Pool Boiling Heat Transfer to Water/Lithium Bromide Mixture

A. Sathyabhama and V. Krishnan

Abstract--- *This paper presents the results of an experimental investigation carried out to study the heat transfer in saturated nucleate pool boiling of the water/lithium bromide mixture on a uniformly heated vertical cylinder at 2 bar pressure. The concentration of lithium bromide was varied from 0 to 30 wt%. It was observed that the heat transfer coefficient increased for the mixture with an increase in heat flux and with the decrease of lithium bromide concentration. A correlation for the heat transfer coefficient as a function of heat flux and lithium bromide concentration was obtained with a good fit to experimental data.*

Keywords--- *H_2O/LiBr, Pool Boiling, Heat Transfer Coefficient, Correlation*

NOMENCLATURE

h Nucleate boiling heat transfer coefficient ($Wm^{-2} K^{-1}$)
q Heat flux ($W m^{-2} K^{-1}$)
x_{LiBr} Lithium bromide concentration (wt%)

I. INTRODUCTION

ABSORPTION refrigeration systems have attracted increasing research interests in recent years. Unlike mechanical vapour compression refrigerators, these systems cause no ozone depletion and reduce demand on electricity supply. Besides, heat powered systems could be superior to electricity powered systems in that they harness inexpensive waste heat, solar, biomass or geothermal energy sources for which the cost of supply is negligible in many cases. The H_2O/LiBr mixture is widely used as the working fluid in absorption refrigeration systems. To optimize the design of generators in these systems, knowledge of boiling heat transfer coefficients of the H_2O/LiBr mixture is necessary. In the past, considerable research work has been done on the pool boiling of both single-component and multi-component liquids. Most results show that boiling heat transfer in mixtures becomes lower than that in each component of the mixture. But the data on H_2O/LiBr mixtures are found to be scarce. Varma et al. [1] studied the effect of test tube diameter and lithium bromide concentration on pool boiling heat transfer coefficient of H_2O/LiBr mixture at sub-atmospheric pressures. Their study of local and average heat transfer coefficients indicated that the boiling phenomenon is not significantly affected by the tube diameter. The solution concentration was a dominant factor and as it increased the heat transfer coefficient decreased.

This investigation was carried out to measure the pool boiling heat transfer coefficient of H_2O/LiBr mixture at 2 bar pressure at different concentration of LiBr

II. EXPERIMENTAL SETUP

The schematic diagram of experimental setup is shown in Fig. 1. The unit consists of boiling vessel, water pump, vacuum pump, condenser coil and test section. Boiling vessel 80 mm diameter and 200 mm long made up of SS 316 is fitted with SS 316 flanges at the top and at the bottom. The vessel is fitted with two sight glasses to observe and record the boiling phenomena. The top flange has provisions for liquid charging, condenser cooling water inlet and outlet, vacuum pump, pressure transducer and thermocouples to measure liquid and vapour temperatures. Bottom flange has provisions for test section and drain. The test section is a rod heater mounted vertically within the boiling

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vessel. Boiling takes place at the outer surface of acylindrical alloy steel rod with a diameter of 6 mm and a heating length of 20 mm. The test section is heated by an electrical heating element of 1 kW capacity. The heating element is connected to a wattmeter through a dimmerstat to read the power supplied to it. The details of instrumentation, experimentation, calculation, experimental uncertainty and validation of the experimental setup are discussed in detail in ([2],[3]).

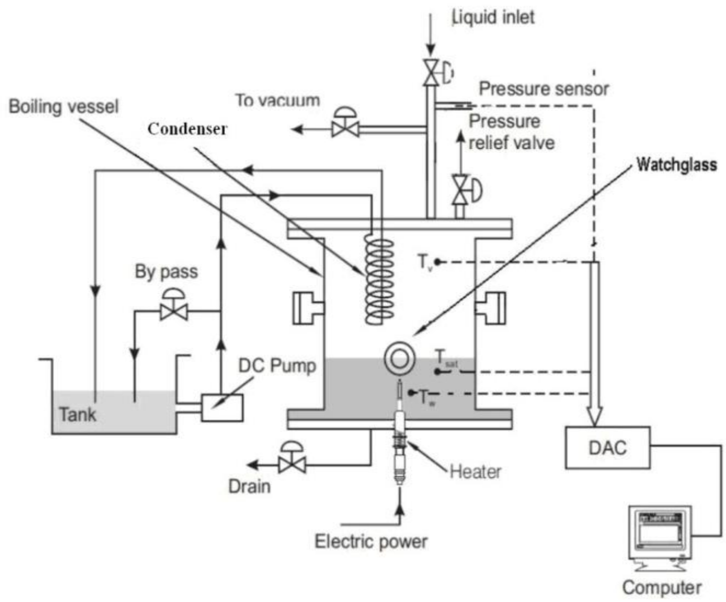

Figure 1: Schematic Diagram of Experimental Setup

Boiling heat transfer experiments were conducted at low concentrations of LiBr and at low pressure of 2 bar in the present work. Anhydrous Lithium bromide, assay 99% (supplied by Spectrochem, Mumbai, India) was used. Measurement of the weight of the salts was done using a weighing scale having a least count of 0.1 gm. Salt solutions were prepared by dissolving the measured quantity of powdered salt in the measured quantity of water at room temperature, and then allowing the solution to stand for about 12 hours to ensure complete mixing. The LiBr concentrations used in the tests were all well below the solubility limits in water.

The mixture was heated to saturation temperature by giving heat input to the rod heater. After equilibrium was reached, the saturation temperature and the heater surface temperature were noted down for different heat flux.

III. EXPERIMENTAL RESULTS

The dependence of heat flux on wall superheat and variation of heat transfer coefficient with heat flux are shown in Fig. 2(a) and (b) respectively. The mixture effect on the boiling heat transfer coefficient in the H_2O/LiBr mixture is clearly evident from these figures. Figure 2(a) clearly shows that the boiling curves for mixtures lie well to the right of the pure component (water) curve. This indicates that it requires a much larger superheat to maintain a given heat flux for the mixture. Similar observations were done by many researchers in other binary mixtures ([4], [5]). It can be seen from Fig. 2(b) that the heat transfer coefficient degradation increases as the LiBr concentration increases. Figure 3 has been drawn to show the effect of LiBr concentration on the heat transfer coefficient at different heat flux values. It may be observed that heat transfer coefficient decreases significantly upto a LiBr concentration of 20%, thereafter there is a slight increase in the heat transfer coefficient.

Exact reason for the deterioration of heat transfer in mixtures is being established. There are many factors that affect the degradation of heat transfer: (a) reduction in temperature driving force because of increase in the boiling point of the micro-layer (the liquid layer trapped under a growing bubble) which is due to the preferential evaporation of the light components during bubble growth, (b) the mass diffusion of the light components to the micro-layer (caused by the preferential evaporation) which is much slower than the heat transfer, (c) the fact that there is usually a significant and non-linear variation in the mixture physical properties with composition and (d) the effect of composition on nucleation itself. Decrease in heat transfer coefficient of H_2O/liBr mixture observed in the present investigation is attributed to the possibility of deposition of a thin film of LiBr salt on the heater surface.

Another possibility is increase in viscosity of water by the addition Another possibility is increase in viscosity of water by the addition of LiBr salt which results in decrease in heat transfer coefficients. $h=0.2285q^{0.93}e^{-0.02x}$ {1}

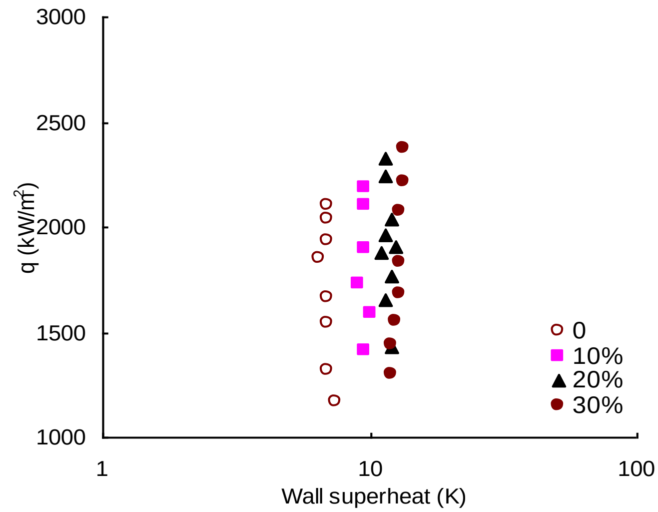

Figure 2(a): Heat Flux Versus Wall Superheat

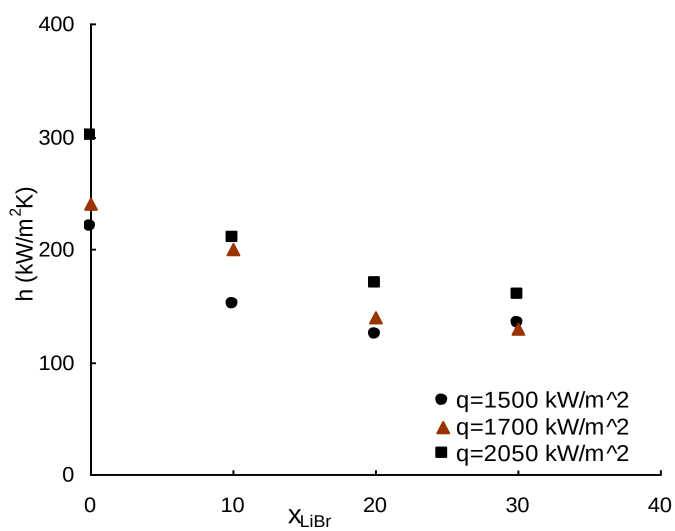

Figure 3: Effect of LiBr Concentration on Heat Transfer Coefficient

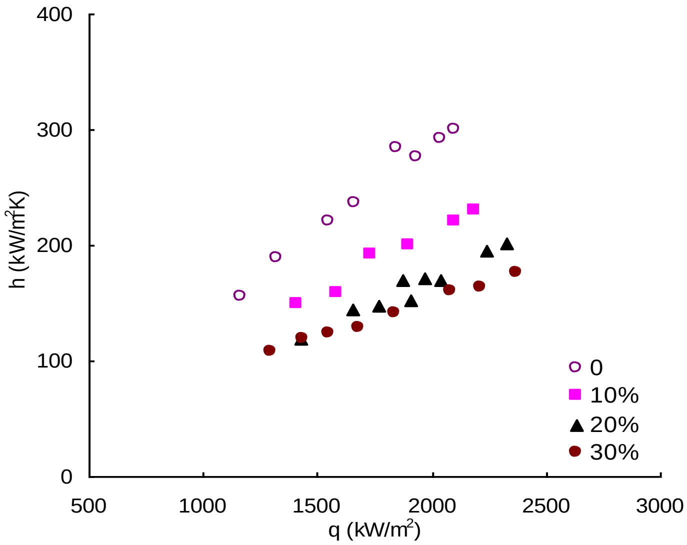

Figure 2(b): Heat Transfer Coefficient Versus Heat Flux

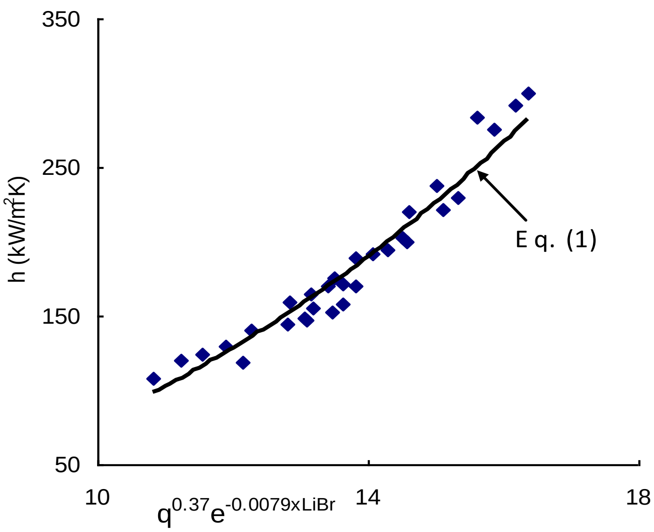

Figure 4: Correlation Development

IV. Correlation for Heat Transfer Coefficient

A simple correlation given by Eq.(1) obtained by curve-fitting (Fig. 4) is proposed to predict the heat transfer coefficient as a function of heat flux and lithium bromide concentration. All the experimental data plotted in the figures 2(b) and 3 now fall in the close range as exemplified in Fig. 4. It may be observed from Eq.(1) that heat transfer coefficient is a strong function of heat flux. The developed correlation for heat transfer coefficient predicts the present experimental data with ±5% deviation as shown in Fig. 5.

V. Conclusion

Pool boiling heat transfer coefficients of H_2O/liBr mixture were experimentally determined at different heat flux and at different LiBr concentration. Heat transfer coefficient increases with increase in heat flux and decreases with increase in LiBr concentration. Developed correlation for heat transfer coefficient for the mixture as a function of heat flux and LiBr concentration indicates that heat flux is a dominant factor. The developed correlation reproduces the experimental data within ±5%.

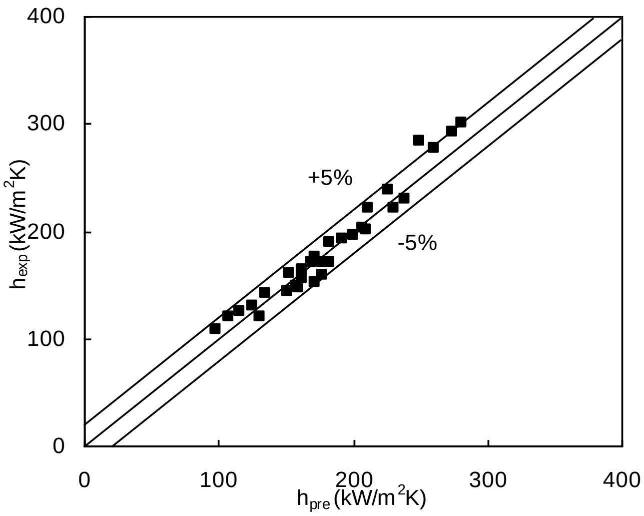

Figure 5: Comparison between Experimental and Predicted Heat Transfer Coefficients

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