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Experimental Investigation of Role of Different Wicks in Heat Pipe

Neda Rakhshandeh[1, 2], **Farshad Farahbod**[3, *]

[1]Department of Chemical Engineering, Sirjan Science and Research Branch, Islamic Azad University, Sirjan, Iran
[2]Department of Chemical Engineering, Sirjan Branch, Islamic Azad University, Sirjan, Iran
[3]Department of Chemical Engineering, Firoozabad Branch, Islamic Azad University, Firoozabad, Iran

Abstract

Over the past decade, heat pipe use in electronic cooling applications has increased dramatically, primarily in notebook computers. In fact, virtually every notebook computer manufactured today uses at least one heat pipe assembly. Utilization of copper and aluminum wick type in one 18 cm copper heat pipe is considered in this experimental study. Water is used as working fluid. The purpose of performed experiments is to investigate the role of wick type in heat transfer parameters and define the difference between performances of heat pipe using these two different materials as wick at the identical operation conditions. Also, the effect of different values of input power on thermal characteristics of heat pipe is investigated.

Keywords

Heat Pipe, Wick, Heat Transfer, Nusselt, Peclet, Thermal Performance

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1. Introduction

Over the past decade, heat pipe use in electronic cooling applications has increased dramatically, primarily in notebook computers. In fact, virtually every notebook computer manufactured today uses at least one heat pipe assembly. Typically designed to carry less than 25W of power, these parts are low in cost and are highly reliable [1, 2 and 3]. Heat pipe use in high-power (>150W) cooling applications has been limited to custom applications requiring either low thermal resistance or with a severely restricted enclosure area [4, 5 and 6]. The cost of these larger diameter heat pipes is high due to a limited number of manufacturers and handmade assembly times [7 and 8]. With the progress in technology of manufacturing of wick and thermal engineering, many efforts have been devoted to heat transfer enhancement [9, 10 and 11]. The usual enhancement techniques for heat transfer can barely meet the ever increasing demand of heat removal in high energy devices [12, 13 and 14]. However, traditional fluids have poor heat transfer properties compared to most solids [15]. Some experimental investigations have revealed that water have remarkably higher thermal conductivity and greater heat transfer characteristics than conventional oily fluids [16]. A theoretical model and an experimental setup are proposed to describe the heat transfer performance of water flowing inside a tube. The experimental results illustrate that the thermal conductivity of water in heat pipe with copper wick remarkably increases. In 2001, a heat pipe consisting of copper wick presented a much higher effective thermal conductivity. The convective heat transfer feature and flow performance of water in a tube are experimentally investigated by Scientifics. The other researchers investigated the increase in thermal conductivity with temperature for oily fluids with water as the base fluid and glycerol as suspension substances. The results indicated an increase in enhancement characteristics with temperature, which makes the wick even more attractive for applications with high energy density than usual room temperature

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* Corresponding author
E-mail address: mf_fche@iauf.ac.ir (F. Farahbod)

measurements reported earlier. The other scientifics performed boiling experiments, varying the conditions of fluids. The measured pool boiling curves for oily fluids saturated at 60 C demonstrated that the critical heat flux increases dramatically (_200% increase) compared to pure water. In 2004, some researchers investigated the thermal performance of fatty fluids in meshed heat pipes. The circular meshed heat pipe had a length of 170 mm and an outer diameter of 6 mm. The heat pipe thermal resistance ranged from 0.17 to 0.215C/W. The measured results showed that the thermal resistance of the heat pipes with fatty fluids is lower than that of pipes containing pure water. Recently, we demonstrated that a fatty fluid consisting of Ethanol molecules in distilled water enhanced grooved heat pipe thermal performance. Similar experiments are observed in another recent study by authors. Their result also showed that copper heat pipe thermal performance is higher than that for a conventional heat pipe. The present study aims at assessing the effect of copper wick on heat pipe. Obtained results are compared with data collected from aluminum wick.

2. Experimental Setup and Procedure

2.1. Experimental Setup

An experimental system is set up to measure the thermal resistance of circular heat pipes (Fig. 1). The outer diameter and length of the heat pipes used in these experiments are about 6 mm and 180 mm, respectively. The heat pipe contained 211 micro meter wide x 217 micro meter deep grooves. The experimental system is composed of a cooling system, a test section, a power supply (CT605D) with an uncertainty of ±0.5%, a measurement system, and a data acquisition system (Spartan-L). The cooling system included a constant-temperature thermal bath and a cooling chamber. The condenser section of the flat heat pipe is inserted horizontally into the cooling chamber. The coolant circulated through the cooling chamber, where heat is removed from the condenser section by forced convection, and then to the constant-temperature bath. The constant-temperature bath is set to the required temperature and held at a constant-temperature through the tests. The temperature variation in the cooling fluid is maintained within 40 C, and the operating temperature is varied over a range of 40–45 C, with an uncertainty of ±0.1 C. The power supply and measurement system utilized an electrical resistance heater powered by a DC power supplier. The electrical heater with a diameter of 10 mm is attached to one side of the evaporator section with thermal grease (SHIN ETSU X-23 7762) to reduce the contact thermal resistance between the heater and the heat pipe surface.

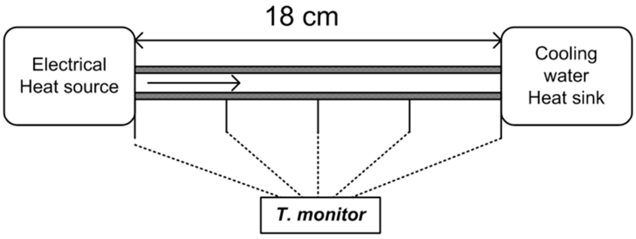

Figure 1. Schematic of heat pipe.

2.1.1. Test Procedure

The power supply is then turned on and the power incremented. At this point in the tests, approximately 20–30 min is required to reach a steady state. Once the steady-state condition had been reached, the temperature distribution along the heat pipe is measured and recorded, along with the other experimental parameters.

The power input is then increased incrementally, and the process repeated until dry out occurred as determined by rapid spikes in the evaporator thermal couple farthest from the condenser. Once dry out is reached, the temperature difference between the evaporator and condenser rapidly increased. The power input at this point is assumed to be the maximum heat transport capacity of the heat pipe at this power level and operating temperature, which is defined as the adiabatic vapor temperature.

The local heat pipe temperature is measured using five isolated Omega type-T thermocouples. Two thermocouples are attached to the evaporator; one is attached to the adiabatic section; and the others are attached to the condenser section. All thermocouples are calibrated against a quartz thermometer. The uncertainty in temperature measurements is ±0.1 C. Two heater bars (maximum 120 W) are used as a heat source in the heating section. Thus, the heating load (Q) and temperature difference (ΔT) are measured, and the thermal resistance (R) is calculated using the equation 1.

$$R = \Delta T/Q. \tag{1}$$

2.1.2. Measurements of Temperature

The temperature values are measured by thermometer which is jointed to the temperature gauge. The temperate in different positions of heat pipe length is measured according to the obtained results.

2.2. Operating Nano Fluid

The di-ionized water is used as operating fluid in the heat pipe. At the first, the pure water is injected to the heat pipe and then the electrical coil is turned. So, considering to the total fixed cost and charge cost in different process are essential.

3. Results and Discussion

Heat transfer in heat pipe and thermal specifications are considered to design and performance of experiments. Two types of wick made of aluminum and copper are used to investigate the effect of wick material on the heat transfer specifications. Also, the heat pipe capacity to tolerate the input powers is surveyed by different amounts of input power. Blow figures illustrate the results related to the heat pipe performance.

3.1. Temperature Profile

The effect of power supply and wick material on the amounts of temperatures through the length of heat pipes are shown in Figures 2 to 7. Temperature decreases from evaporator to the condenser through the length for both types of wick. One 18 cm heat pipe is applied in experiments.

Figure 2 shows the temperature changes in heat pipe emerging 35 watt power. However, copper wick shows the stiff changes in temperature from 41.2 C to 40.5 C.

Aluminum type of wick shows slighter changes in amounts of temperature compared with copper type. The temperature changes from 41.5 C to 41.3 C. So, copper wick shows fast heat transfer since of higher thermal diffusivity and more temperature changes than that aluminum wick present.

Figure 2, 3, 4, 5, 6 and 7 show the effect of increasing in the amount of input powers from 35, 45, 55, 65, 75 and 85 watt, respectively.

The higher amounts of input power show higher temperature levels. However, the difference between the higher and lower value of temperature through the 18 cm length of heat pipe, increases from 0.2 C to 0.4 C with exception trend in 65 W and 85 W, using aluminum wick.

Using copper wick and input power values of 35, 45, 55, 65, 75 and 85 w through the 18 cm heat pipe, obtain increasing trend of difference between the higher temperature and the lower temperature. Changes in temperature difference are as 0.99, 1.06, 1.28, 1.3 and 1.5 C, respectively. This also indicates on the more firm and predictable function of copper wick in heat pipe compared with the heat pipe using aluminum wick.

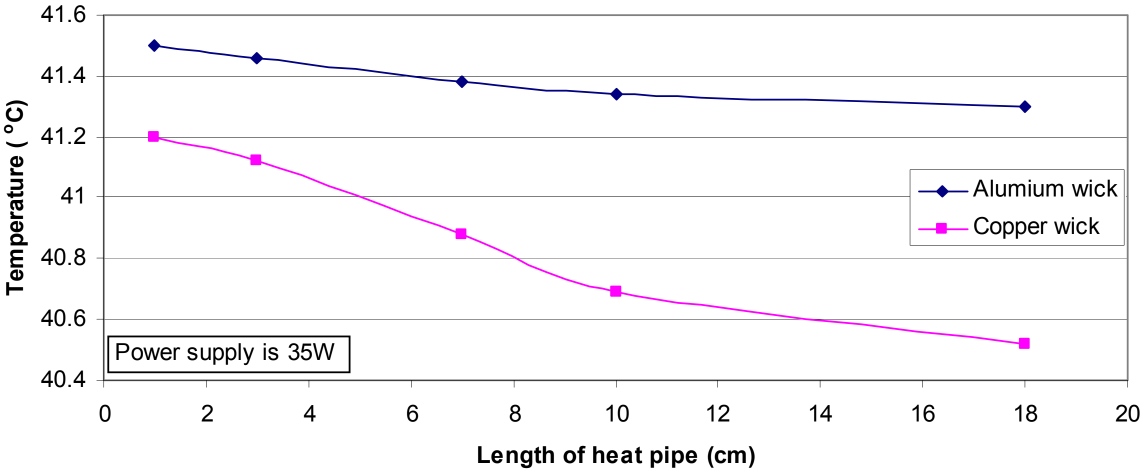

Figure 2. Temperature profile through the pipe length at 35 W.

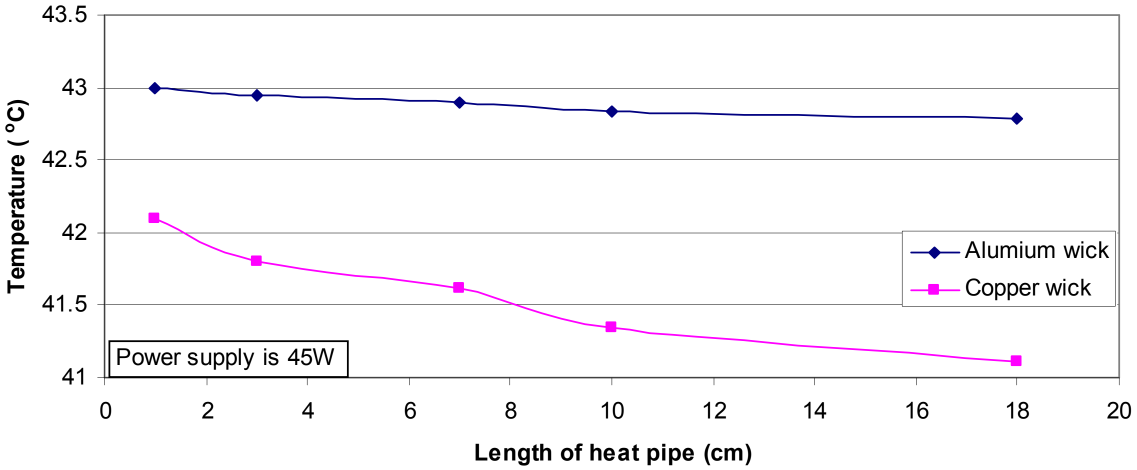

Figure 3. Temperature profile through the pipe length at 45 W.

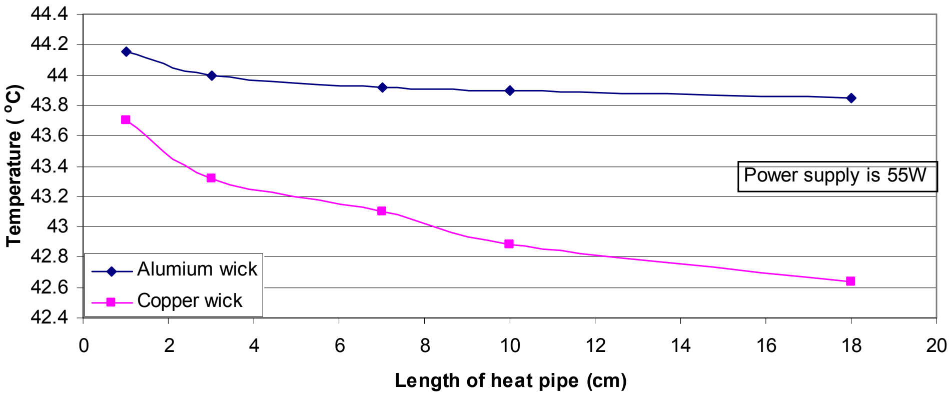

Figure 4. Temperature profile through the pipe length at 55 W.

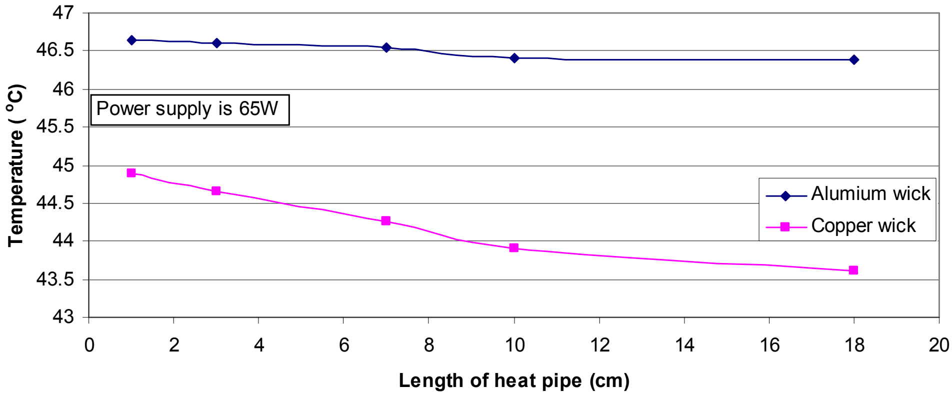

Figure 5. Temperature profile through the pipe length at 65 W.

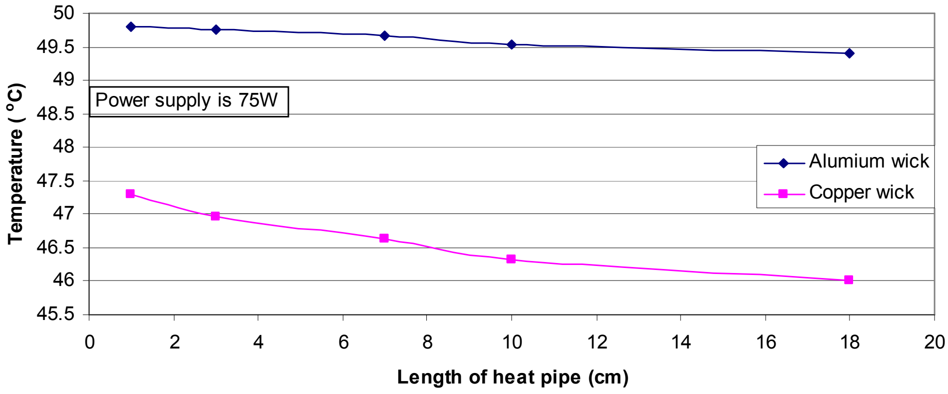

Figure 6. Temperature profile through the pipe length at 75 W.

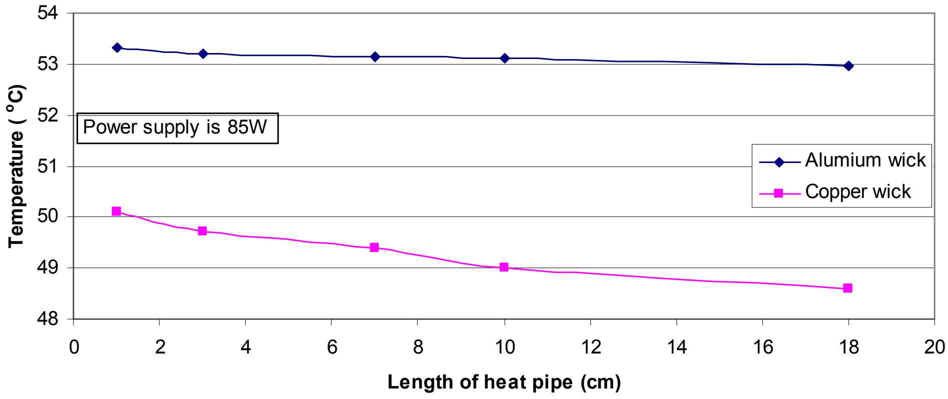

Figure 7. Temperature profile through the pipe length at 85 W.

Results illustrate the lower temperature values using copper wick than that are obtained when aluminum wick is used at all amounts of input powers.

3.2. Thermal Resistance

The obtained results for temperature profile are shown the thermal resistance in length direction of heat pipe for copper wick is less than aluminum wick.

4. Conclusion

This paper discusses the thermal enhancement of heat pipe performance using copper and aluminum as internal wick. In the present case, distilled water inside a 211 micro meter wide x 217 micro meter deep grooved circular heat pipe is experimentally tested. Input power changes in range of 35 w to 85 w and results of the performance test are as follows: Copper wick shows better heat transfer performance than aluminum type, at all amounts of input power. And the lower amounts of temperatures are obtained through the pipe with copper wick 1.2%, 3%, 1.9%, 4.8%, 6% and 7.1% comparing with data obtained using aluminum wick, emerging different input powers 35, 45, 55, 65, 75 and 85 w, respectively.

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