International Journal of Ignited Minds (IJIMIINDS)

Experimental Investigation of Small Bubble Pump

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ABSTRACT

In this paper an experiment investigate the feasibility of bubble pump based on water properties. A bubble pump is a fluid pump that operates on thermal energy to pump liquid from lower level to the higher level. It does not contain any moving parts. The bubble pump operates on the same principle that lifts coffee to the top of a coffee percolator.There are three different inner tube diameters with three sub mergence ratio (H/L) of 0.3, 0.4 and 0.5 are tested. The results showed that the bubble pump capacity increases with the thermal Energy processed and continues to increase up to a maximum value then begin to decline. Each tube diameter has its own maximum discharge; the bigger tube diameter gives higher maximum discharge which is in turn increases with the increasing of submergence ratio.The result shows that the submergence ratio of 0.5 allowed to high pumping because of bubble pump increases with the thermal energy processed and continues to increase up to a maximum value and then begin to decline with increasing heat input. Varying heat input of 10W to 100W and maintained the constant driving head. The main parameters of bubble pump are pumping tube diameter, pump lift, pump heat input and constant driving head. Using above parameters to investigate the mass flow rate, pumping ratio and vapour mass flow rate.

Keywords *– Pump tube diameters, driving head, pump tube length, heat input, and water.*

1. INTRODUCTION

The unique characteristics in that it runs without any mechanical work input. Using this refrigeration system gaining less alteration due to large moving components and noise and greatly showed the bad effect on the atmosphere, in these scenarios, vapor absorption refrigeration showed a greater attraction for its novelty, since it uses heat energy as a primary source of energy to the system. A bubble pump is a fluid pump it lifts up in the tube from lower level to the higher level as a two phase flow pattern. Heat supplied to the bottom of the tube creates a bubble there by increasing the buoyancy of the fluid causing it to rise through the vertical tube. Literature on the two-phase flow provides more than sufficient information for the analysis of a bubble pump. The most of the below publications refers to generally wide range of diameter and length used to lift the fluid in a duel and triple pressure absorption refrigeration system.

1.1 Scope of the project

Recent advancements in science and technology indicate that there is greater demand for compact thermal device. The two-phase flow bubble pump system showed the potential effect in the absorption refrigeration system, bubble pump reduce the mechanical components, noise, environmental effect and also compact size. With this objectives, from the available literature are exhaustively re looked, to minimize the size of the bubble pump it is one of the promising alternate technology.

1.2 The working fluid properties

1. The boiling point temperature must be in the range of 40^0C to 70^0C at atmospheric pressure.
2. The working fluid must be non-reactive and chemically stable at all temperature.
3. It must be non-hazardous and non-flammable.
4. It should be easily available.

2. FABRICATION AND EXPERIMENTAL SET-UP

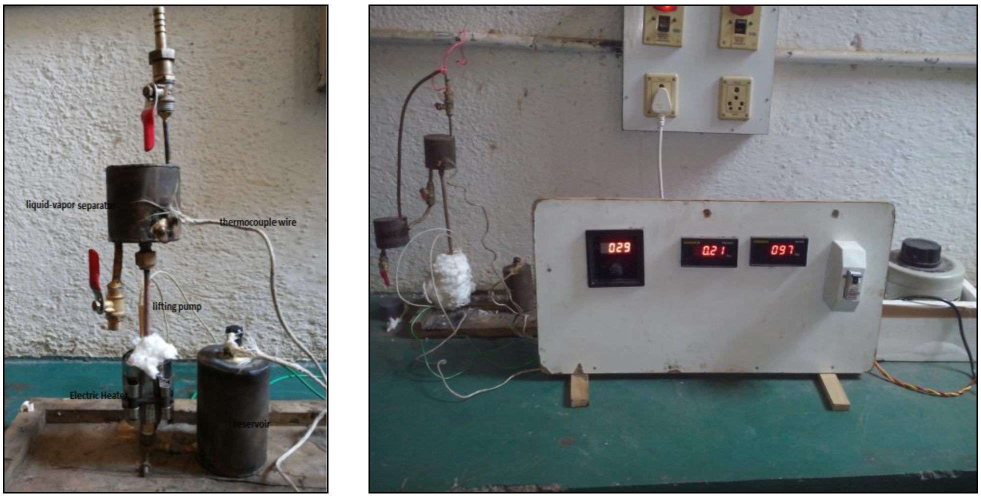

Fig 1:Experimental setup

The actual experimental set-up with all components is shown in the above Fig 1. The water was stored in a liquid reservoir. It was first heated in a liquid and then was boiled at the bottom of the bubble pumps tube using an electrical heater. The liquid that was pumped by the bubble pump was separated from the accompanying vapor bubbles in a liquid-vapor separator. The phases, liquid and vapor were separated. The vapor was condensed in a water-cooled condenser and flow rate of the condensate was measured. The flow rate of the pumped liquid was also measured separately.

2.1Operating Parameters

Tube diameter (mm)	Driving Head (cm)	Length (cm)	Submergence ratio (H/L)
3.2	8	20	0.4
3.2	8	25	0.3
4	8	20	0.4
4	8	25	0.3
5	8	15	0.5
5	8	20	0.4
5	8	25	0.3

Table 1: different operating parameters

2.2 Data Reduction

Following formula were used to calculate the different parameters.

During the steady state condition the refrigerating effect is measured directly from electrical heat input to the water tank. At pull down condition, the refrigerating effect is calculated by using the following equation:

$$Q=m*Cp*\Delta t \quad (1)$$

$$m_f = \frac{(Final\ reading - Intial\ reading)}{\Delta t} \quad (2)$$

$$V_f = \frac{m_f}{\rho_f} \quad (3)$$

$$V_g = \frac{\Delta v.\rho_g}{\rho_g.\Delta t.10^6} \quad (4)$$

$$m_g = V_g\ .\ \rho_g \quad (5)$$

Pumping ratio;

The pumping ratio is the ratio of volume flow rate of the pumped liquid (Vf) to volume flow rate of the vapor (Vg).

$$\text{Pumping ratio} = \frac{V_f}{V_g} \quad \textbf{(6)}$$

3. RESULTS AND DISCUSSION

3.1 The Frequency of Pumping Action

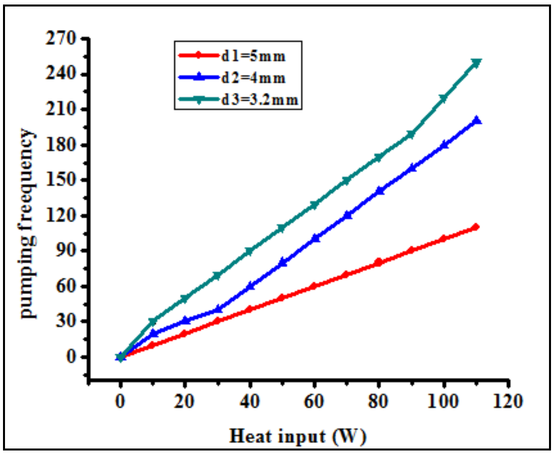

Fig 2: variation of frequency of pumping action

The pumping action is intermittent and the frequency of pumping varies with the heat input. A typical variation of the pumping frequency with the bubble pump heat input. The pumping frequency increases linearly with the heat input. As the boiling rate increases with the heat input, the duration for each pumping action reduces and the frequency increases. At very low heat inputs, the frequency of pumping is extremely small. The frequency of pumping action also depends on the geometry of the heating elements. At higher heat input, a large amount of liquid is pumped. Also at low heat inputs, the time interval between the two consecutive pumping actions is not constant for a given heat input. But it is reasonably constant at higher heat inputs. The diameter of the pump tube also affects the pumping frequency. Pumping frequency is more for a smaller diameter pump tube for the same heat input. This is because; the process of forming a vapor slug at the surface of the heating element takes a finite time. The smaller the diameter of the tube, smaller is the residence time for formation and transportation of the vapor slug. Since the vapor slugs form quickly, the liquid is lifted more frequently thereby increasing the pumping frequency.

3.2 Effect of Mass Flow Rate of Heat input

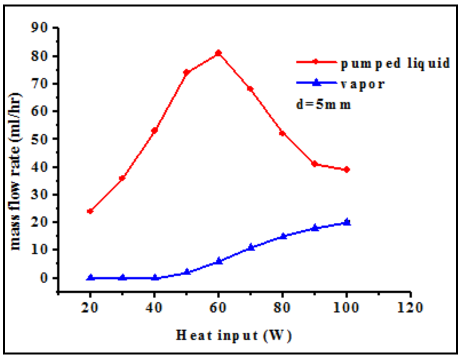

Fig 3 (a)

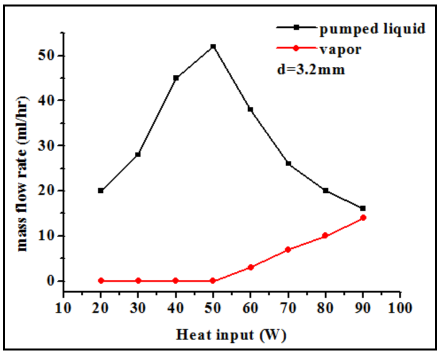

Fig 3 (b)

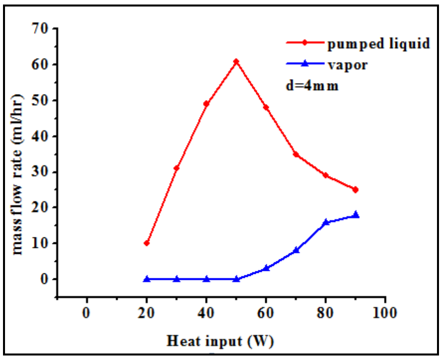

Fig 3 (c)

Fig 3 a, b & c: variation of effect of mass flow rate with heat input.

Performance of the bubble pump is evaluated on the basis of the amount of liquid pumped by the bubble pump for a given heat input. Many factors influence the performance. The general trend of variation of the mass flow rate of the pumped liquid with the pump heat input is shown in Fig 3 a, b and c. At low heat input, the mass of liquid pumped by the bubble pump per unit time increases almost linearly with the heat input. This is due to the fact that, as the heat input to the liquid in the bubble pump increases, more and more number of vapor bubbles form which lift more and more amount of liquid. This is a slug flow regime, where the liquid is trapped between the slugs of vapor. Hence the liquid flow rate increases as the heat input increases though the rate of increase decreases. The mass flow reaches a maximum value. This maximum flow occurs when the increase in the frictional pressure drop caused by increased vapor flow rate exceeds the increased buoyancy effect of the vapor to pump the liquid. Further increase in the heat input, results in decrease in the mass flow of the pumped liquid. This is because, at very high heat inputs, the vapor flow rate is very high which means the frictional losses are heavy resulting in lower amount of pumped liquid. Thus the region to the left side of the maximum mass flow rate can be called as a buoyancy force dominated region while the one to the right side of the maximum mass flow rate can increases proportionately with the heat input. It is much lower as compared to the mass flow of pumped liquid. If the bubble pump tube is inadequately insulated, some vapor may condense as it travels upwards thus further lowering the vapor flow rate. The variation of the mass flow rate of the pumped liquid with that of the vapor should essentially be same as the variation of pumped liquid flow rate with the heat input.

3.3 Effect of pump tube diameter on the mass flow rate of pumped liquid

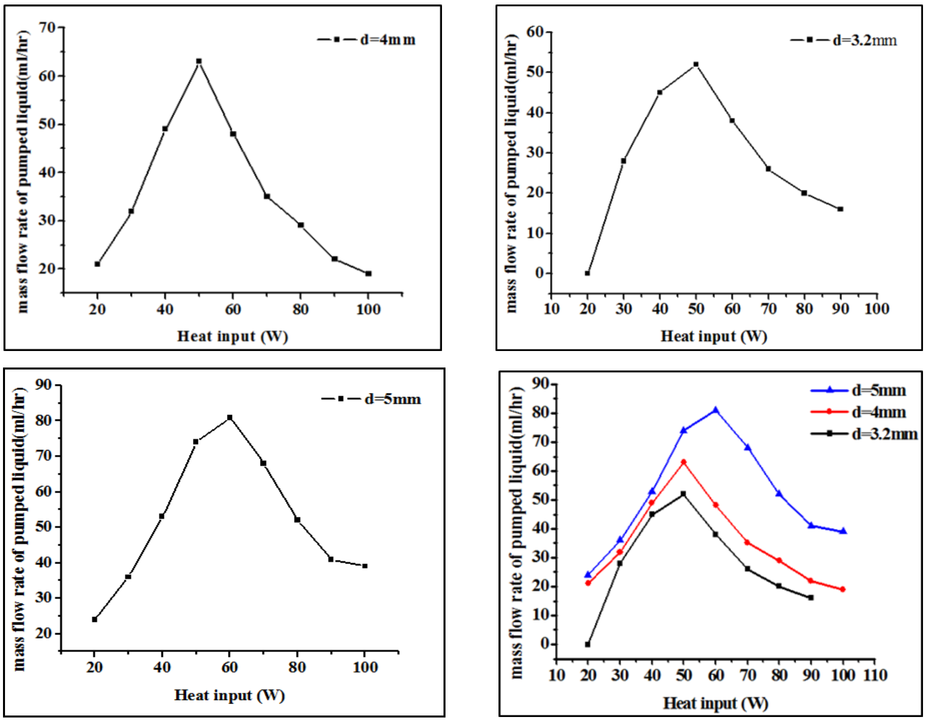

Fig 4 a, b, C & d: Variation of effect of pump tube diameters with mass flow rate of pumped liquid.

Increase in the diameter of the pump tube results in increased liquid mass flow rate. This is because, as the diameter increases, the frictional pressure drops decreases thereby increasing the efficiency of the bubble pump which results in increased liquid mass flow rate. The behavior of the bubble pump remains the same, the mass flow rate of pumped liquid increases with heat input, reaches the maximum value and then starts decreasing with further increase in heat input.

3.4 Effect of mass flow rate of pumped liquid with heat input

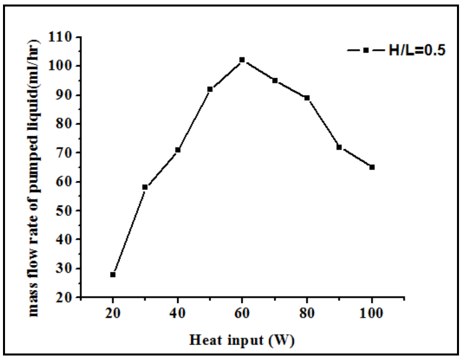

Fig 5 (a)

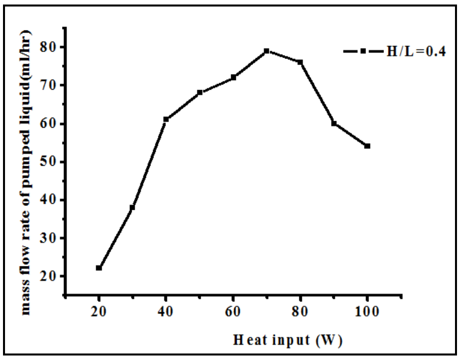

Fig 5 (b)

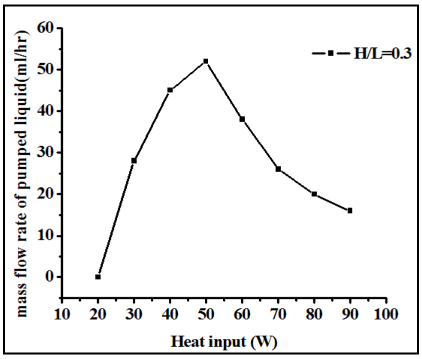

Fig 5 (c)

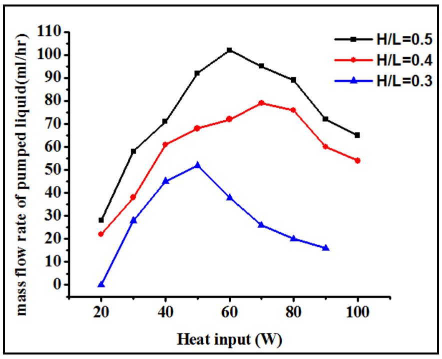

Fig 5 (d)

Fig 5 a, b, c & d: Variation of mass flow rate of pumped liquid with heat input for same driving head, varying length and different sub mergence ratio.

Above Fig a, b, c & d demonstrates the effect of sub mergence ratio (H/L) on the mass flow rate. The figure shows that the larger H/L has the larger mass flow rate. For the same tube diameter, increasing the submergence ratio leads to increase the liquid level so the relative height to which the pump must lift the liquid decreases. So the mass flow rate can be increased by increasing the submergence ratio.

3.5 Effect of the vapor mass flow rate with heat input for different tube diameters

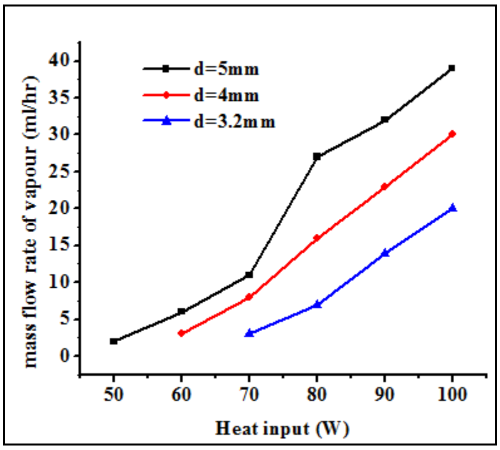

Fig 6: variation of vapor flow rate versus internal heat power for different tube diameters.

The experiment result show that, the vapor flow rate increased in larger tubes than that of the smaller tube. There for the larger tubes in bubble pump are more desirable. The vapor mass flow rate is directly proportional to the heat input. It clearly shows that the driving head does not influence the vapor flow rate much. A higher driving head results in a slightly higher vapor flow rate. This is because of the increased force offered by the liquid column. The vapor flow rates at higher heat inputs are nearly constant for all the driving heads. Fig 6 shows the variation of vapor flow rate with heat input for different pump tube diameters. The curves for 4 mm and 3.2 mm diameter pump tubes run parallel to each other for all the heat inputs. The curve for 5mm diameter tube, however, shows a departure from the other two curves.

3.6 Effect of pumping ratio with heat input for different pump tube diameters

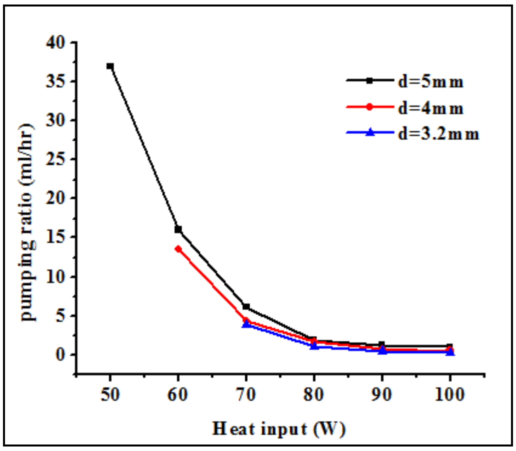

Fig 7: Variation of pumping ratio with heat input for different pump tube diameters.

The pumping ratio is the ratio of volume flow rate of the pumped liquid (Vf) to volume flow rate of the vapor (Vg). A bigger diameter pump tube render higher pumping ratio for the same input. Bigger the diameter, smaller is the pressure drop, higher is the mass flow rate and so higher is the pumping ratio. This is because of a very high friction loss experienced by the smaller diameter pump tube which results in a much reduced mass flow rate and a very low pumping ratio. The variation of the pumping ratio with the heat input while that for a constant driving head and different pump tube diameters are shown in Fig 7. Irrespective of the diameter of pump tube and the driving head, the general behavior of the pumping ratio with respect to the heat input seems similar. The pumping ratio decreases almost linearly with the increase in heat input. This is due to the increased flow rate and consequently the increased pressure head loss at higher heat inputs. Fig 7 reveals that all the three curves run almost parallel to each other for all the heat inputs. At higher heat inputs, the curves seem to flatten a bit which indicates that the rate of decrease in pumping ratio is decreased. Also at low heat inputs, a similar behavior are observed, the rate of decrease in pumping ratio is decreased. It is clear that for the same heat input, a smaller driving head, gives a lower pumping ratio. When the driving head is reduced, each cycle (pumping action) takes more time and correspondingly more vapors escapes from the pump. The temperature inside the pump will also increase to a higher level before the cycle completes. Thus vapor is vaporized and less solution is pumped, resulting in lower pumping ratio.

4. CONCLUSION

The experimental test of the vapor bubble pump has been successfully conducted to demonstrate the pump actions. These actions showed the same trend as that obtained from the previously done experimental bubble pump model .The pumping capacity is affected certainly with the increasing of both the tube diameter and submergence ratio. The optimum tube diameter is not restricted but the submergence ratio cannot agree the higher value of 0.5.Tested was carried by varying tube length of 15cm, 20cm and 25cm & varying the temperature and heat input. The result showed, as the heat input and mass flow rate increases there is an increase heat input and reach maximum heat then suddenly decreases.

5. SCOPE FOR FUTURE WORK

- To conduct more experiments on different inner tube diameter.
- To conduct more experiments on different tube length.
- To conduct more experiments on different driving heads.
- To conduct more experiments on using different fluids.
- To conduct more experiments on varying the properties of fluids.

Acknowledgements

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without mention of the people who made it possible and support had been a constant source of encouragement which crowned my efforts with success.

I am deeply indebted and would like to express my sincere thanks to our beloved Principal **Dr. K.A.Krishnamurthy**, for providing me an opportunity to do this Project.

My special gratitude to **Dr. Sanjeevmurthy**, HOD, Department of Mechanical Engineering, S.S.I.T for his guidance, constant encouragement and wholehearted support.

My sincere thanks to my guide **Mr. Manu. S** Asst. Professor, Department of Mechanical Engineering, S.S.I.T for their guidance, constant encouragement and whole hearted support.

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