

Working Characteristics of Bubble Pump in Solar Heating System

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ABSTRACT: Purpose of this study is to confirm that whether bubble pump can be used as a working fluid pump in solar water heater system. Device is consisted of bubble pump, solar collector and heat exchanger. Bubble pump is mainly manufactured by steel. In order to see the inside we installed a glass window on the up of pump and made water level indicator to check water level. At the mean time, we attached temperature sensors and pressure sensors at bubble pump. In addition, the flow meter was installed at outlet of heat exchanger. And then, We used the result to analysis whether bubble pump can be used for the circulation of the system.

Keywords: Bubble pump, Solar collector, heat exchanger, Solar heating system

NOMENCLATURE

A : Cross-sectional area, m²

x : Dryness fraction

m : Mass flow rate, kg/s

G : Mass velocity, kg/m²s

1. INTRODUCTION

Typical things of renewable energy are wind force, hydrogen, solar energy. We will focus and study to heating water system that use solar heat energy among great many system that utilize renewable energy.

First, we composed the solar heating water system of simplest form for research. Composition of solar heating water system is at heat collection department, heat storage department and using department. It is circulating pump that do to transfer heat that get in solar collector at heat storage. Circulating pump works, it needs electricity. This pump acts properly in system, it need special controller. To use solar energy, there are many problems. Compulsorily, according to each situation, it need controller who can control system. Many additional devices adhere to system to install this controller and device

becomes complicated. Therefore, we try to study bubble Pump for frugality of energy and simplification of device. Bubble Pump relationship power source is heat energy. And in solar heat system these get easy. In addition, bubble Pump can take over controller's function. We wish to compare and analyze Performance of pump. Hereupon, we wish to compare and analyze Performance.

2. BUBBLE PUMP

2.1 Two-phase flow and Flow pattern

Multiphase flow passes in state that countenance such as gas, liquid, solid is mixed. A two-phase flow is defined as a flow of two separate parts of a heterogeneous body or system. Vapor liquid mixtures, where the vapor and liquid are phases of the same fluid are referred to as two-phase single component mixtures while gas-liquid mixtures where the vapor and liquid are different fluids are referred to as two-phase two component system. Following are some commonly used terms in two-phase flow.

- 1) Dryness fraction: It was defined as ratio of mass flux of gas to gas and liquid.

$$x = \frac{m_g}{m} = \frac{m_g}{m_g + m_l} \quad (1)$$

- 2) Void fraction: It was defined as ratio of gas sectional area in sectional area all.

$$\alpha = \frac{A_g}{A} = \frac{A_g}{A_g + A_l} \quad (2)$$

- 3) Mass velocity: in two phase flow literature, mass velocity is extensively used. It is the ratio of

mass flow rate to the total flow cross-section area of the mixture.

$$G_g = \frac{m_g}{A}, \quad G_l = \frac{m_l}{A} \quad (3)$$

The flow patterns encountered in vertical upwards co-current flows are shown in figure 1. Following flow patterns are encountered when a mixture of vapour and liquid flows through a vertical pipe.

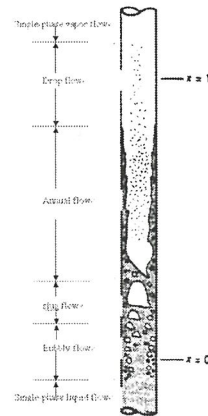


Figure 1. Pattern of two-phase flow in Vertical

1) Bubbly flow :

In bubbly flow, the gas phase is distributed as discrete bubbles in a continuous liquid phase. At one extreme, the bubbles may be small and spherical and at the other extreme the bubbles may be large with a spherical cap and a flat tail. In this latter state although the size of bubbles does not approach the diameter of pipe, there may be some confusion with slug flow.

2) Slug flow :

In slug flow the gas or vapor bubbles are approximately the diameter of the pipe.

The nose of the bubble has a characteristic spherical cap and the gas in the bubble is separated from the pipe wall by a slowly descending film of liquid. The liquid flow is contained in liquid slugs which separate successive gas bubbles. These slugs may or may not contain smaller entrained gas bubbles carried in the wake of the large bubble. The length of the main gas bubble can vary considerably.

3) Churn flow :

Churn flow is formed by the breakdown of the large vapor bubble in the slug flow. The gas or vapor flows in a more or less chaotic manner through the liquid which is mainly displaced to the channel wall. The flow has an oscillatory or slug annular flow.

4) Wispy annular flow :

Wispy-annular flow has been identified as a distinct flow pattern. The flow in this region takes the form of a relatively thick liquid film on the walls of the pipe together with a considerable amount of liquid entrained in a central gas or vapor core. The liquid in the film is aerated by small gas bubbles and the entrained liquid phase appears as large droplets which have agglomerated into long irregular filaments or wisps. This region occurs at high mass velocities and because of the aerated nature of liquid film could be confused with high velocity bubbly flow.

5) Annular flow :

In annular flow a liquid film forms at the

pipe wall with a continuous central gas or vapor core. Large amplitude coherent waves are usually present on the surface of the film and the continuous break up of these waves forms a source for droplet entrainment which occurs in varying amounts in the central gas core. In this case, as distinct from the wispy-annular pattern, the droplets are separate rather than agglomerated.

2.2 Structure and operation principle of bubble Pump

The schematic structure of Bubble Pump was showed in Figure 2. The whole pump can be separated in to two parts, upper part and lower part, and these two parts are connected by a steel pipe □. Pipe □ which we call core tube cross both separator and condenser was connected to the outlet of solar collector. Pipe □ was connected with the outlet of heat exchanger.

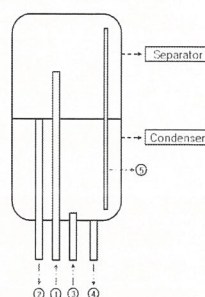


Figure 2. Diagram of Bubble Pump

Pipe □ and pipe □ have no different in the bubble pump but they connected with the outlet of heat exchanger and inlet of collector respectively. The following is operation principle of bubble Pump.

- 1) Heat transfer medium gets heat energy from solar collector.

- 2) Heat transfer medium started to boil.
- 3) In the core tube is Two-phase flow. Bubble flow changed into slug flow.
- 4) Heat transfer medium cross pipe □ from Separator to solar collector. Vapor from separator will be condensed in condenser through pipe □.
- 5) It enters by condenser through a pipe that comes out in heat exchanger. And then Heat transfer medium that supply energy in heat exchanger goes by solar collector along a pipe □.
- 6) System makes closed circuit. And heat transfer medium circulates continuously.

3. EXPERIMENT DEVICE

Figure 3 is schematic diagram of experiment device.

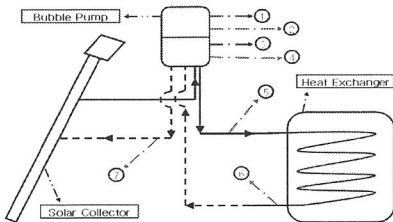


Figure 3. Diagram of Solar Heating System

Device is consisted of solar collector, heat storing tank, circulating pump, heat exchanger. And system used two pressure sensor and six temperature sensors, single pyrheliometer. Setup position of sensor marked to figure 3.

Model Name of pressure sensor is PSH0760HAAJ

Measurement range value of this sensor is 0 - 760mmhg. The working temperature of bubble pump is 338K-348K and working pressure is 25kPa. The temperature is depend upon the solar water heater,

commonly the fluid temperature is from 338K-348K

4. RESULT ANALYSIS

Table I. weather data of a day

	Maximum temp.(°C)	Minimum temp.(°C)	Average temp.(°C)	Cloud rate
1	17	7.5	12.5	4.5
2	18.2	9.3	14.4	2.3
3	17.8	8.1	13.3	1.4
4	19.2	12.1	16.6	7.4

Table I is weather data of a day that acquire data that use at this time

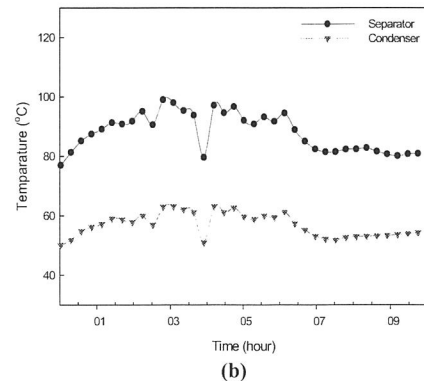
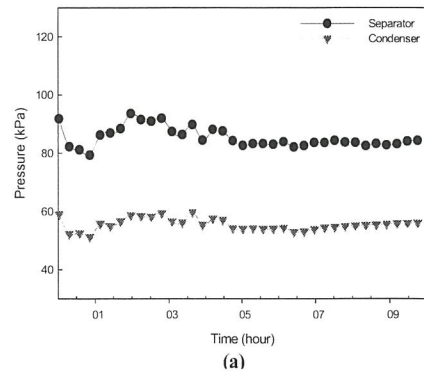
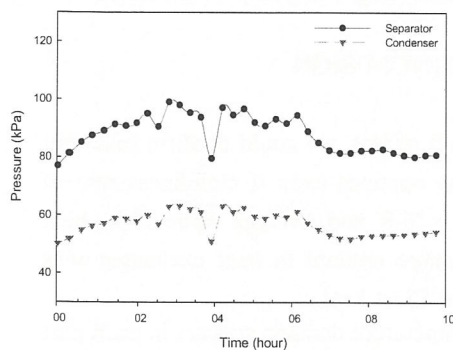


Figure 4. Pressure of Daily data 1 to 2

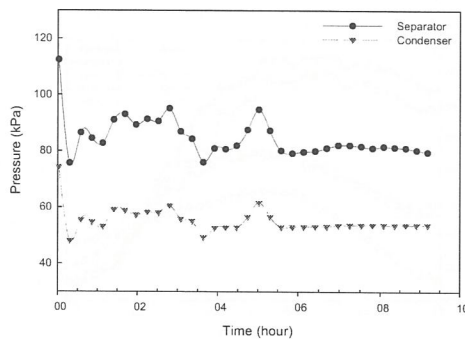
Figure 4 (a) shows pressure that get in a day of weather-data No.1. And (b) is data No.2. .

Fig. 5 (a) is No.3, and (b) is data of pressure that get in No.4.

Figure 4 (a) in a day, cloudiness rate was clear as 4.5, but sunlight was not so strong. So, as can confirm in figure 6, temperature was not so high. And temperature limits that bubble pump can operate is about 4 hours. Pressure is not stabilized figure 4 and figure 5 that show value of pressure and change of pressure can see serious section. This is thing by environmental factor. If shadow that cause by cloud occurs to system, Change occurs in temperature in system. And it is influenced in pressure.



(a)



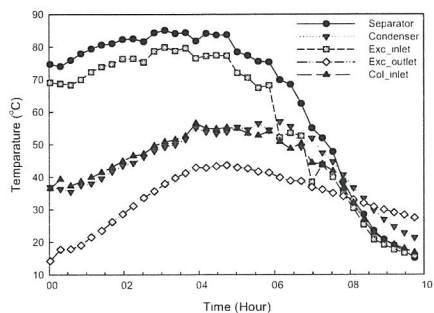
(b)

Figure 5. Pressure of Daily data 3 to 4

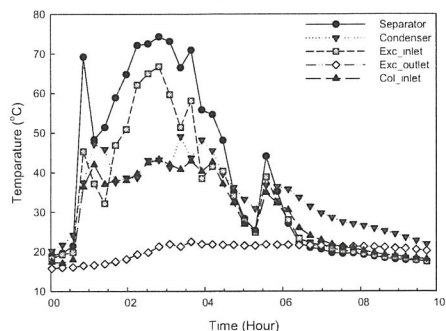
There is section that pressure is fixed almost in graph of figure 4 and figure 5.

This section is section that Bubble Pump does not run by insufficiency of the calories. If solar collector absorbs sun radiant energy, heat transfer medium does not circulate. And heat transfer medium is stagnant within system. Figure 6 and figure 7 show that temperature difference in heat exchanger is about 60-70°. This time, a calorie is about 15.61 kcal.

We can see damage about 7° at temperature of heat transfer medium that flow from 'Separator' by heat exchanger. This is thought by heat loss through window that install to device.

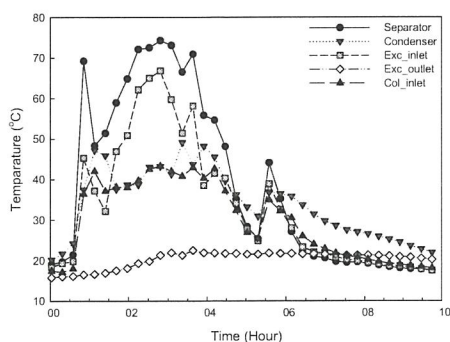


(a)

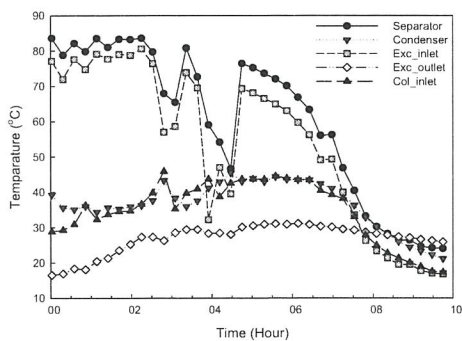


(b)

Figure 7 Temperature of Daily data 3 to 4



(a)



(b)

Figure 6 Temperature of Daily data 1 to 2

Also, result that measure flow rate of heat transfer medium, it was about average 0.3-0.5 l/min. and maximum flow rate is about 0.71 l/min, minimum flow rate is about 0.03 l/min. Flow special quality of device includes pulsation. Because flow shape of slug flow shows aspect such as reciprocating fluid pump's flow shape.

5. CONCLUSION

Result of test, we could confirm case that pump operates even if cloudiness rate of day is '6-8' and Average value of the heat exchange amount in heat exchanger was about 15.61 kcal.

Temperature damage appears in each part. These problems are arising from manufacture process of window to confirm state of interior. Heat loss is arising from Windows. Flow of heat transfer medium is stagnant when solar radiant energy was weak time zone. And flow showed pulsation.

ACKNOWLEDGEMENT

This research was financially supported by the Ministry of Commerce Industry and Energy (MOCIE) and Korea Industrial Technology Foundation (KOTEF) through

the Human Resource Training Project for Regional Innovation, second-phase of Brain Korea 21 and NURI Project.

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