the energy equation of von Karman **[7]** the following:

$$\frac{d}{dx}\left[\int_0^{\delta_{th}} u(T_\infty - T)dy\right] = \frac{k}{\rho.C_p}.\frac{dT}{dy}\bigg|_{y=0} \qquad (1)$$

will be obtained the condensation heat transfer coefficient that occurs.

For the case of a flat plate, Djafar and Piarah **[8]** in their paper have obtained the dimensionless temperature distribution, namely

$$\frac{T-T_s}{T_\infty-T_s} = 1.94\left(\frac{y}{\delta_{th}}\right) - 1.04\left(\frac{y}{\delta_{th}}\right)^2 \qquad (2)$$

Where Ts ≡ surface temperature, T∞ ≡ steam temperature in far position from the surface, δth ≡ thick of thermal boundary layer.

Assuming the temperature distribution profile identical to the profile of the velocity distribution, the velocity distribution can be written as:

$$\frac{u}{u_\infty} = 1.94\left(\frac{y}{\delta}\right) - 1.04\left(\frac{y}{\delta}\right)^2 \qquad (3)$$

Whereδ ≡hydrodynamicboundary layer.

By substituting equation (2) and (3) above to the Von Karman Energy Equation (1), is obtained:

$$\frac{\delta_{th}}{\delta} = 0.838P_r^{-1/3} \qquad (4)$$

On the surface, conduction of heat is equal to convection of heat

$$\frac{q}{A} = \dot{-}k\frac{dT}{dy} = h_c(T_s - T_\infty) \quad (5)$$

By substituting integration of equation (2) into the equation (5), obtained an average convection coefficient

$$\bar{h}_L = 0.846\left(\frac{k}{L}\right)Re_L^{1/2}Pr^{1/3} \quad (6)$$

Andobtained the averag Nusselt number

$$\overline{Nu_L} = 0.846Re_L^{1/2}Pr^{1/3} \quad (7)$$

Result and Discussion

Testing parameters that serves as the focus of observation are the dimension temperature profile (T), non-dimension temperature profiles $\frac{T-T_s}{T_\infty-T_s}$, the condensation heat transfer coefficient (hx) and the average Nusselt number (Nu).

The Experiments Temperature Profile of Vertical Wavy Plates. The temperature profiles of steam condensed can be seen in Figure 2. Temperatures at x = 0 is temperature of plate surface. The others temperature are steam temperature on the spesific distance from the plate surface. In the picture, it can be seen that the 4 existing chart shows the same phenomenon of the temperature distribution, which the minimum temperature occurs on the surface of the plate and then will increase with increasing distance position (y) from the surface of the plate. Starting at the certain position from the plate surface, the temperature will be constant. Significant temperature rise can be seen at the chart for distance of x = 10 and 30mm from the end plate. For the graph x = 50 and 70mm increase in temperature that occurs relatively small. This suggests that the rate of heat transfer at the plate surface will be smaller with increasing the distance from the end plate.

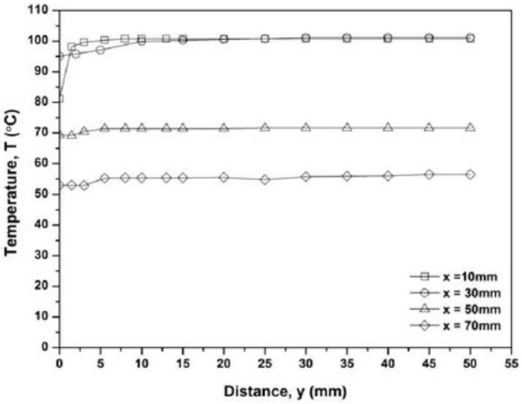

Fig.2 Temperature profile T (ºC) to the distance y (mm) for some value x the Vertical Wave Plates

Results of temperature measurement in another x position are shown in Figure 3.Seen in the picture, the graph for the position x = 80 mm to x = 220.

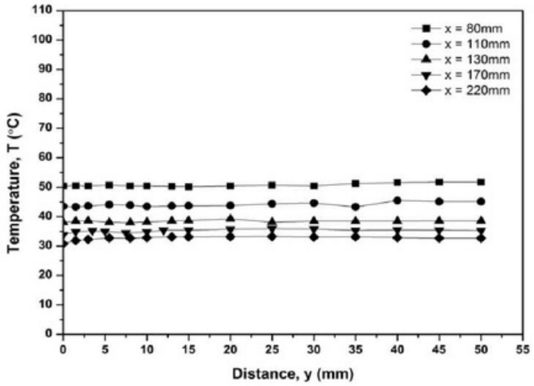

Fig.3 Temperature profile T (ºC) to the distance y (mm) for x = 80mm until x = 220mm in the Vertical Wave Plates

To obtain a standard temperature profile is usually made in the form of dimensionless results as shown in Figure 4 below.

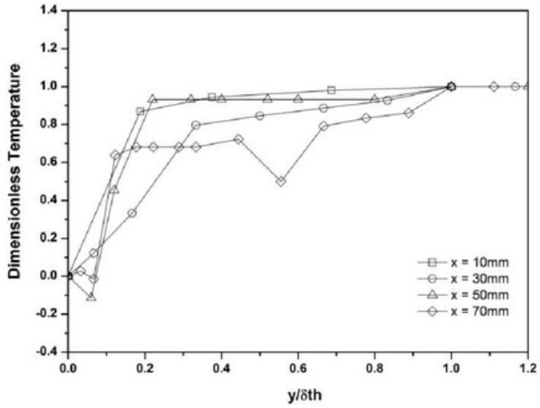

Fig.4 Dimensionless temperature profile for several distance from the plate tip

Figure 4 shows that the pattern of distribution (phenomenon) is identical to the existing pattern in Figure 2, however with strong tendency. The minimum temperature occurs on the surface of the plate and then will increase when it is farther away from the surface of the plate and start at a certain distance from the surface of the plate, the temperature will be constant. Distance where the temperature is constant at about $^{y}/_{\delta_{th}} = 1$. Furthermore it is also seen that the temperature fluctuation began to occur at a distance of x = 50 mm where the farther from the plate tip, the greater the fluctuation that occur.

Temperature fluctuations are more evident for a distance of x = 80 mm to x = 220 mm that can be seen in Figure 5 below. Because in many cases the temperature profile is identical to the velocity profile thus it can be said that in the boundary layer, the turbulence will be larger when a distance more farther from the plate tip.

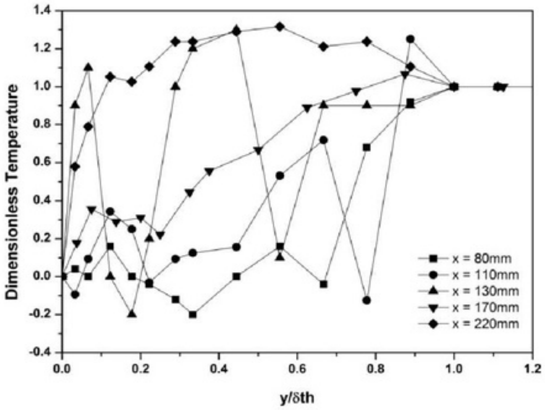

Fig.5 Dimensionless temperature profile for the distance of x=80mm to x=220mm

By using statistical methods (regression)an equation of temperature distribution is obtained as follow:

$$\frac{T-T_s}{T_\infty-T_s}=2.23\left(\frac{y}{\delta_{th}}\right)-1.32\left(\frac{y}{\delta_{th}}\right)^2$$

Heat Transfer Coefficient and Nusselt Numbers on the Vertical Wave plates. With the procedures as described in the methodology, the equation of the average convection coefficient and the Nusselt number for wavy plate are obtained as follows:

$\bar{h}_L = 0.888\left(\frac{k}{L}\right)Re_L^{1/2}Pr^{1/3}$ and $Nu_L = 0.888Re_L^{1/2}Pr^{1/3}$.

The results obtained for the wave plate are different about 5% compare with for a flat plate.

Summary

Observations of the heat transfer characteristics of the vapour that experience condensation can be summarised as follows:

1. Temperature fluctuation will occur starting at a certain distance from the plate tip (in this case starting at 30 mm) and getting away from the plate tip the resulting fluctuation will be even greater.
2. Experimental results of the temperature distribution profile for the wave plate is

$$\frac{T-T_s}{T_\infty-T_s}=2.23\left(\frac{y}{\delta_{th}}\right)-1.32\left(\frac{y}{\delta_{th}}\right)^2$$

3. The relationship between the condensation heat transfer coefficient with Reynolds number and Prandtlnumber are:

$$\bar{h}_L = 0.888\left(\frac{k}{L}\right)Re_L^{1/2}Pr^{1/3}$$

And the relationship between the average Nussel number with Reynolds number and Prandtlnumber is:

$$Nu_L = 0.888Re_L^{1/2}Pr^{1/3}$$

References

[1]. Frank Kreith, Arkoprijono M.Sc,. Perpindahan Panas. Penerbit Erlangga. Jakarta. 1994.

[2]. Burmeister, Louis C. Convective Heat Transfer, First Edition. John Wiley & Sons,inc., Toronto. 1983.

[3]. William H.,Mc. Adams,. Heat Transmission, Third Edition, McGrawHill Book Company Kogashuka Co.,LTD, Tokyo. 1954.

[4]. Westwater, J.W.Dropwise Condensation. Lectures on Advanced Heat Transfer. University of Illinois Press, Chicago. 1969.

[5]. Jian-Jun SHU. Condensation on a Vertical Flat Plate. Proceedings of the International Conference on Fluid and Thermal Energy Conversion 2006. Jakarta. Indonesia. December 10 – 14, 2006. ISSN 0854 – 9346.

[6]. Jang,J.H., et al.Natural Convection Heat and Mass Transfer along a Vertical Wavy Surface. Int. Journal of Heat and Mass Transfer Vol.46. 2003: p.1075-1083.

[7]. Christie J. Geankoplis.Transport Processes and Unit Operations. Third Edition Prentice-Hall International, Inc. Englewood Cliffs, New Jersey.1993.

[8]. Zuryati Djafar,.Wahyu H. Piarah. Studi Karakteristik Perpindahan Kalor Aliran Terkondensasi pada Pelat Rata Vertikal. Prosiding Seminar Nasional Mesin dan Industri (SNMI4). Fakultas Teknik Universitas Tarumanagara. Jakarta. Indonesia.2008. ISBN 978-979-95752-8-9.

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