HEAT TRANSFER PERFORMANCE OF A SELF-OSCILLATING HEAT PIPE USING PURE WATER AND EFFECT OF INCLINATION TO THIS PERFORMANCE

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Received Date: December 30, 2011

Abstract

This experimental study is performed to investigate heat transfer performance and effect of inclinations to a self-oscillating heat pipe developed. In this experiment, pure water is employed as the working fluid. The heat pipe is composed of a heating section, a cooling section and an adiabatic section. The heating and cooling sections have the same size and are connected by four circular parallel pipes. The corresponding external dimensions are 45mm in length, 45mm in width and 8mm in thickness, and the internal dimensions are 42mm, 42mm and 5mm, respectively. The adiabatic section is consisted of four parallel circular pipes whose dimension is ϕ6 (external diameter) x ϕ5 (internal diameter) x 45 (length) mm. According to the experimental results, the effective thermal conductivity of the heat pipe in the case of fill charge ratio at 100% is higher than that of 30% and this effective thermal conductivity is decreased when the angle between the axis of the heat pipes and vertical direction is increased.

Keywords: Fill charge ratio, Heat transfer performance, Inclination, Self-oscillating heat pipe, Working fluid

Introduction

Nowadays, there are a lot of equipment or parts inside machines called heating elements need to be cooled during working process, especially with electrical or electronic devices. About their size, manufacturers are minifying with every passing day in order to satisfy requirements of users but the power must be maintained. This makes elements stand a high amount of heat, that is, high heat flux would be generated during working process. Therefore, there is a need of professional component to cool heating elements so that maintain their appropriate temperature and that is the maintenance of their longevity. However, with many actual cases, one saw that it is difficult to arrange a cooling device near the heating elements so that can rapidly decrease the heat amount that is generating.

Now there are a number of different cooling devices that are being used to cool heating elements. With normal cases as low heat flux, one can use conventional cooling systems as: heat sinks; or direct cooling systems with the use of water. However, as presented above, there are many cases having high heat flux but it is difficult to properly arrange cooling systems, for example with electrical or electronic devices. This requires manufacturers must suggest a new method to cool heating elements. The most common device is heat pipe. It works base on boiling heat transfer and condensation heat transfer principle.

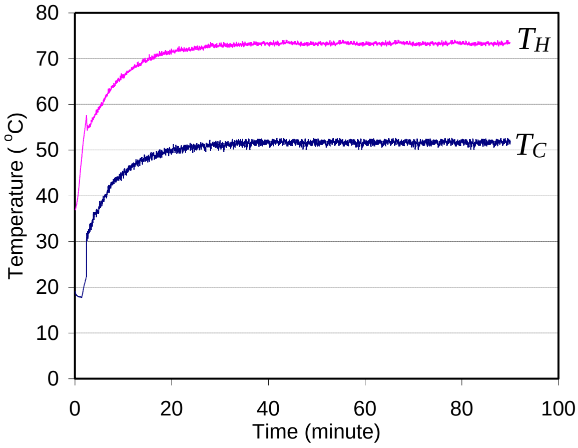

Figure 7**.** Variation of temperatures of the heating section T_H (**73,25°C**) and the cooling section T_C (**51,65°C)** for 100% of fill charge ratio and the angle between the axis of the heat pipe and vertical direction is 45°

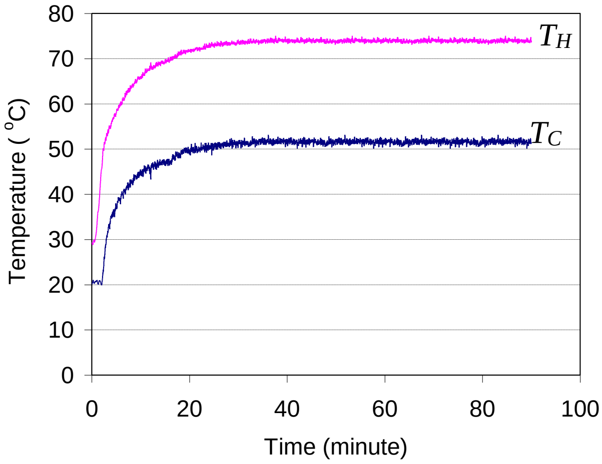

Figure 8**.** Variation of temperatures of the heating section T_H (**74°C**) and the cooling section T_C (**51,95°C)** for 100% of fill charge ratio and the angle between the axis of the heat pipe and vertical direction is 60°

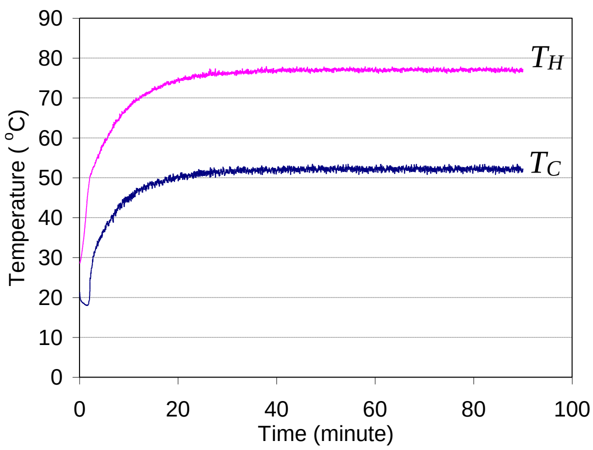

Figure 9. Variation of temperatures of the heating section T_H (**77°C**) and the cooling section T_C (**52,16°C)** for 100% of fill charge ratio and the angle between the axis of the heat pipe and vertical direction is 75°

Figure 6 illustrates four cases in order to investigate heat transfer performance of the heat pipe with different angles: 0^o; 45^o; 60^o; 75^o.

Figures 7, 8 and 9 show the effect of inclination of the heat pipe on mean temperature of the heating and the cooling section, from these results, it can be seen that the higher the angle, the higher the mean temperature of the sections of the heat pipe.

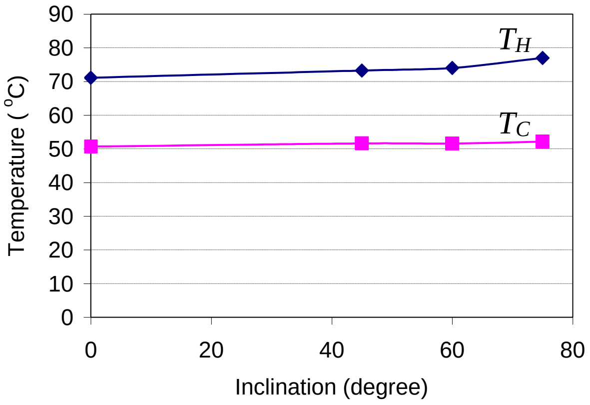

Figure 10. Mean temperatures of the heating section T_H and the cooling section T_C of the heat pipe versus the angle between the axis of the heat pipe and vertical direction

As shown in figure 10, it can be seen that when the angle of the heat pipe increases up to 60^o, mean temperature of the heat pipe also increases but not so high. But when the angle increases until 75^o, mean temperature of the heating and the cooling section of the heat pipe increases very rapidly, especially of the heating section. This explains that when the angle of the heat pipe exceeds a certain value, the heat transfer performance of the heat pipe approaches it working limit very rapidly.

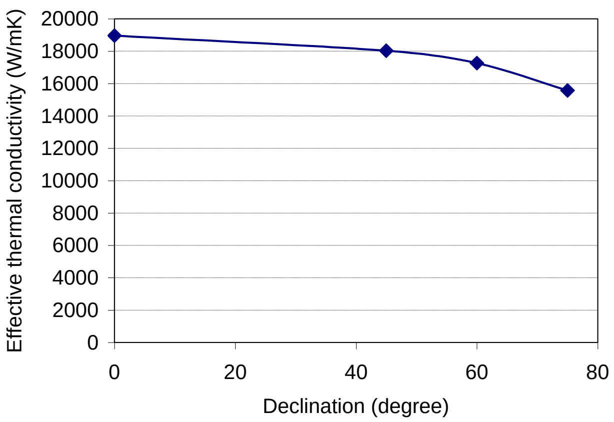

Figure 11. Effective thermal conductivity of the heat pipe versus different inclinations

Figure 11 shows the variation of effective thermal conductivity k_{eff} as a function of inclination. Effective thermal conductivity was calculated as follows:

$$Q = \mathrm{NA}q' = \mathrm{NA}k_{eff}\frac{T_H - T_C}{\mathrm{L}} \quad (1)$$

$$k_{eff} = \frac{Q\mathrm{L}}{\mathrm{NA}(T_H - T_C)} \quad (2)$$

Where, Q is total heat load, q' is the heat flux from the heating section to the cooling section, L is the length from the center of the heating section to the center of the cooling section, that is, the approximate distance between T_H measuring point and T_C measuring point. N is the number of tubes of the adiabatic section (N = 4). A is the flux area of the inner part of a tube in the adiabatic section. To get mean temperature T_H of the heating section and T_C of the cooling section, temperatures were measured and averaged. For this, with the measurement by K thermocouples, points H_1, H_2, H_3, H_4 and H_5 are for the heating section and C_1; C_2; C_3 are for the cooling section. These points were depicted in figure 1. In figure 11, effective thermal conductivity k_{eff} decreases when the angle (compared to vertical direction) of the heat pipe increases, but this k_{eff} does not so much change when the angle increases up to 60^o, effective thermal conductivity k_{eff} decreases rapidly when the angle approaches 75^o. This can be explained that when the angle is so high, working fluid inside of the heat pipe is difficult to travel back the heating section to cool it.

From the result shown in figure 11, the effective thermal conductivity of the heat pipe 18958W/mK is 47 times greater than that of copper 401W/mK, Even in the case of the inclination is 75^o, the effective thermal conductivity of the heat pipe is still 38 times greater than that of copper, Thus this type of heat pipe has excellent transport characteristics even structure is very simple.

In the future, the remaining fill charge ratios 40%; 50%; 60%; 70%; 80% should be experimented and other values of heat flux also should be experimented in order to determine the optimal fill charge ratio and limited heat flux of the heat pipe. In addition, other working fluid also should be employed to compare with the effect of the use of pure water.

Conclusions

From the observation of the results in this study, the following conclusions are drawn:

- With this type of heat pipe in the conditions of the experiment as 150kW/m^2 of heat flux, 3,5l/min and 15^{o}C of cooling water applied for the cooling part, the heat transfer performance of the heat pipe in the case of 100% of fill charge ratio is higher than that of 30% of fill charge ratio.
- The effective thermal conductivity of this heat pipe with the conditions of experiment and in the case of 100% of fill charge ratio is 18958 W/mK, which is much higher than that of copper 401W/mK 47 times.
- The higher the inclination is (angle between the axis of the heat pipe and vertical direction), the lower the heat transfer performance is. And the heat transfer performance of the heat pipe decreases rapidly when the inclination exceeds a certain value - beyond 60^o.
- When the inclination of the heat pipe approaches 75^o, the effective thermal conductivity of the heat pipe is still 38 times greater than that of copper.

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