11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

A NEW CORRELATION OF THE HEAT TRANSFER COEFFICIENT ON TWO - PHASE FLOW IN VERTICAL TUBES

Kemal Altinişik*, Kemal Aldaş, Muhittin Tekin*, Şenay Yalçin*****
*** Selcuk University, Engineering Faculty, Konya , Turkey**
**** Nigde University, Aksaray Engineering Faculty, Aksaray, Turkey**
***** Bahcesehir University, Engineering Faculty, Istanbul , Turkey**

ABSTRACT
Heat transfer is very important concept for engineers projects, main factoring and industry processes. In order to reach the high heat transfer coefficints, it is necessery to change the phase of fluid. The main problem in two-phase flow is to investigate the heat transfer coefficient.
In this study, a new correlation for two-phase flow in a vertical tube, where water flows upward, has been developed. The correlation being developed by using the least-squares metots has been compared with the correlations of Kandlikar, Gungor and Chen. It can be stated that the correlation proposed for x<0.44 is in accordance with the correlations compared excep Gungor. The mean deviation is 13.4 % for G= 30 - 100 kg/m^2 s and q=29256 - 131655 W/m^2 .
Keywords: Two - Phase flow, Vertical tubes, Correlation, Heat transfer coefficient

1. INTRODUCTION
It is pretty difficult to predict the heat transfer coefficient in two-phase flow properly. Just as, analitical and experimental studies being done in this field put forth the importance of two-phase flow. A good correlation of heat transfer coefficient in two-phase affects dimensions, the cost and design of all equipment used in industry. The target of this study is to develop a new correlation at the heat transfer coefficient in two-phase flow and to compare with same well know correlation.

2. CORRELATION DEVELOPMENT
In order to calculate the pressure drops in two-phase flow for the system. It is necessary to write the equations of the energy and the momentum and while writting those equations, the same acceptance should be considered. For the calculation of the pressure drop, there are three models which are the separated flow model, the homogeneos model and the Lockart-Martinelli model has used. The pressure drop event in two-phase flow is divided into three components which are the friction, the momentum and the gravity pressure drop. Those components can be written as [16,17].

$$D_p = D_{pf} + D_{pm} + D_{pg} \tag{1}$$

Four basic gradiants are important in two-phase flow and those can be given as follows,

D_{PLo} : All mixture is flowing the fluid

$$D_{PLo} = \frac{\lambda_{Lo} G^2 \vartheta_L}{2D} \tag{2}$$

D_{PL} : The liquid component is only flowing

$$D_{PL} = \frac{\lambda_L (1-x)^2 G^2 \vartheta_L}{2D} \tag{3}$$

D_{Pgo} : All mixture is flowing as gas

$$D_{Pgo} = \frac{\lambda_{go} G^2 \vartheta_s}{2D} \tag{4}$$

D_{Pg} : The gas component is only flowing

$$D_{PL} = \frac{\lambda_g x^2 G^2 \vartheta s}{2D} \tag{5}$$

Reynolds numbers, which are in accordance with values given above can be specified as,

$$\mathrm{Re}_{Lo} = \frac{GD}{\mu_L} \quad , \quad \mathrm{Re}_L = \frac{GD(1-x)}{\mu_L} \tag{6}$$

$$\mathrm{Re}_{go} = \frac{GD}{\mu_g} \quad , \quad \mathrm{Re} = \frac{xGD}{\mu_g} \tag{7}$$

The friction coefficients together with Blasius equations are,

$$\lambda_{Lo} = \frac{C}{\mathrm{Re}_{Lo}{}^n} \quad , \quad \lambda_L = \frac{C}{\mathrm{Re}_L{}^n} \tag{8}$$

$$\lambda_{go} = \frac{C}{\mathrm{Re}_{go}{}^n} \quad , \quad \lambda_g = \frac{C}{\mathrm{Re}_g{}^n} \tag{9}$$

By means of expressions given above, Lochart-Martinelli parameter can be stated as square root of ratio of the liquid friction pressure drop to the gas friction pressure drop. That is to say,

$$x = \left(\frac{D_{pL}}{D_{pg}}\right)^{0,5} \tag{10}$$

When the values given in equation (10) are substitute the following equation can be written,

$$x = \frac{\lambda_L}{\lambda_g} \frac{(1-x)^2}{x^2} \frac{\vartheta_L}{\vartheta_g} \tag{11}$$

If the friction coefficients are replaced in equation (l 1), Lockhart- Martinelli parameter can be obtained for the circler tubes in two-phase flow,

$$x = \left(\frac{1-x}{x}\right)^{\frac{2-n}{2}} \left(\frac{\vartheta_L}{\vartheta_g}\right)^{\frac{1}{2}} \left(\frac{\mu_L}{\mu_g}\right)^{\frac{n}{2}} \tag{12}$$

In order to develop the correlation 120 experiments have been realized. The value of 15 points for each experiment have been measured and all value have been loaded into the computer. Temperatures have been read at 13 point on the tube surface. By means of temperatures, inside temperature of the tube, mean temperature of the fluid, quality, density, enthalpy, local heat transfer coefficient, specific heat, Prandtl and Reynolds numbers, dynamic viscosity, speed and conductivity of the fluid for a certain mass flow rate, have been calculated and givin in tables. The following correlation by utilizing the experimental data has been secured.

$$h_{Tp} = 0,08456\left[\left(\frac{x}{1-x}\right)^{0,43398}\left(\frac{\rho_L}{\rho_g}\right)^{0,2209}\left(\frac{\mu_g}{\mu_L}\right)^{0,0542}\right]\mathrm{Re}^{0,8}\,\mathrm{Pr}^{0,4}\left(\frac{k_L}{D}\right) \tag{13}$$

In order to obtain the correlation the least-squares methods have been used. The correlation has been compared with the correlations of Kandlikar, Gungor and Chen.

3. EXPERIMENTAL STUDY

The experimental rig has been given in Figure 1. and the sub elements of the system are shown on it. The test tube made of copper has 85 cm length and its inside and outside diameters are 11.3 cm and 12.8 cm respectively. In order to measure the surface temperature, PT-100 thermo-elements have been stuck on the tube surface with intervals 8 cm, Rock wool has been inserted around of the tube. In order to heat up the test tube, 4 resistances of which length are 40 m diameters are 0.8 mm and electrical resistivity 2.07 Q/m. In order to obstruct the heat loos in radial direction, out side of the tube has been coated with Glass-Wool and foam.

Before starting the experiments, water in the main tank is heated up to about 80 ^0C mass flow rate are retained at a certain value and the experiment is run. The power given into the resistance is changed with a interval of 500 Watt. For each experiment, the tube inside temperature, the mean fluid temperature, quality, density, enthalpy, local convection heat transfer coefficient, specific heat, Prandtl and Reynolds numbers, dynamic viscosity and fluid conductivity are calculated.

During the experiments, atmosphere temperature and surface temperature of the main test tube are measured and lost heat from the test tube is withdraw from the power given into the test tube and then net heat transferred in to the fluid is computed. These experiments are repeated by changing the mass flow rate.

4. RESULTS AND DISCUSSIONS

While doing the experiments, the power is holded constant and the mass flow rate is changed, then this is turned on the contrary. The enter temperature of main test tube is restrained at 80 ^{0}C in both stations. By means of data obtained the graph of the $h_{TP}/h_L - x$ has been drowen and the graph has been compared with the correlation of Kandlikar, Gungor and Chen (Figure 2,3,4,5).

The correlation for G= 40 kg/m^{2}s , q=131655 W/m^3 and x<0,35 is in accordance with the correlations of Kandlikar. For the values of x>0,35 there is a small deviation according to Chen's correlation. For the same values there are a definite deviation of Gungor's correlation according to the of Kandlikar and Chen. On the other hand, there is enough harmony between the Altınışık-Aldaş 's correlations and Kandlikar correlations. The value of h_{TP}/h_L increases in the correlations developed by Altınışık-Aldaş, Kandlikar, Gungor and Chen for the bigger values of x. The reason of this is that Gungor have used h_L the additional term, This situation affects the inclination of ($h_{TP} - x$) in the nucleate boiling region and the data of the mean heat transfer coefficient has been used in the correlation developed by Chen.

Boiling depending on convection in Kandlikar correlation does not affect the heat transfer in the nucleate boiling region. Due to convection, boiling decreases heat transfer for high heat flux will affect on the nucleate boiling. Heat transfer depending on the convection for low heat flux is considered. Figure 3. shows the change of $h_{TP}/h_l - x$ for G= 40 kg/m^{2}s, q= 43885 W/m^2 between correlation for x<0,12 Altınışık- Aldaş 's correlation is in accordance with Kandlikar and Chen. Gungor's correlation is not enough harmony between those correlation.

Figure 4. show that the correlation developed for G= 60 kg/m^{2}s, q= 87770 W/m^2 is in accordance with Kandlikar and Chen's correlations except Gungor's correlation. The correlation being given with equation (13) approximately follows the same progress with the correlations of Kandlikar for all data point. When examining the graphes obtained with theoritical way and the experimental data it show that the deviation for x<0,44 (Figure 6,7) are very close each other.

As a result it can be expressed that the correlation proposed is in accordance with Kandlikar's correlation. The mean deviation of results obtained for G=40-100 kg/m^2 s and q= 29252-131655 w/ m^2 is 13.47%. At the same time the deviation of the correlation can be compared with each correlation given here.

The mean deviation is 2.1% between experimental data and the correlation given by equation(13)(Figure 6). At the same time, Kandlikar, Gungor and Chen' correlations it has been seen that the deviations of Kandlikar, Gungor and Chen's correlation are 5.66%, 29.39%, 11.59%, with respect to the correlation given equation(13) respectively for G=40 kg/m^2 s and q=43885 w/ m^2.

5. REFERENCES

[1] Chen, J.C-,1966,"A Correlation for Boiling Heat Transfer to Saturated Fluids in Convective Flow", Industrial and Engineering Chemistry, Process Design and Development, Vol.5, No.3, pp.322-328.

[2] Anderson, S.W.,Rich,D.G., and Geary, D.F.,1966,"Evaporation of R22in a Horizontal ¾ in. OD Tube, "ASHRAE Transactions,Vol. 72,pp.28-41.

[3] Chaddock, IB., and Noerager, I A.,1966,"Evaporation of R-22 in Horizontal Tube With Constant Heat Flux,"ASHRAE Transaction, Vol. 72, Part I, pp.99-103.

[4] JalloukjP.A., 1974,"Two-Phase Flow Pressure Drop and Heat Transfer Characteristics of Refrigerants in Vertical Tubes",Ph.D.Dissertation, University of Tennessee, Knoxville,TN.

[5] Mohr, V., and Runge, R.,1977,"Forced Convection Boiling of Neon in Horizontal Tubes, "Heat Transfer in Boiling,E.Hahne, and U. grigull,eds., Hemisphere Publishing Corporation, New York.

[6] Shah, M. M.,1976,"A New Correlation for Heat Transfer During Boiling Flow Through Pipes," ASHRAE Transaction, Vol. 82, Part II, pp.66-86.

[7] Shah, M. M.,1982, "Chart Correlation for Saturated Boiling Heat Transfer Equations and Further Study, "ASHRAE Transaction, Vol. 88,Part I, pp,185-196.

[8] Bjorge, R. W., Hall, G. R., and Rohsenow, W. M., 1982,"Correlation of Forced Convection Boiling Heat Transfer Data," International Journal of Heat and Mass Transfer, Vol. 25, No. 6,pp.753-757.

[9] Colbum, A. P., 1933"Amethod of Correlating Forced Convection Heat Transfer Data and a Comparison With Fluid Friction, "Reprined in: International Journal of Heat and Mass Transfer, Vol. 7, 1964, pp.1359-1384.

[10] Bergles, A. E., and Rohsenow,W. M.,1964,"The Determination of Forced Convection Surface Boiling

Heat Transfer," ASME Journal of Heat Transfer, Vol. 86,pp.365-372.
[11] Mikic, B.B.,and Rohsenow, W. M., 1969,"ANew Correlation of Pool Boiling of Data Including the Effect of Heating Surface Characteristics," ASME Journal of Heat Transfer, Vol.91,p245.
[12] Kandlicar, S. G., and Thakur, B. K., 1982, "A New Correlation for Heat Transfer During Flow Boiling, "Proceedings, 16th Southeastern Seminer on Thermal Sciences, Miami,FL.
[13] Kandlikar, S. G.,1983,"An Improved Correlation for Predicting Two-Phase Flow Boiling Heat Transfer Coefficient in Horizontal and Vertical Tubes, "in: Heat Exchanges for Tow-Phase Flow Applications, ASME, New York.
[14] Gungor, K. E.,and Winterton, R. H S.,1986,"A General Correlation for Flow Boiling in Tubes and Annuli,"International Jornal of Heat and Mass Transfer, Vol. 29, No.3, pp.351-358.
[15] Gungor, K. E.,and Winterton, R. H. S.^ST/'Simplified General Correlation for Saturated Flow Boiling and Comparisons of Correlation With Data," The Canadian Journal of Chemical Engineering, Vol.65, No. 1, pp. 148-156.
[16] Lookhart, R. W., Martinelli, R. C. 1949,"Proposed Correlation of Data for Isotermal Two-Phase, Two Component Flow in Pipe," Chemical Eng. Prog., Vol. 45, p.39
[17] Collier, J.G.1981,"Convective Boiling and Condensation," 2nd. ed., McGraw-Hill,New York.

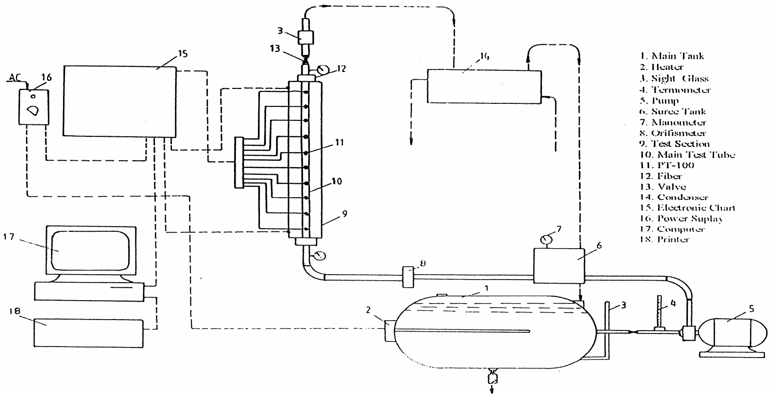

Figure 1. Experimental rig

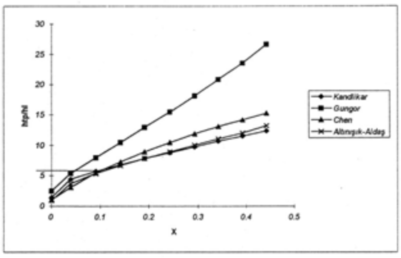

Figure 2. The comparasion of the correlation with Kandlikar, Gungor and Chen and the change of the htp/hl for G=40 kg/m²s, q=134655 w/m²

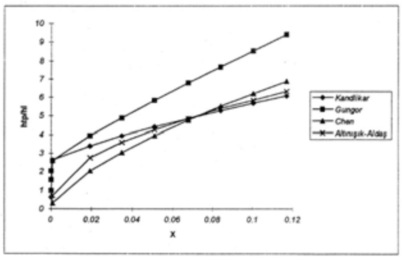

Figure 3. The comparasion of the correlation with Kandlikar, Gungor and Chen and the change of the htp/hl for G=40 kg/m²s, q=43855 w/m2

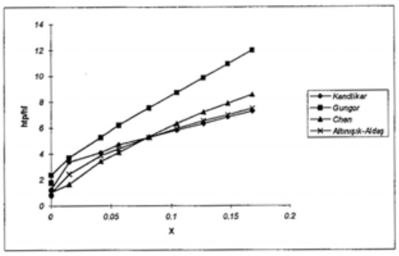

Figure 4. The comparasion of the correlation with and change of thehtp/hl-X for G=60 kg/m²s, q=87770 w/m²

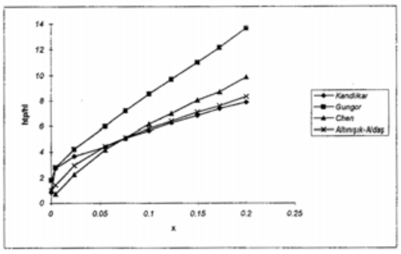

Figure 5. The comparasion of the correlation with and change of thehtp/hl-X for G=80 kg/m²s, q=131655 w/m²

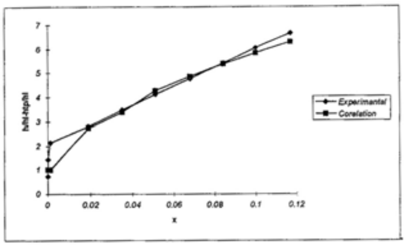

Figure 6. The comparasion of the correlation being given by equation (13) with experimental for G=40 kg/m²s, q=43855 w/m²

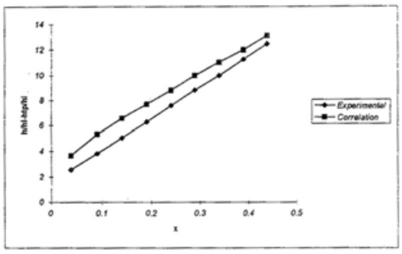

Figure 7. The comparasion of the correlation being given by equation (13) with experimental for G=40 kg/m²s, q=131655 w/m²