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Study on the Operating Characteristics in Small Size Heat Pipe using Nanofluids

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Abstract: - This paper is to research the operating characteristics of the copper heat pipe using nanofluids. The nanofluids with Ag nano particle was used as the working fluid. At the inclination angle 90° in bottom heat mode, nanofluids has much higher thermal transfer performance than the conventional fluids, water. Experimental results showed that the heat pipe with 10,000ppm Ag nanofluids had the high heat transfer performance. The thermal resistance of the heat pipe with nanofluids was 0.36 ℃/W.

Key-Words: - Heat pipe, Nanofluid, Heat transfer performance, Bottom heat mode, Thermal resistance

1 Introduction

Nanofluids are the heat transfer fluids created by dispersing solid particles of the order of nanometers in size in the traditional heat transfer fluids. Recently, these have created considerable interest for their improved heat transfer capabilities because these enhance the heat transfer performance considerably with the few problems encountered in common slurries and additives such as clogging, erosion, sedimentation and in crease in pressure drop. So, it is possible to reduce the size of the heat exchanger and to decrease the driving power and energy cost.

In these point of view, nanofluids could be used in a wide range of industrial application such as transportation system, micromachines, electronic cooling and HAVC systems, etc..

Recently, there has been rapid growth of technical applications and systems which require to transport large quantity of heat in relatively small space and volume such as computer and telecommunication equipment with high power density.

Heat pipe is heat transfer devices which transfer large quantities of heat with minimum temperature gradient. Also, it is possible to extend the heat transfer area to be used in field with high thermal load such as electronic cooling and heat recovery system.

So, heat pipe is excellent one which makes it possible to considerably extend the capabilities of two phase heat transfer devices with a capillary pumping force.

In this study, we have manufactured the Ag-water nanofluid heat pipe and investigated the working characteristics and heat transfer performance of heat pipe experimentally.

2 Experiment and procedures

The diameter of heat pipe used in electronic cooling field such as CPU module and amplifier, etc. ranged usually 2-12.7mm. In this study, we made the 6mm copper tube heat pipe with nanofluid(water-Ag).

Effective length of heat pipe is 300mm, the length of evaporating part, adiabatic part and condensing part are 50mm, 90mm and 160mm respectively. Fill charge ratio of working fluid(water-Ag) was 40(vol.%) of the volume of evaporating part. The specification of heat pipe used in this study was shown in Table 1.

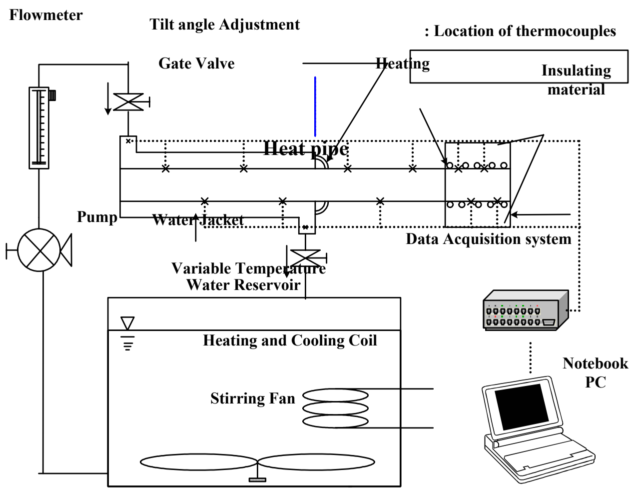

Fig. 1 Schematic diagram of experimental apparatus.

Table 1 Specification of heat pipe.

Parameters	Description
Container	
material	Copper
pipe diameter	6mm
total length	300mm
length of evaporating part	50mm
length of adiabatic part	90mm
length of condensing part	160mm
Working fluid	Distilled water + Ag
Inclination angle	90° (Bottom heating mode)
Cooling water temp.	20 °C

Fig. 1 shows the schematic diagram of experimental apparatus to conduct the performance test of heat pipe. Experimental apparatus consist of heating section to supply the evaporating part with heat flux, cooling water circulating section to cool the condensing part and data acquisition system.

Electricity was supplied to the chrome wire(4.5Ω/m) which is wrapped around the evaporating part through the variable voltage adjuster. It was once insulated with the creak wool(k=0.075W/m℃) and then with urethane foam in order to minimize the heat loss.

The temperatures in the vicinity of nichrome wire and the outside temperatures were measured to calculate the heat loss. Adiabatic part was wrapped by insulation tape, and it was connected to the inclination angle adjuster made of insulation material of teflon.

Water in constant temperature cooling water bath(heating /cooling capacity : 750W/250W) was supplied to the water jacket in condenser section, which is a pyrex tube of 260mm length and 15mm diameter, this tube was insulated with 10mm thick urethane.

Heating rate, surface temperatures (8, 4, 6 pieces of thermocouples were installed at the evaporating, adiabatic and condensing part respectively) at each position, saturation temperature and pressure were measured to investigate the characteristics of heat pipe.

Data from these thermocouples and pressure sensor were acquired by the PC via data acquisition system(DR230, Hybrid Recorder, YOKOGAWA).

Heat was loaded from 20W to about 80W at an interval of 10W, operating mode was bottom heating mode(inclination angle : 90°).

3 Results and discussion

Fig. 2 shows surface temperature variation of heat pipe as a function of input heat rate when Ag content in distilled water is 10,000ppm. There is a lot of fluctuation in surface temperature of evaporating part at the 20-40W condition. From the 60W, it shows litter fluctuation and seem to be almost steady state. At 80W condition, the surface temperature is about 68℃, which is lower than that of distilled water condition(refer to Fig.3, evaporating temperature). When working fluid is Ag nanofluid, there is relatively litter temperature fluctuation and a few increase(10%) in heat transfer rate.

Fig. 4~6 show temperature distribution in each position of heat pipe when input heat rate is 30W, 50W

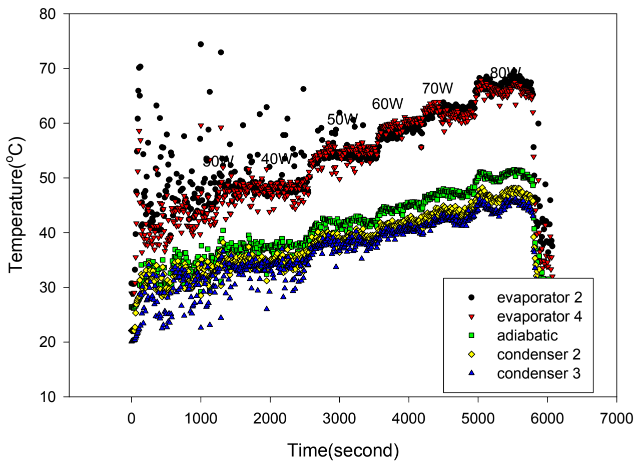

Fig. 2 Wall temperature distribution according to input power for water-Ag nanofluids(10,000ppm).

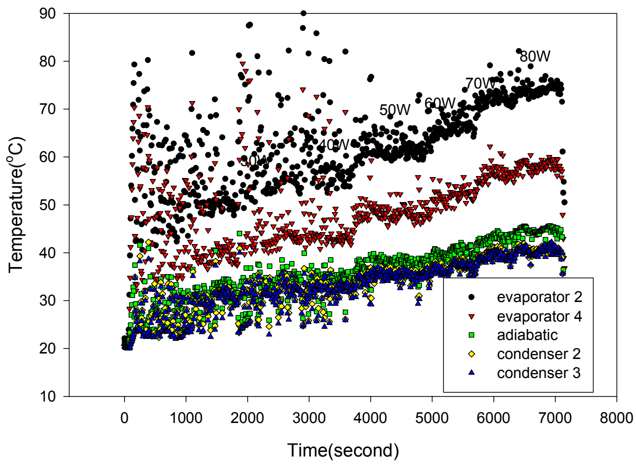

Fig. 3 Wall temperature distribution according to input power for distilled water.

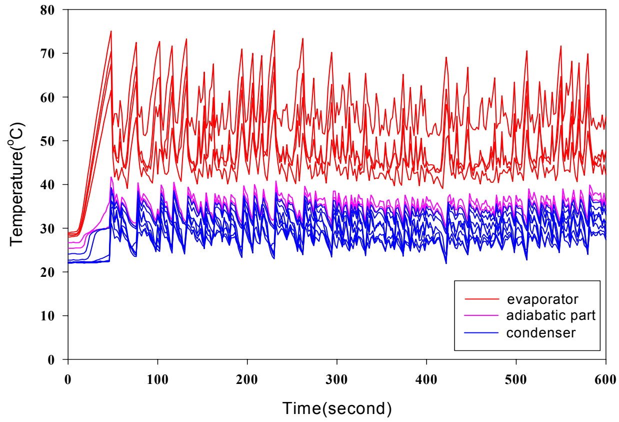

Fig. 4 Wall temperature distribution according to input power Q=30W for nanofluids(10,000ppm).

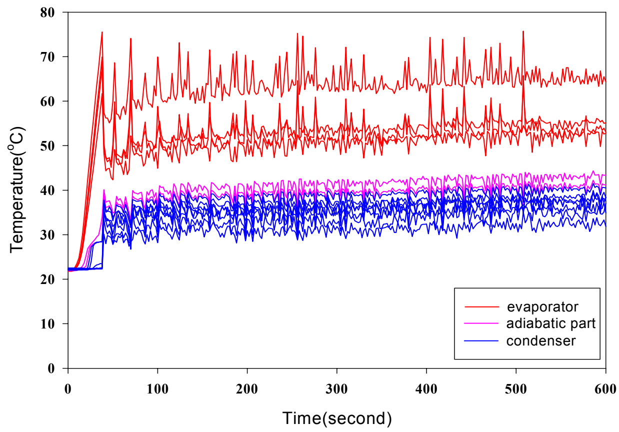

Fig. 5 Wall temperature distribution according to input power Q=50W for nanofluids(10,000ppm).

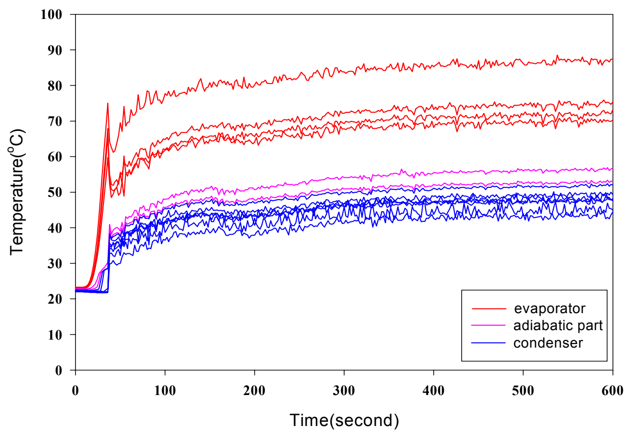

Fig. 6 Wall temperature distribution according to input power Q=90W for nanofluids(10,000ppm).

90W and Ag content in distilled water is 10,000ppm. As the input heat rate increase(30W to 90W), temperature fluctuation decrease, it seem to be Geyser boiling due to the local dry-out phenomena and overheating of liquid pool, which give rise to slug flow in the heat pipe. Also, these phenomena show that the fluctuation of evaporating part is sharper than that of the other part at the low heat flux condition.

Fig. 7~8 show temperature distribution of evaporating and condensing part as a function of Ag content in distilled water and input heat rate(50W, 70W). When Ag content in distilled water is 1,000ppm, the surface temperature of condenser is lower than the other content condition, while the temperature at 10,000ppm condition is higher than that of pure water.

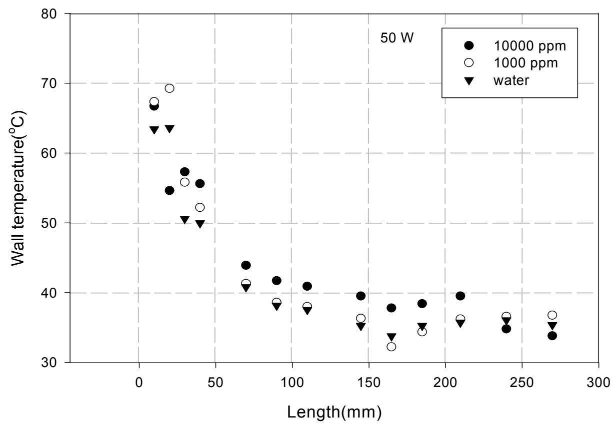

Fig. 7 Wall temperature distribution at input power Q=50W according to Ag content.

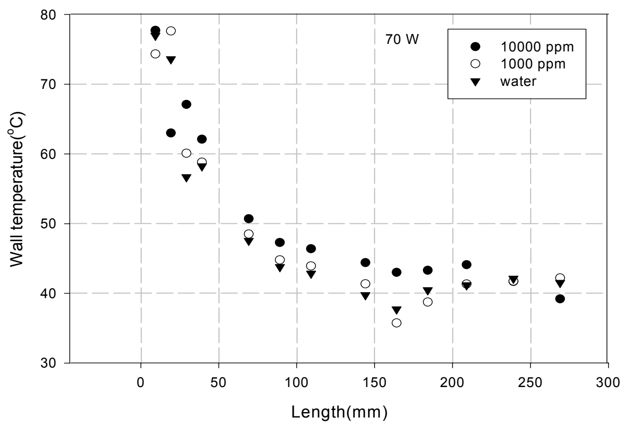

Fig. 8 Wall temperature distribution at input power Q=70W according to Ag content.

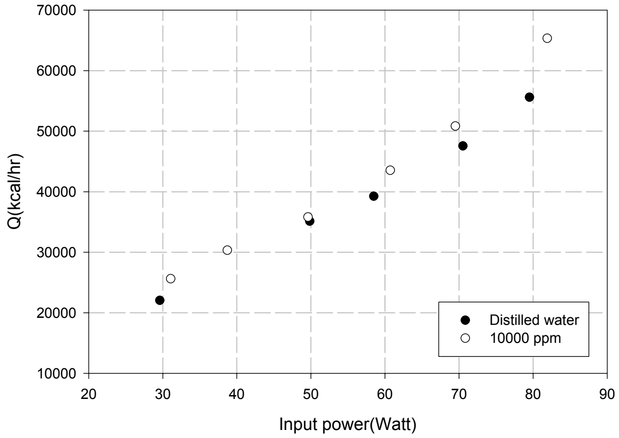

Fig.9 Comparison of heat transfer rate between working fluids.

Fig. 9 shows the comparison of heat transfer rate between distilled water and 10,000ppm nanofluid. As heat input power increase, the difference of heat transfer rate between two fluid condition increase, heat transfer rate in nanofluid heat pipe is larger than that of distilled water heat pipe.

Fig. 10 shows the heat transfer rate as a function of input heat rate and Ag content in distilled water. When input power is 70W, Ag content is 1,000ppm, heat transfer rate is 10% larger than that of the other condition.

Fig. 11 shows the thermal resistance which represent heat transfer performance index as a function of Ag content in distilled water. When Ag content is 10,000ppm, thermal resistance is lower than that of the other condition. In the experimental range, minimum thermal resistance was 0.36 ℃/W.

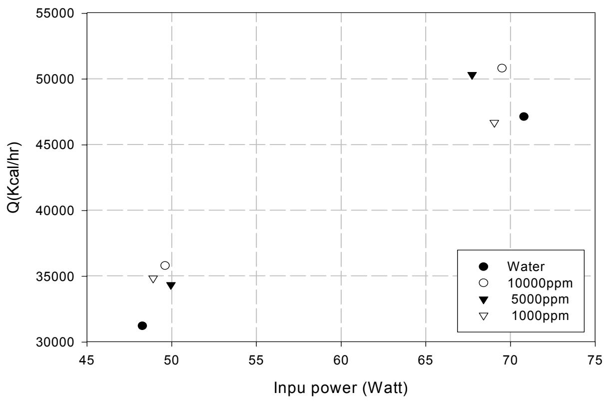

Fig. 10 Heat transfer rate according to working fluids.

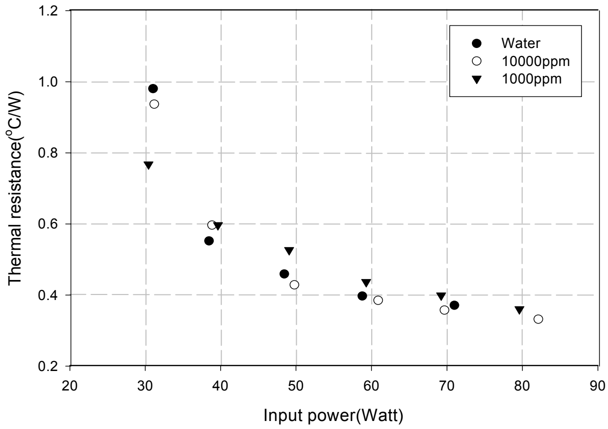

Fig. 11 Thermal resistance of heat pipe according to the Ag content in distilled water.

4 Conclusion

We manufactured 6mm diameter copper heat pipe using Ag nanofluid and investigated working characteristics , heat transfer performance through the experiment. Conclusion are as follows.

1. Heat transfer performance of 10,000ppm Ag-distilled water naofluid is 10% higher than that of the other Ag content nanofluids.
2. In case of nanofluid with 10,000ppm Ag content, characteristics of temperature stabilization is relatively better than the other condition.
3. Optimal Ag content showing the maximum heat transfer performance exist and more detail researches are needed.

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