A Review on two phase flow boiling heat transfer in horizontal small diameter channel

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***Abstract*—Two phase flow boiling heat transfer is attractive over single phase because of high heat transfer coefficient and high heat removal capability for a given mass flow rate. In this Paper, The study presents the fundamentals of flow boiling heat transfer and different flow regimes along the channel length. Literatures from the various researchers are studied in order to know why this study is required and which methodology used in predicting heat transfer parameters. This study involves the basic fundamentals and literature review for predicting the flow boiling heat transfer coefficient in small diameter channel having 2.1 mm diameter.**

***Index Terms*—Flow boiling, Channel , heat transfer**

I. INTRODUCTION

Since past several years, many researchers, scientist and engineers found that flow boiling heat transfer has an extensively importance for defining heat transfer, pressure drop, mass flux and various flow boiling patterns, i.e. bubbly flow, slug flow ,churn flow, annular flow, experimentally or theoretically. In our day to day life we attached with boiling phenomenon and industries also proved that this boiling phenomenon covers lots of things by examine various viewpoint linked with flow boiling heat transfer.

Fluid flow inside channels is at the heart of many natural and man-made systems. Heat and mass transfer is accomplished across channel walls in heat exchanger, nuclear reactors and air separation units [4].

II. FLOW BOILING

Flow boiling is considerably more complicated than pool boiling, owing to the coupling between hydrodynamics and boiling heat transfer processes. A sequence of two-phase and boiling heat transfer regimes takes place along the heated channels during flow boiling.

Figure 1 displays schematically the boiling and heat transfer regimes in a uniformly heated horizontal pipe when the heat and mass fluxes are both moderate. The qualitative axial variations of the heat transfer coefficient are also shown in the Fig.1. Although the main flow and heat transfer regimes are similar to earlier, the effect of buoyancy can be important. Buoyancy tends to promote the stratification of the two phases.

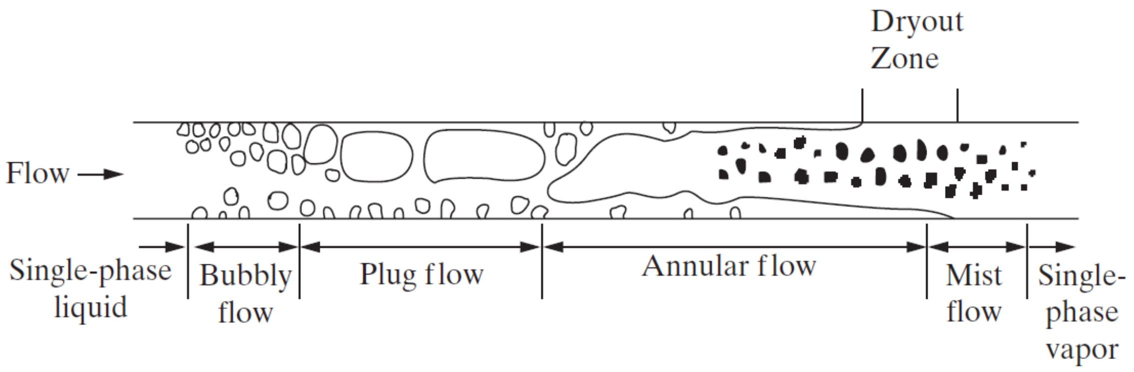

Figure 1 Flow and heat transfer regimes in a uniformly heated horizontal tube with moderate heat flux

This effect becomes particularly important when the annular dispersed flow regime is reached. The liquid film tends to drain downward, often leading to partial dry out, where the liquid film breaks down near the top of the heated channel, while persisting in the lower parts of the channel perimeter [4]. As a result of partial dry out, the critical heat flux conditions in horizontal channels are generally reached at lower vapor quality values than in vertical up flow channels. Flow regimes are extremely important. To get an appreciation for this, one can consider the flow regimes in single-phase flow, where laminar, transition, and turbulent are the main flow regimes. When the flow regime changes from laminar to turbulent, for example, it is as if the personality of the fluid completely changes as well, and the phenomena governing the transport processes in the fluid all change.

III. NEED FOR SMALL CHANNEL FOR FLOW BOILING

A channel serves to accomplish two objectives: (i) bring a fluid into intimate contact with the channel walls and (ii) bring fresh fluid to the walls and remove fluid away from the walls as the transport process is accomplished. The rate of the transport process depends on the surface area, which varies with the diameter D for a circular tube, whereas the flow rate depends on the cross-sectional area, which varies linearly with D^2. Thus, the tube surface area to volume ratio varies as 1/D. Clearly, as the diameter decreases, surface area to volume ratio increases [4]. Channel classification based on hydraulic diameter is intended to serve as a simple guide for conveying the dimensional range under consideration. The reason for using 2.1 mm diameter channel is that found between the threshold limit of the classification of channel.

IV. LITERATURE REVIEW FOR FLOW BOILING HEAT TRANSFER IN SMALL DIAMETER CHANNEL

Satish G. Kandlikar investigated the effect of flow and wall temperature on bubble growth which conclude that higher wall temperature with higher heat flux causes the bubble to grow rapidly and reach the departure condition much sooner [3]. This paper presents a review of literature on evaporation in small diameter passages along with some results obtained by the author for water evaporating in 1-mm hydraulic diameter multi-channel passages. Flow pattern is also observed by author for multi channel evaporator [3]. Design correlation is obtained for multi channel evaporator. Author also observed that in small diameter tubes the effect of evaporation could be quite dramatic.

Yu Xu have performed experiments on flow boiling heat transfer coefficient of R134a in three horizontal smooth copper tubes having circular cross section with inner diameters of 1.002, 2.168, and 4.065 mm [7]. A total of 397 experimental data points are obtained for a mass flux range of 185–935 kg/m^2s, heat flux range of 18.0–35.5 kW/m^2, a saturation pressure range of 0.578 - 0.82 MPa, and a vapour quality range of 0.03–1.0. Authors observed that the heat transfer coefficient of the 1.002 and 2.168 mm tubes was higher and tend to increase with vapor quality, while that of the 4.065 mm tube tended to decrease. The existing correlations of flow boiling heat transfer are compared with the present experimental data. The Fang correlation predicts best for all the 397 experimental data points and performs best in tracing the tendency of the heat transfer coefficient with vapor quality [7].

Sira Saisorn presented experimental investigation of flow boiling heat transfer of R-134a refrigerant in a circular mini-channel having length of 600 mm and diameter of 1.75 mm. The test section is a stainless steel tube placed horizontally. Flow pattern and heat transfer coefficient data are obtained for a mass flux range of 200–1000 kg/m^2s, a heat flux range of 1–83 kW/m^2 and saturation pressures of 8,10,and 13 bar [5]. In this work, the experiments are conducted in such a way that the heat applied to the test section is varied by small increments, while the refrigerant flow rate, saturation pressure, and inlet vapor quality in the test section are kept constant at the desired value. In the present study, the boiling flow pattern observations are carried out at system pressures of 8 and 10 bar [5]. The superficial velocities of gas and liquid vary from 0.69 to 16.6 m/s and 0.01 to 0.81 m/s respectively. Typical photographs are obtained from the viewing window located downstream of the test section as shown in Fig. 2.

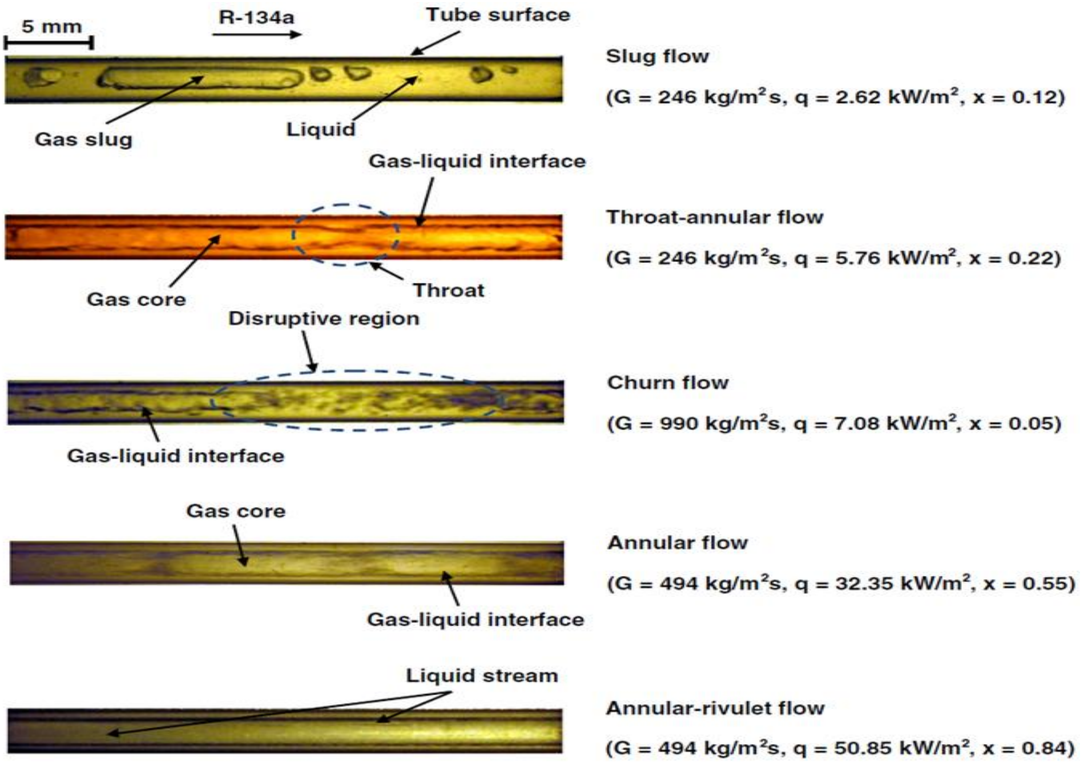

Figure 2 Flow patterns in flow boiling of R-134a through 1.75 mm diameter channel and pressure 8 bar[25]

Chanyoot Keepaiboon et. al have presented the paper describing flow patterns and heat transfer characteristics of R134a refrigerant during flow boiling in a single rectangular micro-channel with 0.68 mm hydraulic diameter. Authors conducted experiments for heat transfer coefficients with heat flux range of 7.63–49.46 kW/m^2, mass flux range of 600–1400 kg/m^{2}s, and saturation temperature range of 23–31^{0}C [1]. Different flow patterns occurring during boiling of R134a refrigerants are noticed like bubbly flow, bubbly-slug flow, slug flow, throat-annular flow, churn flow, and annular flow. It is also found that flow pattern has a significant relation to heat transfer coefficients. The heat transfer coefficient at higher saturation temperatures is greater than that of lower saturation temperatures [1]. In high heat flux ranges, the heat transfer coefficient increases with increasing mass flux. At very high saturation temperature, a partial dry-out observed by authors that results in a lower heat transfer coefficient.

Mirmanto et. al have performed the experiment for Flow pattern visualization and heat transfer measurements of flow boiling heat transfer with water as a working fluid in single horizontal microchannels with widths of 0.5 mm, 1 mm and 1.71 mm and a fixed channel depth and length of 0.39 mm and 62 mm respectively [2]. The mass flux and heat flux were varied from 200 to 1100 kg/m^{2}s and 79 to 793 kW/m² respectively. Inlet conditions of water is 98°C and 125 kPa pressure. Authors were captured flow patterns near the inlet, mid-section and exit of the channel using a high speed camera. They also noted that the local heat transfer coefficient increased with heat flux for all channel sizes. In addition, It found that at a constant heat flux, the local coefficient decrease as the mass flux increased for the D_h = 0.438 mm and 0.561 mm channels [2].

Xiande Fang et. al have developed a new correlation for determining heat transfer coefficient of water as a working fluid in flow boiling applications [6]. A number of correlations for two-phase flow boiling heat transfer coefficients were proposed. However, their prediction accuracies for H_2O are not satisfactory. This work compiles an H_2O database of 1055 experimental data points from micro and mini-channel which evaluates 41 existing correlations to provide a clue for developing a better correlation of saturated flow boiling heat transfer coefficients for H_2O, and then proposes a new one [6]. The new correlation provided by authors incorporates great progress in prediction accuracy. It also works well for several other working fluids such as R22, R134a and NH_3.

V. METHODOLOGY

Two phase flow boiling is gaining importance in research nowadays because of high heat transfer coefficient. Experimental analysis is used in predicting the flow boiling heat transfer coefficient. However, Numerical simulation for flow boiling heat transfer is also used in order to predict the heat transfer coefficient of flow boiling. Different types of multiphase models like eulerian and volume of fluid method is used for predicting the heat transfer coefficient and flow boiling behavior in small diameter channel.

VI. CONCLUSION

Literature from various authors has been studied for two phase flow boiling heat transfer in small diameter channel and having different heated length. From review of literature, it can be seen that two phase flow boiling heat transfer in microchannel is done many times as compared to flow boiling heat transfer in minichannel. The heat transfer coefficient depends on the entering mass flux as well as heat flux applied on the channel walls. the flow boiling heat transfer coefficient increases as the heat flux applied on the channel increases.

REFERENCES

[1] Chanyoot Keepaiboon, Somchai Wongwises," Two-phase flow patterns and heat transfer characteristics of R134a refrigerant during flow boiling in a single rectangular micro-channel", Experimental Thermal and Fluid Science, 2015, vol.66, pp.36–45

[2] Mirmanto, J S Lewis, T G Karayiannis," Flow Boiling of Water in Three Different Hydraulic Diameter Rectangular Microchannels", Proceeding of 13th UK Heat Transfer Conference, UKHTC2013, 2016, pp.1-10

[3] Satish G. Kandlikar, "Two-Phase Flow Patterns, Pressure Drop And Heat Transfer During Boiling In Minichannel and Microchannel Flow Passages Of Compact Evaporators", Heat Transfer Engineering, 2002, vol.23, pp.5-23

[4] S. Mostafa Ghiaasiaan," Two-Phase Flow, Boiling And Condensation In Conventional and Miniature Systems", Cambridge University Press, Cambridge, 2008, ISBN-13 978-0-521-88276-7

[5] Sira Saisorn, Jatuporn Kaew-On, Somchai Wongwises," Flow pattern and heat transfer characteristics of R-134a refrigerant during flow boiling in a horizontal circular mini-channel", International Journal of Heat and Mass Transfer, 2010,vol.53, pp.4023–4038

[6] Xiande Fang, Zhanru Zhou, Hao Wang," Heat transfer correlation for saturated flow boiling of water" , Applied Thermal Engineering, 2015, vol.76, pp.147-156

[7] Yu Xu, Xiande Fang, Guohua Li, Dingkun Li, Yuliang Yuan," An experimental study of flow boiling heat transfer of R134a and evaluation of existing correlations", International Journal of Heat and Mass Transfer, 2016, vol.92, pp.1143–1157

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