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Research Article

Simulation and CFD Analysis of Heat Pipe with Different Wick Geometry using CFX

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Abstract

Miniature cylindrical metal powder sintered wick heat pipe (sintered heat pipe) is an ideal component with super-high thermal efficiency for high heat flux electronics cooling. In this paper circular Heat pipe with various Wick geometry 0.5mm,0.75mm,1mm and also Sintered, V-Groove, Screen Groove wick shapes is considered, Silica is used as a Heat pipe material and nickel alloy nisil (nickel + silicon)is used as a wick material and water, Methanol, Aqueous Methanol is used as the working fluids. The necessary numerical computations are accomplished by CFX (the CFD solver program) and the results are given in graphical representation. The objective is to study the variation of temperature gradient and heat transfer coefficient with different wick's, wick shapes and different working fluids.

Keywords: *Heat pipe, CFD analysis of Heat pipe, Simulation of a Heat pipe.*

1. Introduction

Heat pipes are two-phase heat transfer devices with high effective thermal conductivity. Due to the high heat transport capacity, heat exchanger with heat pipes has become much smaller than traditional heat exchangers in handling high heat fluxes. With the working fluid in a heat pipe, heat can be absorbed on the evaporator region and transported to the condenser region where the vapor condenses releasing the heat to the cooling media

A heat pipe is an evaporation-condensation device for transferring heat in which the latent heat of vaporization is exploited to transport heat over long distances with a corresponding small temperature difference. The heat transport is realized by means of evaporating a liquid in the heat inlet region (called the evaporator) and subsequently condensing the vapor in a heat rejection region (called the condenser). Closed circulation of the working fluid is maintained bycapillary action and /or bulk forces. The heat pipe was originally invented by Gaugler of the General Motors Corporation in 1942, but it was not, however, until its independent invention by Grover in the early 1960s that the remarkable properties of the heat pipe became appreciated and serious development work took place. An advantage of a heat pipe over other conventional methods to transfer heat such an a finned heat sink, is that a heat pipe can have an extremely high thermal conductance in steady state operation. Hence, a heat pipe can transfer a high amount of heat over a relatively long length with a comparatively small temperature differential.The increasing demand for energy efficiency in domestic appliances (such as a dishwasher, air conditioner, durable drier or fridge/freezer) and industrial systems and devices is the main drive for continuously introducing and/or improving heat recovery systems in these appliances, systems and devices. Heat transfer efficiency in such systems is the primary factor for efficient performance of the whole systems.

However, the design of the heat recovery systems with heat pipe units is the key to providing a heat exchanger system to work as efficient as expected. Without correct design of such systems, heat pipes are not able to transport enough heat and may function as an extremely poor thermal conductor in the systems. Computational fluid dynamics is a powerful tool for fluid dynamics and thermal design in industrial applications, as well as in academic research activities. Based on the current capabilities of the main CFD packages suitable for industry (such as FLOTHERM, ICEPAK, FLUENT and CFX) and the nature of industrial applications, understanding the physics of the processes, introducing adequate simplifications and establishing an appropriate model are essential factors for obtaining reasonable results and correct thermal design

2. Structure and operation of heat Pipes:

The main regions of the standard heat pipe are shown in Fig. 1. In the longitudinal direction the heat pipe is

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made up of an evaporator section and a condenser section. Should external geometrical requirements make this necessary, a further, adiabatic, section can be included to separate the evaporator and condenser. The cross-section of the heat pipe, Fig. 1b, consists of the container wall, the wick structure and the vapor space.

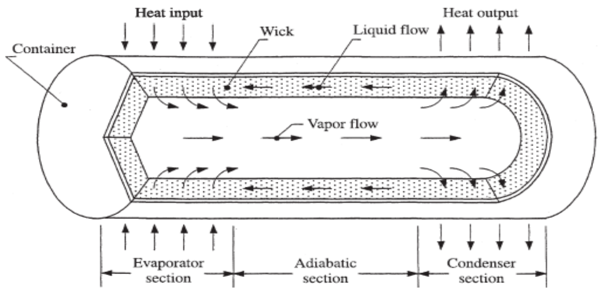

Fig 1: Main Regions of a heat pipe

The heat pipe is characterized by the following:

(i) Very high effective thermal conductance.
(ii) The ability to act as a thermal flux transformer.
(iii) An isothermal surface of low thermal impedance.

The condenser surface of a heat pipe will tend to operate at uniform temperature. If a local heat load is applied, more vapor will condense at this point, tending to maintain the temperature at the original level.

3 CFD Modeling:

3.1Specifications of work

Heat pipe material : Silica
Wick material : Nickel alloy(nisil)
Wick Thickness : 0.5mm, 0.75mm, 1mm.
Types of Wicks : Sintered,VGroove,ScreenGroove
Length of Heat pipe : 210 mm
Thickness of a Heat pipe : 2 mm
Outer diameter of a Heat pipe : 10 mm

3.2Mesh Data

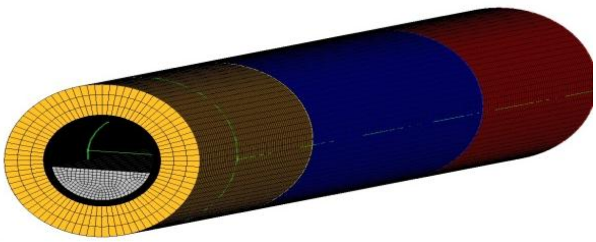

Fig3.2.1: Sintered wick Heat pipe

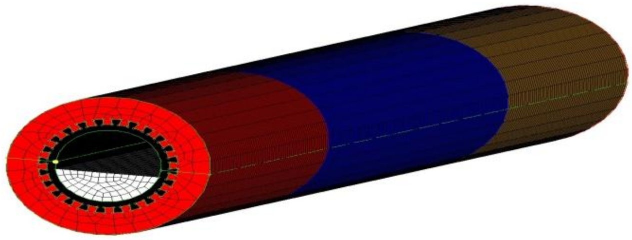

Fig 3.2.2: Screen groove wick Heat pipe

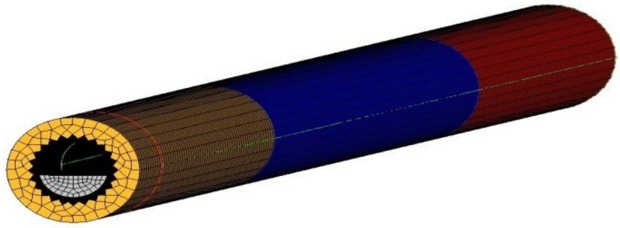

Fig3.2.3: V-groove Heat pipe

3.3 Input data

Water Velocity = 0.01m/s
Water inlet Temperature = 300 k
Evaporator Section Temperature = 350 k
Condenser Section Temperature = 280 k
Contours of Heat pipe:

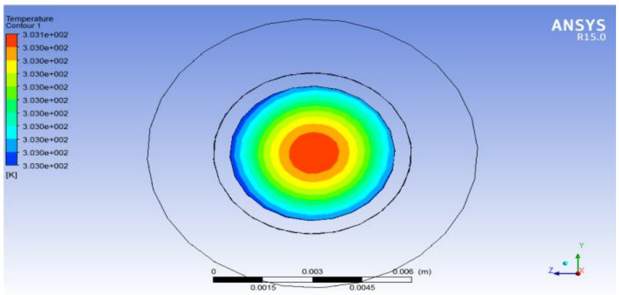

Fig 3.3.1: Contours of a Heat pipe with water as a working fluid

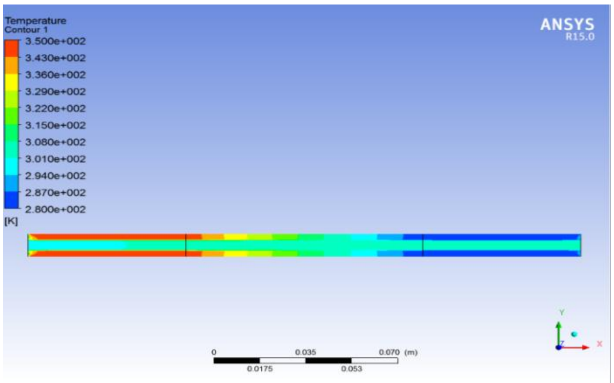

Fig 3.3.2: Contours of a Heat pipe with Methanol as a working fluid

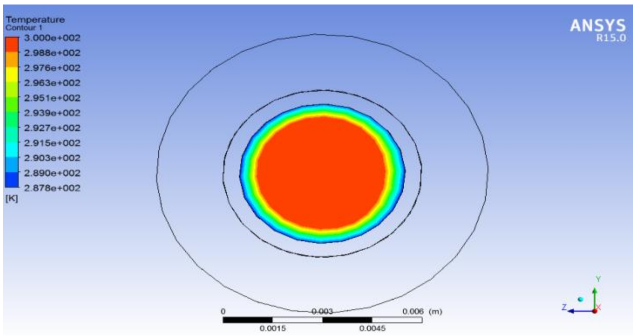

Fig 3.3.3: Contours of a Heat pipe with Methanol as a working fluid

4 Results and Discussion

Finally for convenient comparison table 1 is given that reports average of outlet flow temperature and temperature difference (ΔT). Inlet flow temperature is 350K for all of them.

Table 1 Outlet temperatures and temperature differences for 0.5 mm wick for all shapes of wicks

Wick thickness	Working fluid	Type of wick	Tout(k)	ΔT(k)
0.5 mm	Water	Sintered	308.916	41.09
0.5 mm	Methanol	Sintered	309.246	40.95
0.5 mm	Aqueous Methanol	Sintered	309.981	40.02
0.5 mm	Water	V-Groove	307.62	42.38
0.5 mm	Methanol	V-Groove	308.972	41.028
0.5 mm	Aqueous Methanol	V-Groove	309.272	40.74
0.5 mm	Water	Screen groove	307.321	42.69
0.5 mm	Methanol	Screen groove	308.176	41.824
0.5 mm	Aqueous Methanol	Screen groove	308.872	41.48

Table 2 Outlet temperatures and temperature differences for 0.75 mm wick for all shapes of wicks

Wick thickness	Working fluid	Type of wick	Tout	ΔT
0.75 mm	Water	Sintered	307.001	42.999
0.75 mm	Methanol	Sintered	308.84	41.16
0.75 mm	Aqueous Methanol	Sintered	308.912	41.08
0.75 mm	Water	V-Groove	303.481	46.519
0.75 mm	Methanol	V-Groove	306.952	43.048
0.75 mm	Aqueous Methanol	V-Groove	306.996	43.004
0.75 mm	Water	Screen groove	302.385	47.615
0.75 mm	Methanol	Screen groove	305.82	44.18
0.75 mm	Aqueous Methanol	Screen groove	306.219	43.781

Table 3 Outlet temperatures and temperature differences for 1 mm wick for all shapes of wicks

Wick thickness	Working fluid	Type of wick	Tout	ΔT
1 mm	Water	Sintered	302.221	47.779
1 mm	Methanol	Sintered	303.64	46.36
1 mm	Aqueous Methanol	Sintered	303.782	46.28
1 mm	Water	V-Groove	302.001	47.989
1 mm	Methanol	V-Groove	303.251	46.741
1 mm	Aqueous Methanol	V-Groove	303.6	46.399
1 mm	Water	Screen groove	301.25	48.75
1 mm	Methanol	Screen groove	302.592	47.408
1 mm	Aqueous Methanol	Screen groove	302.9	47.099

4.1Graphs

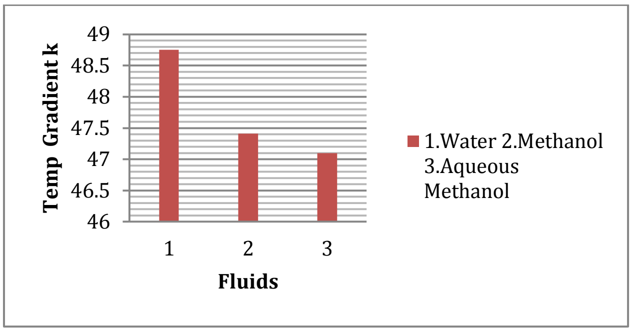

Fig 4.1.1: Graph for 0.5 mm sintered wick

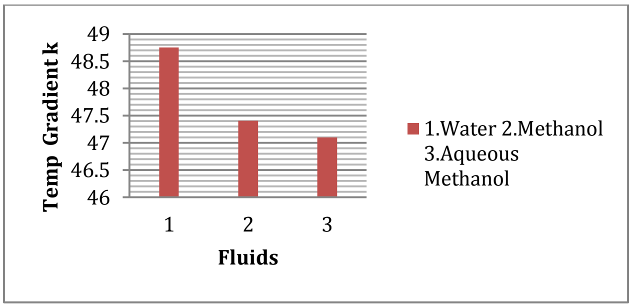

Fig 4.1.2: Graph for 0.5mm V-groove wick

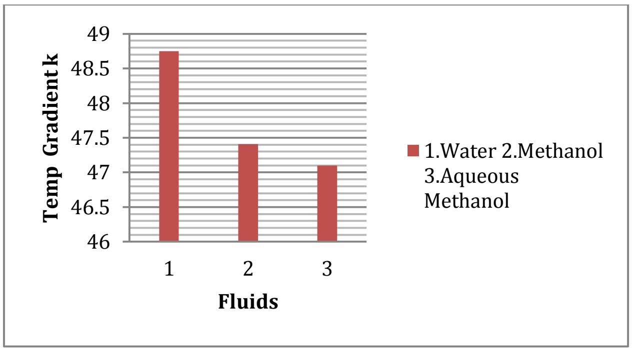

Fig 4.1.3: Graph for 0.5 mm Screen groove wick

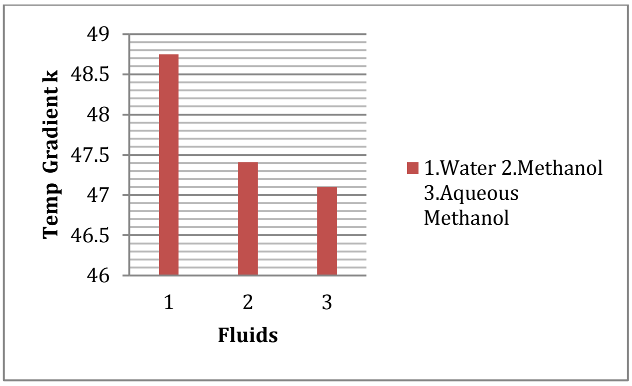

Fig 4.1.4: Graph for 0.75 mm sintered wick

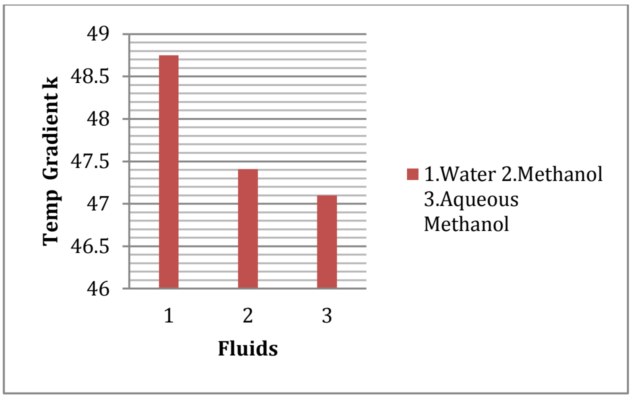

Fig 4.1.5: Graph for 0.75 mm V-Groove wick

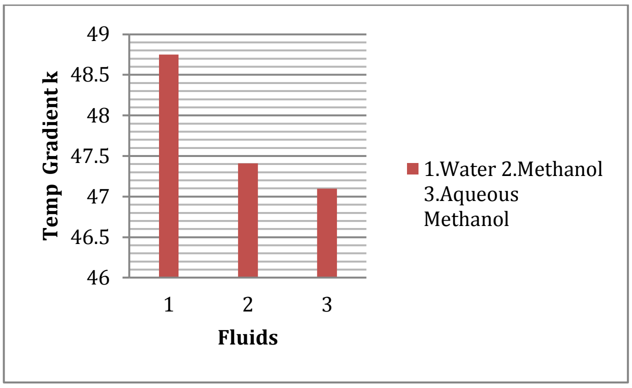

Fig 4.1.6: Graph for 0.75 Screen groove wick

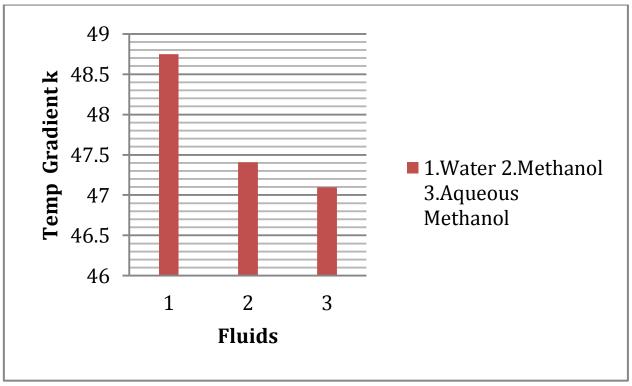

Fig 4.1.7: Graph for 1 mm Sintered wick

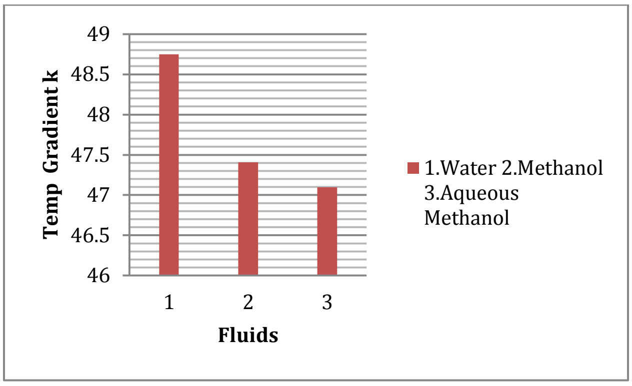

Fig 4.1.8: Graph for 1 mm V-Groove wick

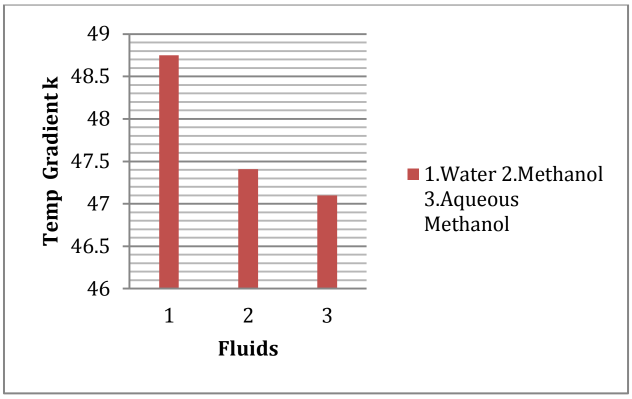

Fig 4.1.9: Graph for 1 mm Screen Groove wick

Conclusions

- From the above tables and graphs it is clear that water has the highest temperature gradient and high heat transfer coefficient among the three working fluids.
- As the wick thickness increases considerably heat transfer rate increases. Screen grooved structured wick can perform more than other wick structures.
- The Heat pipe with a water as a working fluid is a advantage as it is readily availability and cheap in cost.

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