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Experimental Investigation on Micro Heat Pipes (MHP) of Different Lengths

Al-Basir[1], Mohammed Shahed Hossain[2], Rajib Sarkar Rajan[3], Md. Shahrier Hakim[4] & Md. Abdur Razzaq Akhanda[5]

[1] Department of Mechanical and Chemical Engineering, Islamic University of Technology, Gazipur, Bangladesh

[2] Department of Management Information System, EMBA Program, University of Dhaka, Dhaka, Bangladesh

[3]University of Asia Pacific, Department of Electrical and Electronic Engineering

[4]University of Greenwich, Department of Electrical Power Engineering, London, United Kingdom

[5]Department of Mechanical & Chemical Engineering, Islamic University of Technology, Bangladesh

E-mail: al.basir005@yahoo.com

Abstract

The effects of heat pipes of different lengths and orientations on its thermal performances are experimentally investigated in this study. Heat is transferred from the evaporator section to the condenser section and finally dissipated to the environment. Heat pipe evaporator section is heated by electric heater and condenser section is cooled by forced convection of water circulation. For the precise measurement of the maximum heat transfer capability, heat inputs are increased in small steps of 2 W. Tests have conducted by using two different lengths (150 mm, 200mm) of heat pipe having same hydraulic diameter (D=3mm). The results indicate that with the increase in length heat transfer co-efficient increases and thermal resistance decreases.

Keywords: Micro Heat Pipe, Heat pipe, evaporator, condenser, thermal resistance, heat transfer co-efficient

1. Introduction

All electronic components from microprocessor to high end power converters generate heat and rejection of heat is necessary for their optimum and reliable operation. Now-a-days many electronic devices need cooling beyond the capacity of standard metallic heat sinks. Research is doing on heat pipe before 1960 but commercially available since mid-1960's [1].However, only a few past years electronic company and other microelectronic company is using heat pipes as reliable, cost-effective solution for high end and cooling solution.

A heat pipe is a heat transfer mechanism that can transport large quantities of heat with a very small difference in temperature between the hotter and colder interfaces .Inside a heat pipe, at the hot interface a fluid turns to vapor and the gas naturally flows and condenses on the cold interface. The liquid falls or is moved by capillary action back to the hot interface to evaporate again and repeat the cycle. Thus heat pipe is a simple device that can quickly transfer heat from one point to another and the heat transfer takes place by repeated cycles of condensation and evaporation of the working fluid within a sealed system. It is light weight device with no moving parts, silent in operation and having several hundred times the heat transport capacity as compared to the best metallic heat conductor like silver and copper. They are often called "superconductors" of heat, as they possess an extra ordinary heat transfer capacity with almost no loss.

2. Development of micro heat pipe

The application of heat pipes to electronics cooling was beginning to receive attention in late 70's. Pipes of rectangular section were proposed by Sheppard [2] for cooling integrated circuit packages. Cotter [3] was the first to propose the concept of a micro heat pipe (MHP) for the purpose of cooling electronic devices. Babin et al [4] conducted a combined experimental and analytical investigation on two micro heat pipes, one copper and one silver, of length 57 mm with water as working fluid. The results indicated that the steady state model could be used to predict accurately the level of performance. Comparing with cotter [3] investigation, Babin and Peterson and Gerner [5], the maximum heat transfer capacity of the MHP with 0.015-0.5 mm hydraulic radius was 03-0.5

W and corresponded to $1W/cm^2$ in the heat flux based on the surface area of the evaporator. Wu and Peterson [6] also that maximum Q= 4-5 W for a flat micro heat pipe of 1 mm hydraulic diameter. Recently mini flexible heat pipe with transparent plastic tube has been studied by Lu and Li [7]. The extreme flexibility of the plastic tube was proved to possess the advantages in bending, twisting, oscillating and deforming over the traditional metal-based heat pipes when used in compact electronics. V. Maziuk, A Kulakok, M. Rabestsky [8] has investigated the miniature heat pipe thermal prediction tool-software development, using a miniature heat pipe of 2.5 mm thickness and 8-11 mm which with a copper sintered powder wick.
Jun Zhuang [9] compared the performance of micro heat popes in terms of maximum heat transfer performance under condition of antigravity of the miniature heat pipes with three different structural wicks. It is found that all the structures of wicks have little influence on the heat transfer capability of miniature heat pipe with the aid of gravity. Koji Yamamato ,Kenji Nakamizo ,Hideaki and Namba [10] studied the high performance micro heat pipe and was found pipe diameter is seen to have substantial effects such that the larger the pipe diameter, the greater the maximum heat transfer rate improves. Akhanda [11] tested an air cooled micro heat pipe and investigated the effect of working fluid and inclination angle on its thermal performance.

Nomenclature

A Surface area of evaporator ($m^{2)}$

Te Temperature at evaporator (◦C)

Tc Temperature at condenser (◦C)

I Input current, Ampere

V Input Voltage, Volts Q Input power, Watts h_e

Heat transfer co-efficient of evaporator (KW/m^2◦C) h_c

Heat transfer co-efficient of condenser (KW/m^2◦C) h_{eff}

Effective heat transfer co-efficient (KW/m^2◦C) R

Overall thermal resistance (◦C/W)

R_e Thermal resistance of the evaporator (◦C/W)

R_c Thermal resistance of the condenser (◦C/W)

R_{eff} Effective thermal resistance (◦C/W)

3. Objectives

In this experiment thermal performance of Micro Heat pipes of different lengths will be determined with considering the following objectives:

- To investigate thermal performance of micro heat pipes of different lengths.
- To change the length of evaporator and condenser section to investigate thermal performance.
- To determine maximum heat transfer capacity of micro heat pipe at different lengths.

4. Design & fabrication

Three basic components of heat pipe are -The container, the working fluid & the wick or capillary structure. The function of the container is to isolate the working fluid from the outside environment. It has to therefore be leak-proof. In this experiment tubes of different lengths are used as container. All the containers having different lengths have the same hydraulic diameter. The reasons behind selecting copper tubes as container are: Thermal conductivity, the compatibility of copper, Ease of fabrication, Strength of weight ratio & Wettability. The working fluid used in this study is water as water satisfies all the requirements which is necessary for the experiment. Among the wick forms available, meshes are most commonly used. In this study stainless steel mesh (s/s 200 meshes) is used as wick or capillary structure.

5. Manufacturing process

Copper tube of 3 mm internal diameter has used for this experiment with 2 different types of lengths are 150mm and 250 mm. Two pair of thermocouples (K-type) are glued to the wall of the micro heat pipe and one thermocouple (K-type) is glued at adiabatic section. Evaporator and adiabatic sections are thermally isolated by using asbestos cloth. Micro heat pipe is provided with a Ni-Cr thermal wire heater for heat input. Insulated NiCr thermal wires having diameter of 0.28 mm (10Ω/m) are wound around one side of the evaporator wall at a constant interval of 1.5mm. This setup is done in a way as to reproduce the mode of heat pipe heating applications close to realistic. From the main A.C power source, heat is supplied to the heater via a transformer. Regulated electrical energy is supplied to the heater during the experiment using voltage regulator. The condenser section is cooled by constant temperature cooling water circulating in an annular space between the copper tube and the water jacket. The cooling water is supplied from an elevated water tank. The schematic figure is given at fig 1.

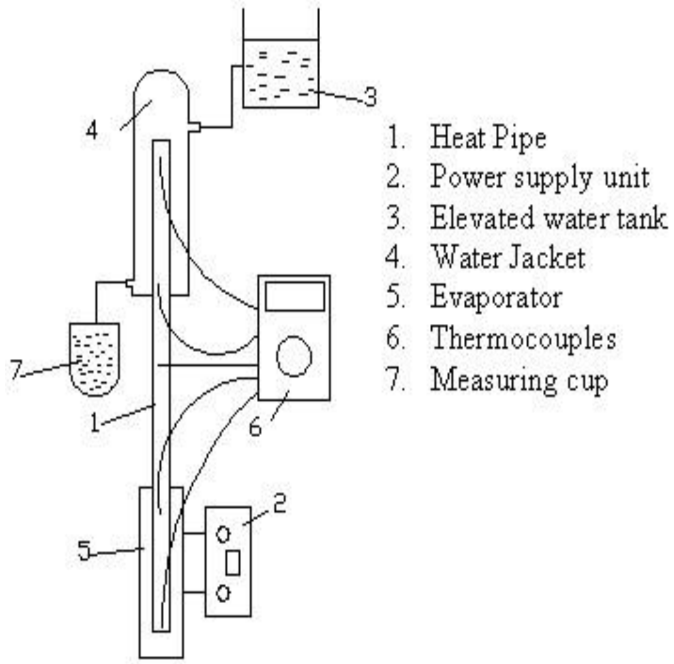

Fig.1: Schematic diagram of Micro Heat Pipe

6. Equation

The thermal resistance computed as:

$$R_c = \frac{T_{sat} - T_c}{Q} \ {}^oC/W$$

$$R_e = \frac{T_e - T_{sat}}{Q} \ {}^oC/W$$

$$R_{eff} = \frac{T_e - T_c}{Q} \ {}^oC/W$$

The heat transfer co-efficient computed as:

$$h_c = \frac{Q}{A_c(T_{sat} - T_c)} \ kW/m^2\,{}^oC$$

$$h_e = \frac{Q}{A_e(T_e - T_{sat})} \ kW/m^2\,{}^oC$$

$$h_{eff} = \frac{Q}{A_e(T_e - T_c)} \ kW/m^2\,{}^oC$$

7. Result & discussion

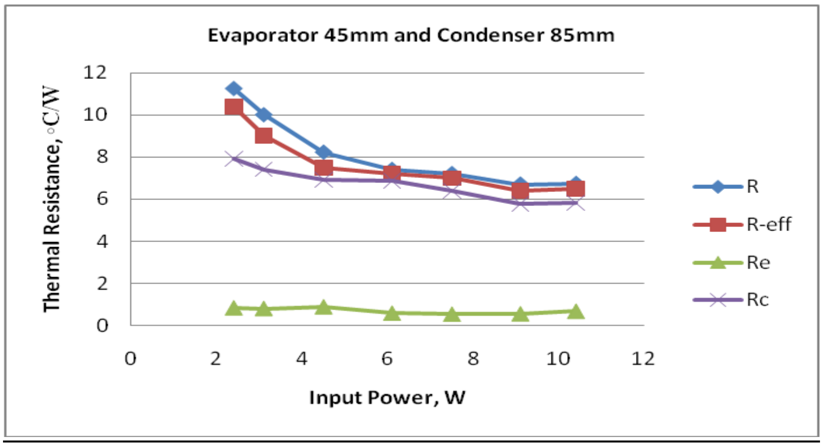

Fig 2: Variation between thermal resistance vs input power

Figure 2 shows variations of overall thermal resistance, effective thermal resistance and condenser heat transfer resistance of heat pipe at evaporator 45 mm and condenser 85 mm. it is evident that the thermal resistance offered by the condenser section is higher than the thermal resistance offered by the evaporator section. Moreover, the rate of change of evaporator thermal resistance with heat input is far lower than the rate of change of condenser thermal resistance with heat input. Thus the overall thermal resistance is mainly dictated by the thermal resistance of the condenser and overall thermal resistance becomes so high when liquid slug is started to form in the condensing zone. Therefore, the slope of condenser thermal resistance with heat input is similar to the slope of overall thermal resistance and effective thermal resistance with heat input. Moreover, the thermal resistance exhibits a decreasing trend with increasing of heat input. But it is true within the operational zone thermal resistance experiences an increasing trend due to sudden temperature rise per unit heat input.

Fig 3 shows the variation of Evaporator and condenser with respect to h_{eff} and Input power. This graphs represents that with the increasing heat input, effective heat transfer co-efficient were increased rapidly. Similar behaviors are also found at Fig 4. It shows the variation of Evaporator and condenser with respect to h_e and Input power.

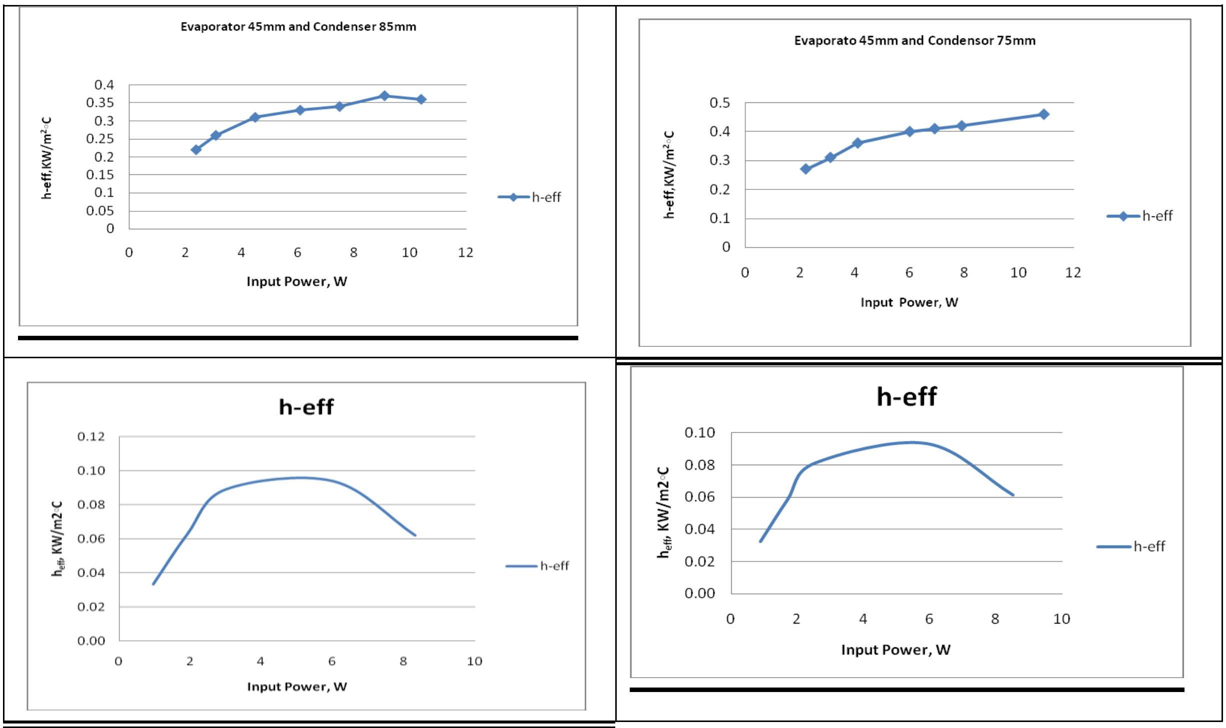

Fig.3: Variation of Evaporator and condenser with respect to h_{eff} and Input power.

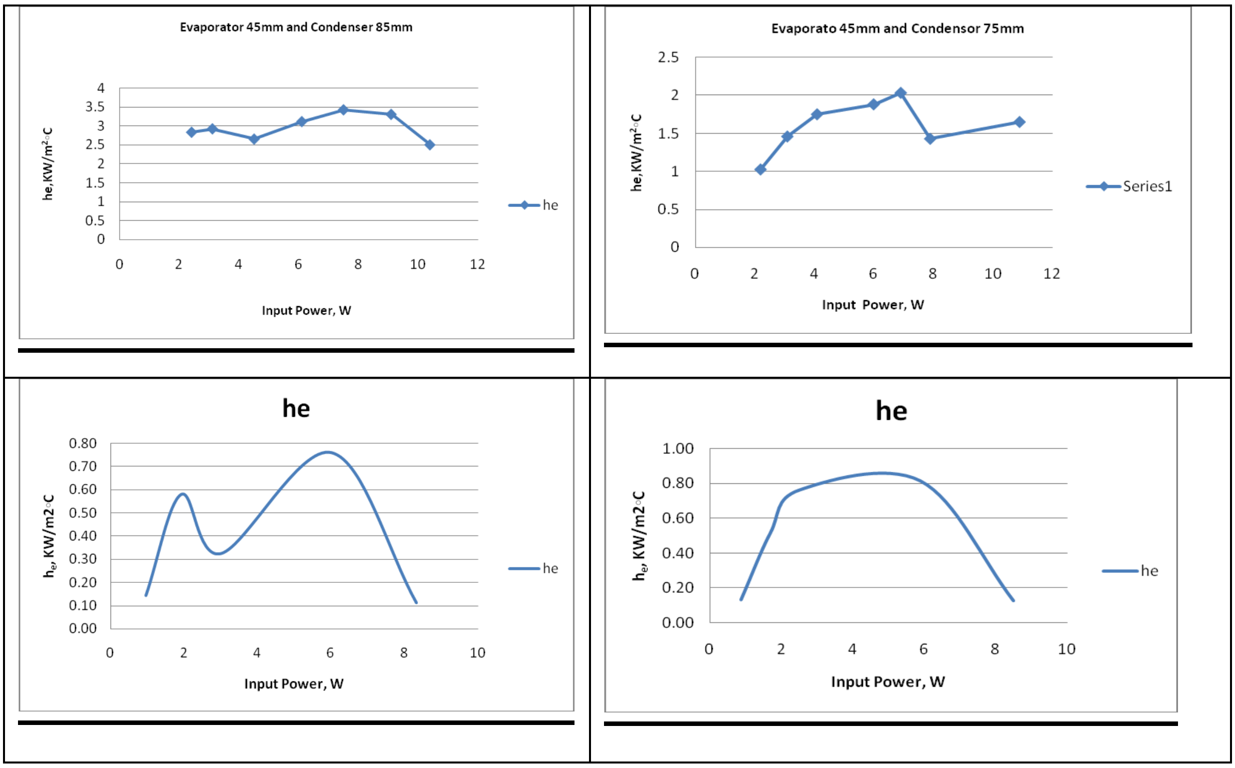

Fig.4: Variation of Evaporator and condenser with respect to h_e and Input power.

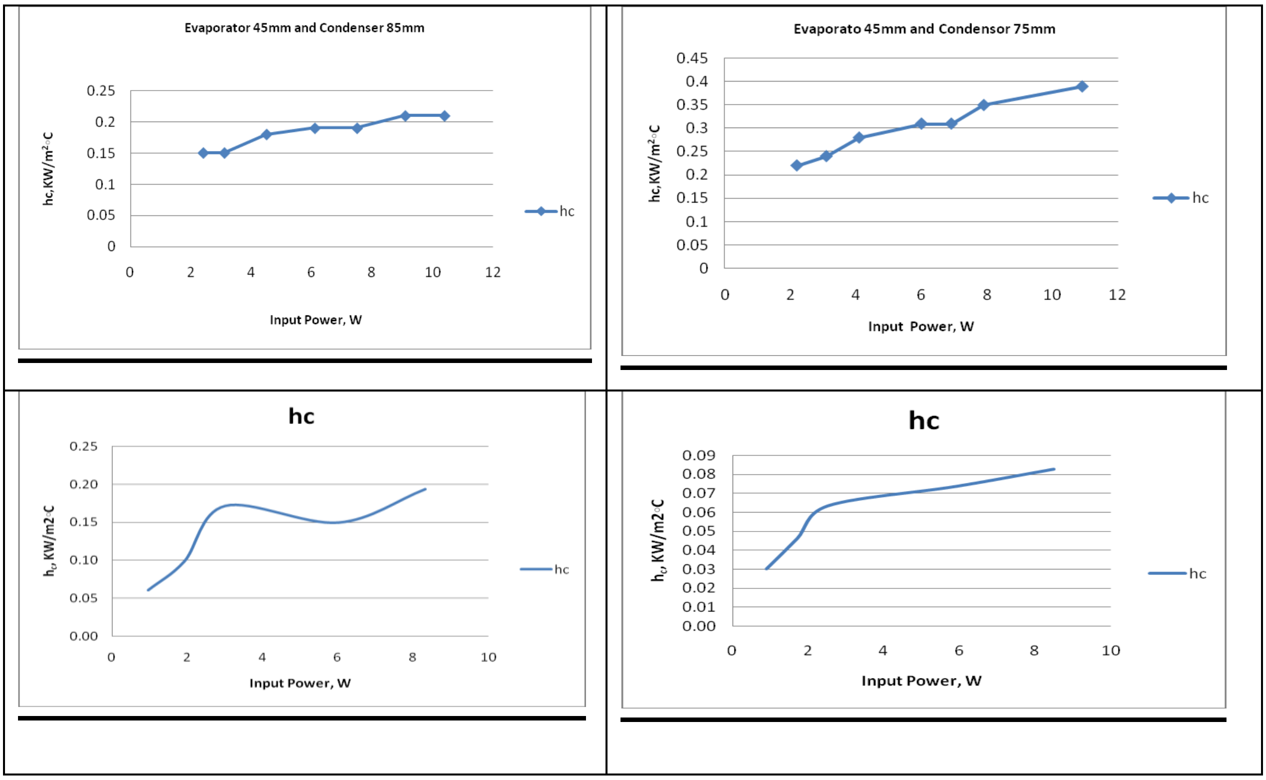

Fig. 5: Variation of Evaporator and condenser with respect to h_c and Input power.

However, Fig 5 shows the variation of Evaporator and condenser with respect to h_c and Input power. With the increasing heat input, heat transfer co-efficient of condenser were increased rapidly.

8. Conclusion

The experimental data were found to be in satisfactory agreement with the well-established correlation. The steady state temperature increases with increasing of heat loads. With the increasing heat input overall heat transfer co-efficient, effective heat transfer co-efficient, heat transfer co-efficient of evaporator and condenser were increased rapidly and overall thermal resistance, thermal resistance of evaporator and condenser were decreased. On the other hand, with the increase in length heat transfer co-efficient increases and thermal resistance decreases. Moreover, the thermal resistance offered by the condenser section is higher than the thermal resistance offered by the evaporator section.

9. References

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