HISTORY OF A TWO-PHASE BUBBLE CONDENSING IN AN IMMISCIBLE LIQUID

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ABSTRACT

The history of a two-phase bubble of light hydrocarbon condensing in an immiscible liquid was studied. The process was direct contact heat transfer by condensation of n-pentane, n-hexane and n-heptane single bubbles in water. The change in the dimensions of the resulting two-phase bubble were measured using a digital camera.

INTRODUCTION

The process of condensation of single vapor bubble of a light hydrocarbon as a dispersed phase in an immiscible liquid as the continuous phase, such as cold water, was studied by many researchers from different points of view such as Sideman and Hirsch (1964), Moalem-Maron and Sideman (1973), Dimic (1977), Mori (1977), Jacobs, Fannar and Beggs (1978), Mori (1981), Sudhoff, Plischke and Weinspach (1982), Mori (1984), Jacobs (1988), Fair (1989), and others. The combination of such two fluids, i.e., the hydrocarbon and the water, is determined by the field of applicability of the direct contact heat transfer equipments (Mori, 1987).

When a bubble of light hydrocarbon vapor is passed through a cold medium, it starts to condense forming a two-phase bubble as shown in Fig.(1).

By this process the condensate begins to accumulate through the bubble confines. As the time passes by, more condensate is formed thus increasing the condensate volume or ratio of condensate to the two-phase bubble.

The pattern of condensation prevails as long as the condensate wets the walls of the bubble relatively well. If the condensate does not wet the bubble wall well, the condensate does not always stay in the confines of the bubble throughout the condensation process. As an example of this process is the condensation of steam bubbles in a hydrophobic oil.

The condensate film forming at the top of the bubble begins to thin out draining the liquid to the lower part of the bubble. One can expext the condensation process to be completed within the confines of the liquid shell and it can rupture (Mori, 1987). If this is what happens then the two-phase bubble turns in a complete liquid drop and then falls through the continuous phase due to the difference in density.

According to Sudhoff, et al, 1982, the two-phase bubble is assumed spherical and symmetrical. The continuous phase is considered infinite with constant tmperature and velocity. The flow around the two-phase bubble is assumed potential and the bubble rises without oscilllation.

The aim of the work consisted of studying the history of the two-phase bubble rising in the continuous phase or the changes in its shape and dimensions according to the time and height.

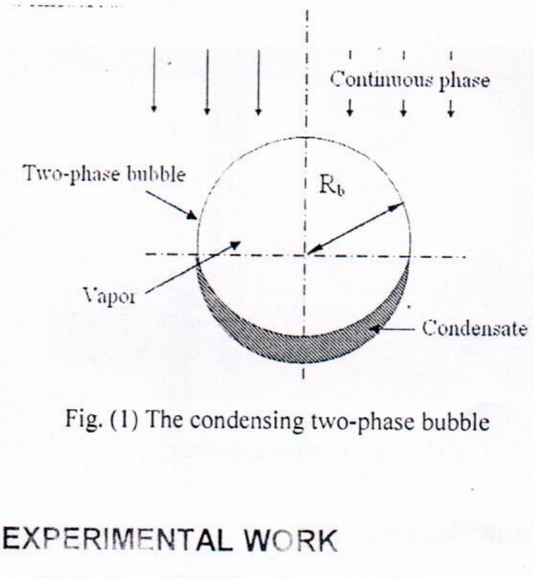

Fig. (1) The condensing two-phase bubble

EXPERIMENTAL WORK

The oil or light hydrocarbon saturated vapor enters a column, filled by cold water, through a nozzle at the bottom. As it enters it began to condense forming the two-phase bubble. With the upward movement of this bubble more condensate is formed. It should be noted that along with this process the bubble decreases in size. The radius of the bubble was measured together with the size of the vapor phase using a digital camera. These dimensions were recorded according to heights where thermocouples were located. The reason for the thermocouples is to measure the difference in temperatures between the saturation temperature of the condensing oil and that of water. This differnce in temperature was because of the heat transfer as the condensation process proceedes.

The different experimental fluids studied were n-pentane, n-hexane and n-heptane as dispersed phases in water as continuous phase.

The experimental apparatus, as shown in Fig.(2), Basma A. (2002), consisted of a QVF column of one meter long and (0.1) meter in diameter situated in a rectangular container filled with water to ensure a constant temperature bath and to minimize the visual distortion during filming by a digital camera. The dispersed phase was introduced through nozzles of wo different diameters at the bottom of the column. Two different starting bubble diameters as (0.3) and (0.2) cm were ensured.

The vapor of the dispersed phase was generated in a three-knecked round-bottomed QVF flask. The liquid dispersed phase was heated in the flask where adequate quantity of heat was introduced to ensure the complete formation of a vapor bubble and to prevent back condensation.

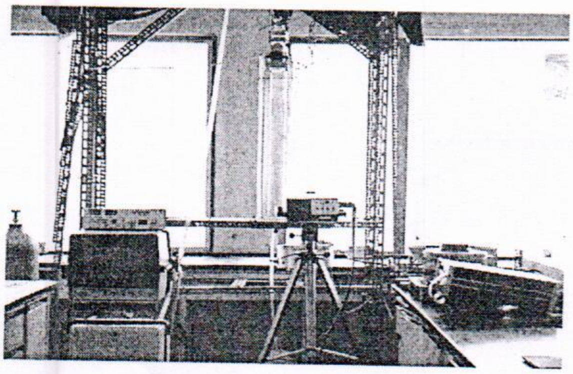

Fig. (1) Experimental apparatus

Condensation History

Fig. (3) represents the history of the condensing hydrocarbon bubble with the corresponding time and flow direction. Fig. (4) shows the history of the ascending bubble with time and height. It could be seen from these two figures that the volume of the entrained oil proceeds to increase with time and height. The immediate contact between the bubble as it emerges from the nozzle and the cold water, or the difference in temperatures between the two phases, makes the bubble condense shortly after its entrance.

This suggests that condensation could be near completion at the intermediate part of the column. Aslo, regarding these figures, if a layer of the same oil is introduced in the cold water, the condensed bubbles could fall and coalesces with the oil layer. This may provide a way to increase the condensation of the vapor, where the bubble condensation could be completed within the confines of this layer before it ruptures.

The velocity of rise of the two-phase bubble can be calculated from Fig.(4) at different points or heights as it represents the slop of the curve that may pass through the two-phase bubble figures.

Figures (5), (6), (7) and (8) show the change of the two-phase bubble radius with time and with height for different initial radii respectively. These were drawn for different temperature differences and for different combinations of dispersed phase and continuous phase. The two-phase radius is the equivalent spherical radius since this bubble has either a spherical shape or an elliptical one. The initial reading was taken as initial bubble radius after its entrance. The first thermocouple was located as near as possible to the nozzle and the other were located at equal spaces.

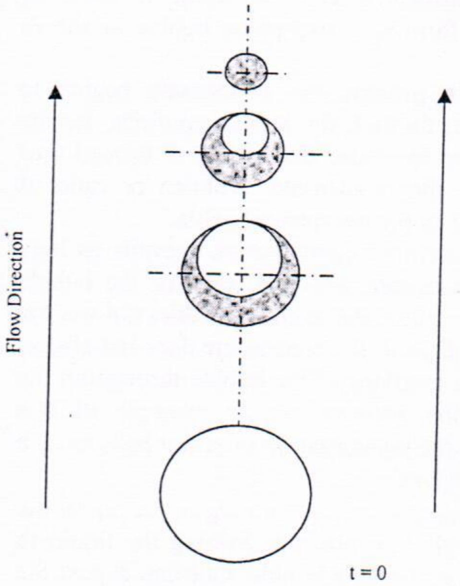

Fig. (3) History of the Condensing Bubble with Time and Flow Direction

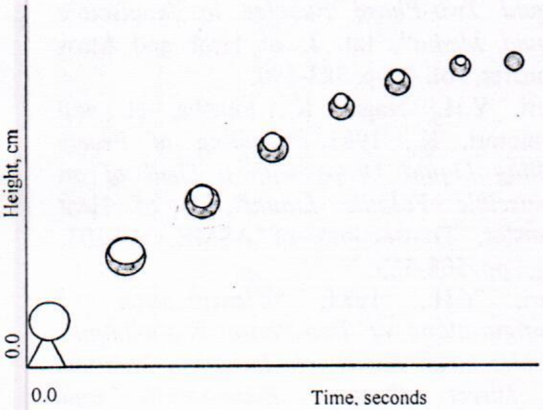

Fig. (4) History of the Condensing Bubble with Time and Height

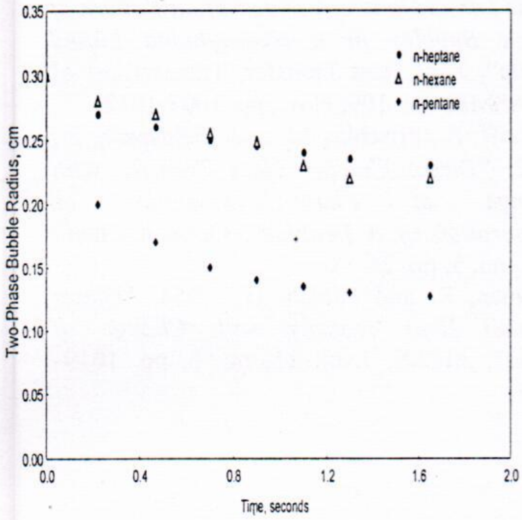

Fig.(5) Two-Phase Bubble Radius with Time, Initial radius of 0.3 cm

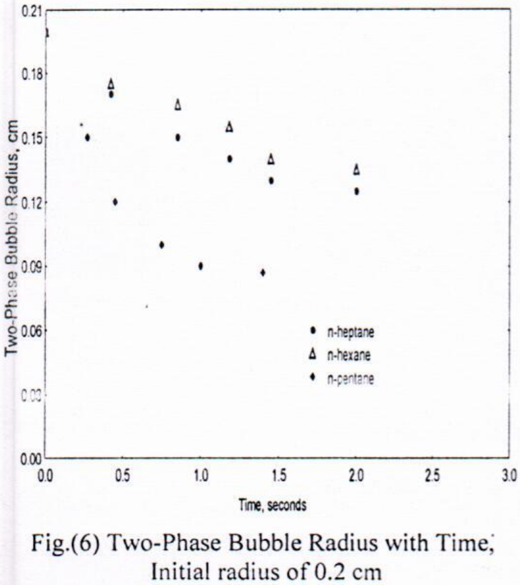

Fig.(6) Two-Phase Bubble Radius with Time, Initial radius of 0.2 cm

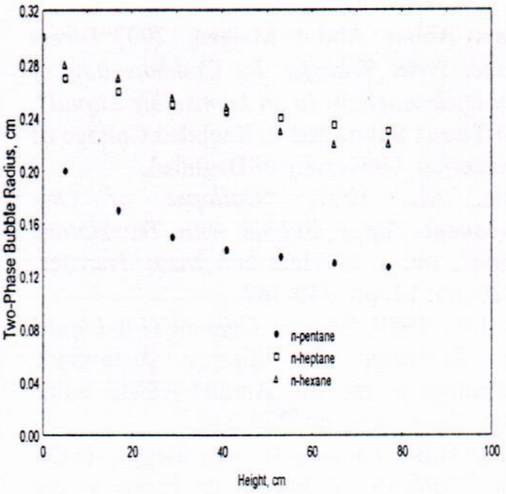

Fig.(7) Two-Phase Bubble Radius with Height, Initial radius of 0.2 cm

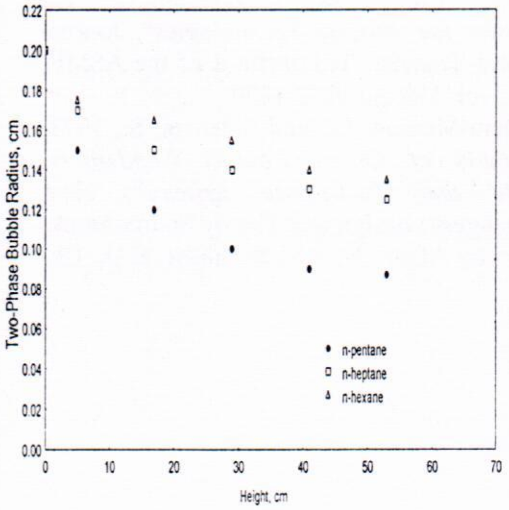

Fig.(8) Two-Phase Bubble Radius with Height, Initial radius of 0.2 cm

CONCLUSIONS

The history of the two-phase condensing bubble depends on the combination of the dispersed-continuous phases, the physical properties of these two phases, the rise velocity of the bubble, initial radius of the vapor bubble. Also, it must be noticed that the condensate film presents a resistance to heat transfer or the condensation process, thus the completion of the condensation process is hindered.

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