Pergamon

Int. Comm. Heat Mass Transfer, Vol. 26, No. 5, pp. 679–684, 1999

0735-1933/99/$–see front matter

PII S0735-1933(99)00054-8

EXPERIMENTAL PERFORMANCE OF A HEAT PIPE

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(Communicated by J.P. Hartnett and W.J. Minkowycz)

ABSTRACT

Two types of heat pipes were studied experimentally using water as a working fluid. One with a wick and another with no wick. The wick was made of cotton, which is normally used in oil lamps. The heat pipe was positioned at different angles of 30°, 60°, and 90° with the horizontal. Results show that the performance of the heat pipe that contained a wick was more significant in terms of overall heat transfer coefficient than that with no wick, for the temperature range studied. It resulted in about 55%, 25%, and 70% increase for 30°, 60°, and 90° tilt angles, respectively. The overall heat transfer coefficients are reported. © 1999 Elsevier Science Ltd

Introduction

Heat pipes can be used to enhance the amount of heat transfer. Since heat transmitted through a heat pipe is based on phase change, it can be pointed out that using a heat pipe with similar dimensions of a solid metal pipe, larger amounts of heat transfer will be obtained. Their application is wide and can be used, for example, in energy conservation, such as heat recovery in hot exhaust gas system, and for use in domestic and industrial applications [1]. Solar heating is also another example for the application of heat pipes. For example, heat pipe solar collector is widely used now a days [2]. Also, heat pipes can be used to enhance heat transfer in electronic chips [3]. Experimental work was published for circumferential-heating and block-heating under steady-state and transient operation in annular heat pipes and multiple heat sources [4-7]. In previous studies different cases of heat pipes were considered ranging from a rotating porous pipe [8], to consideration of water heat pipe in a frozen state [9].

In this paper two types of heat pipes are studied experimentally at different tilt angles with the horizontal. One type contained a wick while the other with no wick. The copper-water heat pipe was considered, since it can have a wide application.

Experimental

Figure 1 presents a schematic diagram of a heat pipe. Briefly, it is made of copper with an inside diameter of 22.0 mm and an outside diameter of 25.4 mm; its total length is 780 mm. In the figure the heat pipe is positioned vertically (i.e., 90° with the horizontal). The lower part of the heat pipe is considered to be the evaporator of which heat is added. The length of evaporator section is 240 mm of the heat pipe. The source of the heat is a 100 W-electric heater, wrapped around the lower end of the heat pipe (evaporator) with a constant heat flux on the wall surface. The middle section is adiabatic and insulated with glass wool, which is 350 mm in length. The upper remaining section of 190 mm is the condenser of which heat is extracted out of the system. As the heat is added in the evaporator the working fluid, in this case water, evaporates. The vapor is carried naturally upwards through the pipe's center along the middle section of the heat pipe until reaching the upper section, i.e., the condenser. In the condenser section water is condensed and is returned by gravity force back to the evaporator area, flowing around the inside wall of the pipe penetrating a wick. The wick is made of cotton with a thickness of 35 mm. It is the similar to the type of wick that is used in kerosene (oil) lamps. As water condenses it flows much easier when the wick is used.

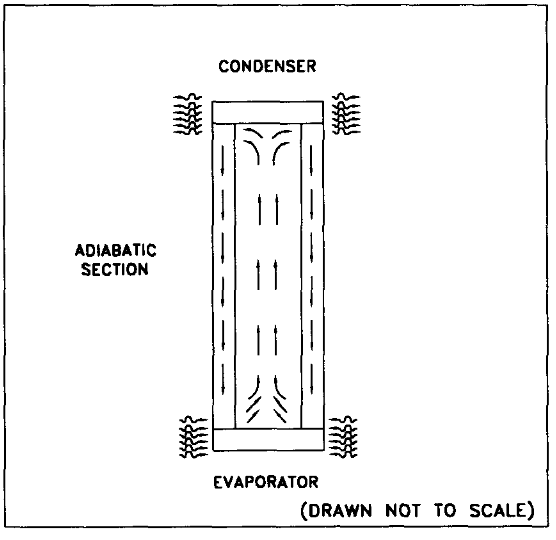

FIG. 1

Schematic diagram of the heat pipe

Results and Discussion

Figure 2 presents the variation of evaporator temperature with time for both types of heat pipes considered at the different angles. It is obvious that the steady-state temperature is always higher for a heat pipe with no wick as compared to that with a wick for a given tilt angle with the horizontal. The biggest temperature difference was at angle of 30° for which the steady-state evaporator temperature was about 155 °C, and 180 °C for the heat pipe with a wick, and with no wick, respectively. For all given tilt angles considered, it is shown that the heat pipe with no wick reached a steady-state evaporator temperature condition faster than the heat pipe with a wick. Also, the temperature gradient was higher for heat pipes with no wick. For example, a temperature gradient of about 6.5 °C min^{-1} was obtained for the heat pipe with no wick. On the other hand the temperature gradient was about 3.0 °C min^{-1} for the heat pipe with a wick. This indicates that drawing heat from the evaporator section is faster in heat pipe with wick than that with no wick.

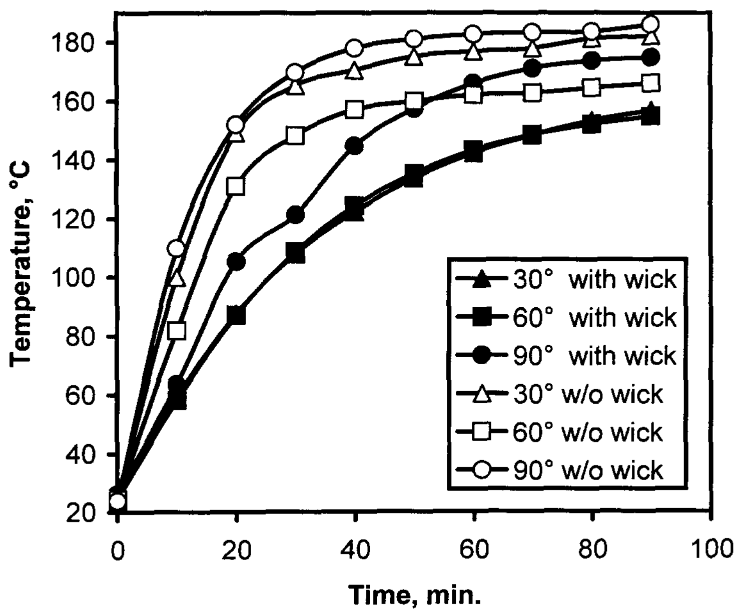

FIG. 2

Variation of evaporator's temperature with time for different heat pipes at different tilt angles.

The variation of condenser temperature with time for both types of heat pipes is presented in Fig. 3. The performance of a heat pipe would be better when the steady-state temperature of condenser is as close as possible to the steady-state evaporator temperature. In other words it is better to have the condenser at a high steady-state temperature. When wick was used the best performance occurred when the heat pipe was positioned at an angle of 90°, by which its steady-state temperature reached a value of about 150 °C. On the other hand its counter part (i.e., the heat pipe with no wick) reached a steady-state temperature of about 140 °C, when positioned at 90° with the horizontal. The opposite was true when the tilt angle was at both 60° and 30°. It is noted that the temperature gradient was higher when no wick was used in all cases (about 4.3 °C min^{-1}), as compared to about 2.6 °C min^{-1}, when wick was used. It was true for all cases except at 90° tilt angle, the heat pipe with a wick started with a slow temperature gradient in the first 20 to 30 minutes (of about 1.0 °C min^{-1}) before it accelerated at a high temperature gradient of about 4.0 °C min^{-1}.

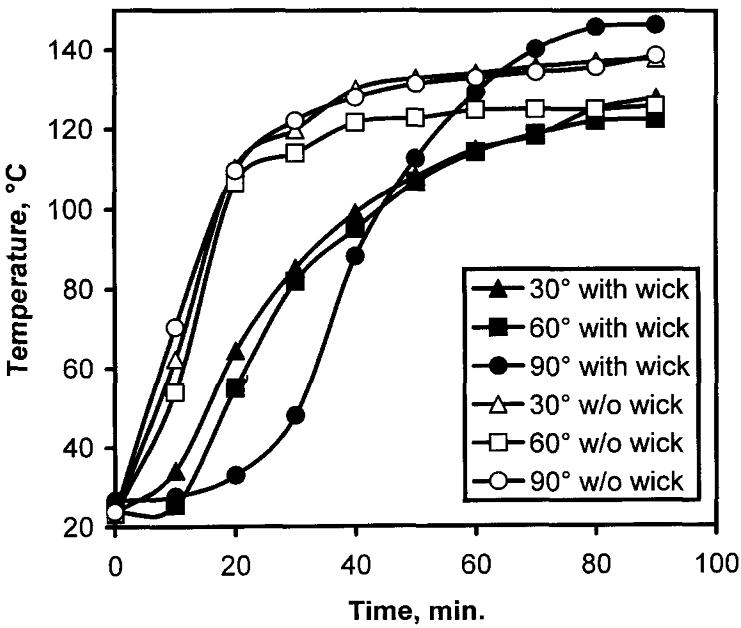

FIG. 3

Variation of condenser's temperature with time for different heat pipes at different tilt angles.

In order to obtain clear comparison between heat pipes with wick and those without, Fig. 4 was plotted. It shows variation of the difference between evaporator and condenser temperatures with time. In all three cases considered when wick was used, lower temperature difference was obtained for the same amount heat rate input of 100 W. At steady-state the temperature difference was about 40 °C to 50°C when no wick was used, and 25 °C to 30 °C when wick was present. This indicates that for the same amount of heat transfer rate, higher values of the overall heat transfer coefficient can be obtained when wick was present.

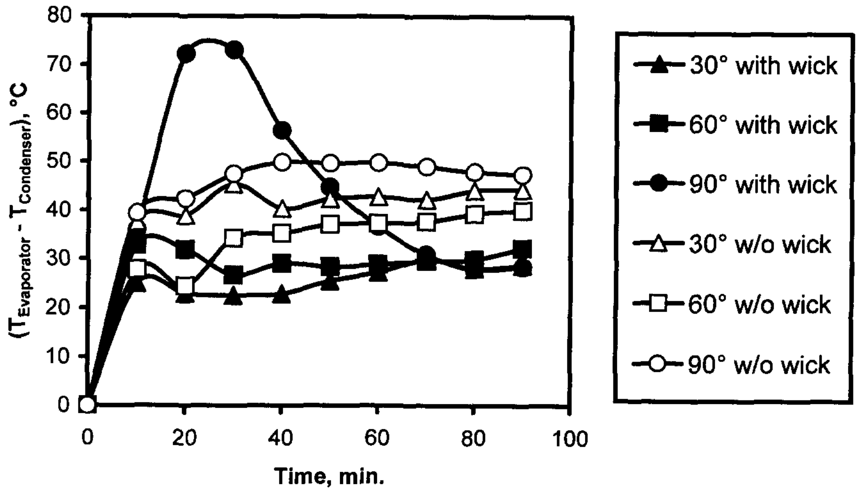

FIG. 4

Variation of the difference between evaporator and condenser temperatures with time for different heat pipes at different tilt angles.

The overall heat transfer coefficients for the conditions studied were evaluated for all six cases. They are shown in Fig. 5. As pointed out earlier the performance of the heat pipe was improved when wick was used. It is true also in terms of the overall heat transfer coefficients. When no wick was used the overall heat transfer coefficient had a value ranging from 4000 to 5000 W-m^{-2}-°C^{-1}. However, when wick was present under similar conditions, the overall heat transfer coefficient reached higher values ranging from 6000 to 7000 W-m^{-2}-°C^{-1}. The amount of enhancement, when wick was used in a heat pipe, was about 55 %, 25 %, and 70 % at tilt angles of 30°, 60°, and 90° with the horizontal, respectively.

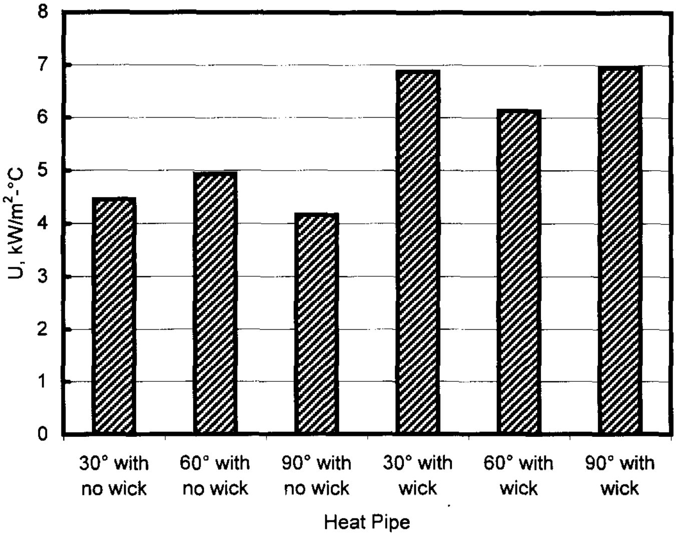

FIG. 5

Overall heat transfer coefficients for different heat pipes at different tilt angles.

Conclusions

For the cases considered in this paper, the overall heat transfer coefficient was higher for the heat pipe that contained a wick than that with no wick. In other words, the performance of a heat pipe is improved significantly when using a wick, especially when the heat pipe is positioned vertically. In this work copper-water heat pipe was used, thus for future work, other types of heat pipe should be considered.

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Received February 16, 1999