International Journal of Engineering & Technology, 8 (1.9) (2019) 343-347

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Thermal Performance on Tapering Heat Pipe

Sarip[1*], Sudjito[2], LilisYuliati[3], Moch. Agus Choiron[4]

[1234]Mechanical of Engineering, Brawijaya University Jl. MT. Haryono 167, Malang 65151, Indonesia*
**Corresponding author E-mail: hidayatullohsarip566@gmail.com*

Abstract

Various design of heat pipes had been developed in previous research to enhance thermal performance. In this study, tapering heat pipe is developed. The method used true experimental to observe temperature distribution in the heat pipe. Geometric design is set as the ratio of diameter evaporator (d) and condenser (D) which are d/D =1/1, 1/2, 1/3 and 1/4. Heat source (Q) is varied by using DC power supply of 25, 30, 35, 40, 45 and 50 Watt. The temperature was measured by using k-type thermocouple with NI-9211 and c-DAQ 9271 module. Wick heat pipe is set as screen mesh with 56,5 µm wire diameter with one single layer. Wick screen mesh material used is stainless steel with 40 W/(m•K) thermal conductivity on layer shape. Thermal resistance decrease, high evaporation time, and stable temperature distribution are an indicator performance to determine the best thermal performance. Based on the results, it can be denoted that d/D and Q affected to thermal performance difference. Both of d/D and Q increased, thermal performance increases. The tapering heat pipe with d/D = 1/4 and Q = 50 Watt provide the better thermal performance.

Keywords: *Tapering Heat Pipe, Thermal Performance, Ratio Diameter Evaporator and Condenser, Heat Source*

1. Introduction

The heat pipe is a passive device of heat transfer from the heat source as the evaporator to the heat sink as the dissipation of heat in a relatively long time span through evaporation latent heat of the working fluid. The heat pipe has three section, namely the evaporator, adiabatic section and condenser as the heat dissipation. H.T. Chien, C.T. Tsai, P.H. Chen, P.Y. Chen. (2003)

Faghri (1995), Brautsch et al (2002), Li et al (2006) described about a recession in the liquid film process as well as the possibility of evaporation or boiling transition with the increased heat flux. Availability of the capillary wick which is in the heat pipe cause evaporation or boiling intensive transitional resulting heat flux significantly increased.

Thermal performance heat pipe is influenced by many parameters, such as heat load, porosity and permeability of the wick, the type and amount of the working fluid and the geometry of the heat pipe. The geometry heat pipes depend on the type of heat pipe applications, the five main types of heat pipe, which are micro heat pipe, flat plate, and an array of micro heat pipe, loop heat pipe and direct contact system by Davit. R (2006).

The finned U-shape Heat pipe has been introduced by Liang and Hung (2010) to cool the high-frequency microprocessors such as Intel Core 2 Duo, Intel Core 2 Quad, AMD Phenomena series and AMD Athlon 64. Russell et al (2011) studied the effect of orientation on the thermal performance of the U-shaped heat pipe with difference wick structures.

Inclination angle increases heat pipe thermal resistance down by S.M. Peyghambarzadeh, et al (2013), while the inclination angle of the heat pipe 45o may affect the efficiency of the thermal optimum heat pipe with working fluid DI Water or nano fluid copper by Senthilkumar R. et al (2012).

Based on the above background, it is important to develop a new heat pipe design which is tapering heat pipe. The purpose of this research is to improve the thermal performance by using tapering heat pipe in order to obtain thermal resistance decreases.

2. Materials and Methods

2.1. Tapering Heat Pipe Design

Tapering heat pipes made of copper tubing with a ratio of diameter d / D = 1/1, 1/2, 1/3 and 1/4, with the d is the outside diameter of evaporator, in which d is constant = 10 mm, while D is the condenser outside diameter 2 x d (mm) and d/D varies of 1/1, 1/2, 1/3, 1/4. The length of the tapering heat pipe 200 mm. Screen mesh wick serves as the axis of the capillary to the return liquid / back flow of fluid from the condenser to the evaporator.

The condenser ends mounted a valve for injecting a working fluid into the heat pipe tapering. Wick heat pipe of the mesh screen wire diameter in the form of 56,5µm single array with the number 67.416 per mm. Screen mesh wick made from of stainless steel wire with a thermal conductivity of 40 W / (moK), in the form of rolls following shape the tapering heat pipe so that the shape layer with a screen of 100 mesh. Design tapering pipe heat copper pipes can be seen in Fig. 1.

Figure 2 is a testing scheme boiling on tapering heat pipes made of copper pipe with a inclination position 45° and Figure 3 is inclination position thermocouple on tapering heat pipe.

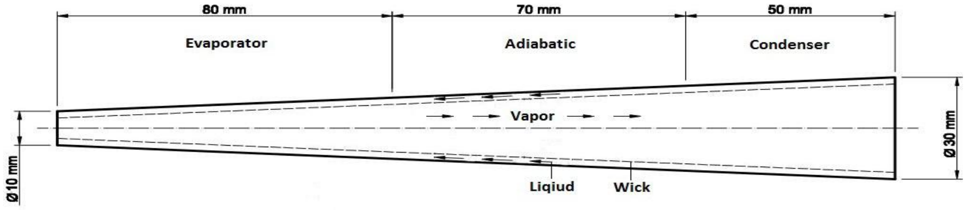
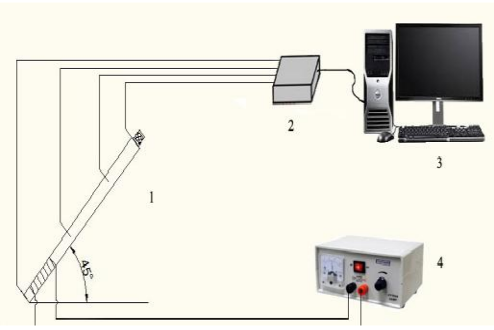


Fig. 1: Tapering heat pipe made copper tube with diameter ratio d/D=1/3

2.2. Experimental setup



Legend:

1. *Tapering heat pipe* made copper tube
2. 9171=c-DAQ and NI 9211- Module
3. Thermocouple (T1, T2, T3, T4)
4. Computer Unit
5. Heater DC-Power Supply

Fig 2: Experimental set - up.

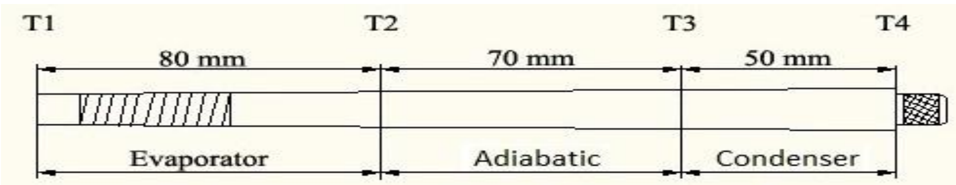


Fig 3: Thermocouple positions

Tapering heat pipe testing was done by measuring the temperature at some point with the of thermocouple positions 10 mm, 80 mm, 150 mm and 200 mm, as in Figure 3. One end of the Tapering heat pipe is used as an evaporator, wires heater (flexible heater) is wound on the side of the evaporator serves as a heat source and the condenser serves of heat dissipation. To avoid heat loss in the evaporator and adiabatic sections are isolated and condenser left open freely to the outside air so that the heat dissipation can run freely. Heat source (Q) of the DC-power supply varied start (25, 30, 35, 40, 45, 50) Watt, to provide heat energy to the tapering heat pipe. K-type thermocouples installed at some point to measuring the boiling temperature distribution associated with data acquisition, 9171 c-DAQ and module NI-9211. According to the Harris, James (2008) heat flux at the evaporator (qe) was calculated by the equation:

$$q_e = {}^{Q}\!/_{(2\pi r_0 L_e)} \tag{1}$$

$$T_i = T_0 \frac{q_e r_0}{\lambda_w} ln \frac{r_i}{r_0} \tag{2}$$

Where Q adalah heat source, r0 and ri a radius of the outer and inner tapering heat pipes, Le is the length of the evaporator, Ti and T0 is the temperature of the inside and outside walls tapering heat pipes and λw is the thermal conductivity of copper. The coefficient of heat transfer from the evaporator can be calculated through a comparison between the heat flux at the evaporator compared with the temperature decrease ΔT:

$$h_e = \frac{q_e}{\Delta T} \tag{3}$$

For thermal resistance can be calculated by the equation:

$$R = \frac{T_{hot-} \ T_{cool}}{Q} \tag{4}$$

3. Results and discussion

3.1. Effect diameter ratio d/D of evaporator and condenser on the Tapering heat pipe performance.

3.1.1. Heat source = 25 Watt

In Figures 4 and 5 show that there is a difference of temperature distribution and time evaporating on Tapering heat pipe with values different diameter ratio d/D. Values diameter ratio d/D increased in size causing a cross-condenser as the dissipation heat expanded so as to accelerate the process of heat dissipation causes the boiling time takes longer than the tapering heat pipe with a diameter ratio d/D = 1/1. Temperature distribution evaporation on each diameter ratio d/D is measured from the end of the evaporator that there are differences in boiling temperatures due to lower pressure in the evaporator and condenser. Meanwhile, to achieve each evaporating time on the diameter ratio d/D also occurs a difference, if the diameter ratio d/D = 1/1 requires a relative evaporation faster than the tapering heat pipe has a diameter ratio d/D is greater than 1.

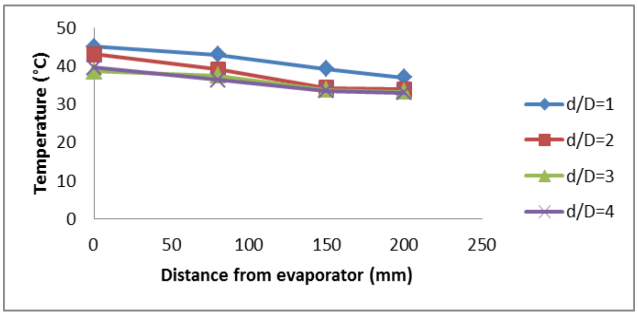


Fig 4 Temperature distribution evaporation on tapering heat pipe with diameter ratio (d/D) variation.

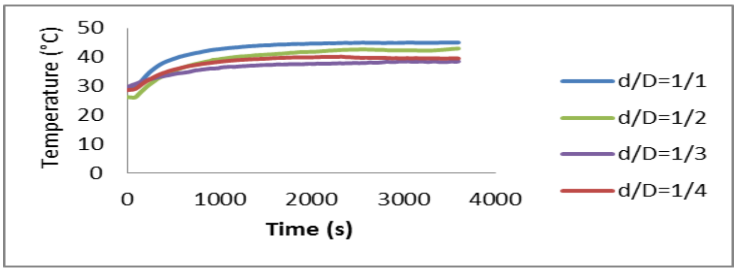


Fig 5: Evaporation temperature on Tapering heat pipe with diameter ratio d/D variation.

Heat source of 30-40 Watt shows that the temperature distribution and evaporation time is a difference with heat source of 25 Watt. There is small difference for temperature distribution lines and evaporation time coincident due to a difference of heat source are relatively small. Temperature distribution and evaporation time during boiling occurs in a stable condition, the situation is a good indicator of thermal performance.

3.1.2. Heat source = 45 Watt

In figure 6 and 7 with heat source of 45 Watt show that the temperature distribution and evaporation time that uniform decreased though occur not sequentially. Temperature distribution and evaporation time starting of d/D = 1/1, 1/4, 1/3 and 1/2 indicate that these differences occur because the heat source is increasingly rising. Evaporation time at each diameter ratio d/D started show differences appear with be marked lines began to separate.

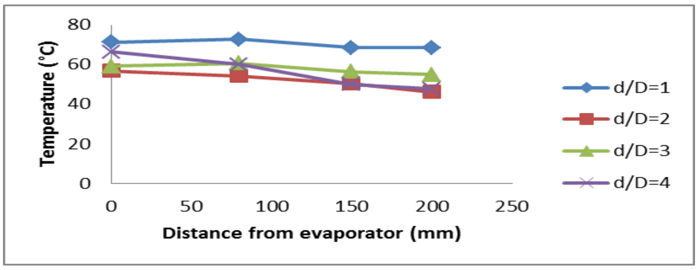


Fig 6 Temperature distribution on Tapering heat pipe with diameter ratio d/D variation.

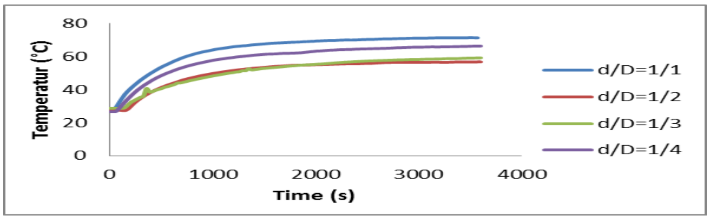


Fig 7: Evaporation temperature on Tapering heat pipe with diameter ratio d/D variation.

3.1.3. Heat source = 50 Watt

In figure 8 and 9 with heat source of 50 Watt show that the temperature distribution and evaporation time also decreased uniform though occur not sequentially. Temperature distribution and evaporation time starting of d/D = 1/4, 1/1, 1/3 and 1/2 indicate that these differences occur because the heat source is increasingly rising. Evaporation time at each diameter ratio d/D shows a clear difference marked by widened the distance between the lines.

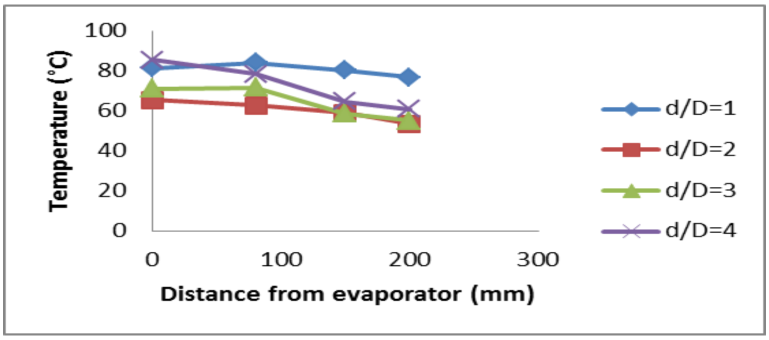


Fig 8: Temperature distribution on Tapering heat pipe with diameter ratio d/D variation.

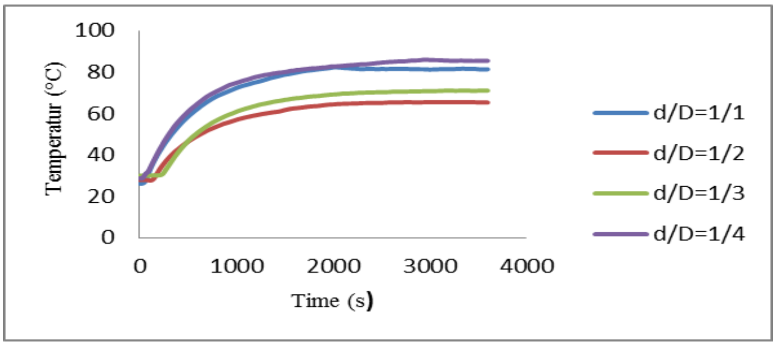


Fig 9: Evaporation temperature on Tapering heat pipe with variation of diameter ratio d/D.

3.2. Heat Transfer Coefficient (HTC)

In the figure 10 show that the heat transfer coefficient with the diameter ratio d/D = 1/4 result the highest value indicates that the value of taper could affect the heat transfer coefficient result. Heat transfer coefficient has an important role in the process of boiling and heat transfer due to the higher value of heat transfer coefficient means thermal performance tapering heat pipe is getting better.

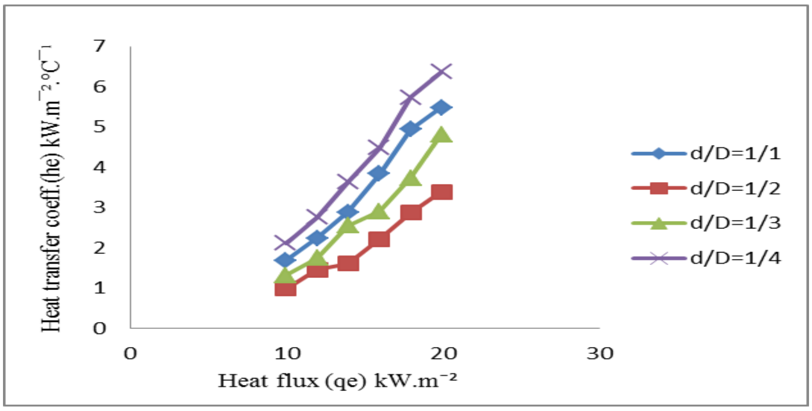


Fig 10: Heat transfer coefficient with variation of diameter ratio d/D.

3.3. Thermal resistance

In the figure 11 show that thermal resistance to diameter ratio d/D= 1/4 result the lowest value indicates that the value of taper can affect the value of thermal resistance. Thermal resistance has an important role in the process of boiling and heat transfer due to the lower thermal resistance values indicating more tapering heat pipe thermal performance is getting better.

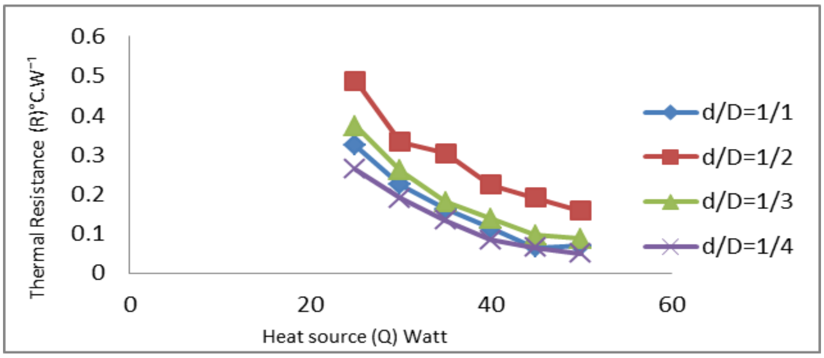


Fig 11: Thermal resistance with variation of diameter ratio d/D.

4. Conclusion

Based on the research, it can be concluded that the design of tapering heat pipes with diameter ratio d/D and the variation of a heat source (Q) affected to temperature distribution evaporation or boiling and evaporation time is tend more stable. The d/D= 1/4 and Q = 50 Watt produce the best thermal performance due to the highest heat transfer coefficient and the lowest thermal resistance.

References

[1] A. Faghri, Heat pipe science and technology, Taylor & Francis publishing, Oxon (1995).
[2] A. Brautsch, P.A. Kew., Examination and visualization of heat transfer processes during evaporation in capillary porous structures, Appl. Therm. Eng. 22 (2002) 815–824
[3] C.Li, G.P.Peterson, Y.Wang, Evaporation/ boiling in thin capillary wicks (I) – wick thickness effects, J. Heat Transfer 128 (2006) 1312–1319
[4] H.T. Chien, C.T. Tsai, P.H. Chen, P.Y. Chen, Improvement on thermal performance of a disk-shaped miniature heat pipe with Nanofluids, in: Proceedings of the Fifth International Conference on Electronic Packaging Technology, IEEE, Shanghai, China, 2003, pp. 389e391
[5] Harris, James R., Modeling, Designing, Fabricating and Testing of Channel Panel Flat Plate Heat Pipe. Utah State University, pp.1-6, 2008
[6] Liang TS, Hung YM., Experimental investigation on the thermal performance and optimization of heat sink with U-shape heat pipes. Energy Convers Manage 2010; 51:21: 09-16
[7] Reay, David & Peter Kew., Heat Pipe, Theory, Design and Applications, 5th Edition, USA, 2006
[8] Russel MK, Young C, Cotton JS, Ching CY, The effect of orientation on U-shaped grooved and sintered wick heat pipe, Appl Therm Eng 2011; 31: 69-76
[9] R. Senthilkumar, S. Vaidyanathan, B. Sivaraman, Effect of Inclination Angle in Heat Pipe Performance Using Copper Nanofluid, Procedia Engineering 38 (2012); 3715 – 3721
[10] S.M. Peyghambarzadeh, S. Shahpouri, N. Aslanzadeh, M. Rahimnejad, Thermal performance of different working fluids in a dual diameter circular heat pipe, Ain Shams Engineering Journal (201