ARTICLE IN PRESS

Engineering Science and Technology, an International Journal xxx (2018) xxx–xxx

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: www.elsevier.com/locate/jestch

Full Length Article

Using of phase change materials to enhance the thermal performance of micro channel heat sink

Mushtaq I. Hasan *, Hind Lafta Tbena

Mechanical Engineering Department, College of Engineering, Thi-Qar University, Iraq

ARTICLE INFO

Article history:
Received 10 August 2017
Revised 20 December 2017
Accepted 29 March 2018
Available online xxxx

Keywords:
Micro-channel heat sink
Heat sinks
Phase change materials
Numerical investigation
Electronic cooling

ABSTRACT

In this paper using of the phase change materials (PCMs) in a micro-channel heat sink (MCHS) is numerically investigated. The air is first used in heat sink and then four phase change materials (paraffin wax, n-eicosane, p116 and RT41) have been used as cooling mediums in different types and different configurations at different ambient temperatures. Constant heat flux is applied on the base of heat sink and mixed (convection and radiation) boundary condition is applied at the top surfaces of heat sink.

The results showed that, using of the phase change materials in micro-channels heat sink with different configurations lead to enhance the cooling performance of micro heat sink. The phase change material should be selected according to its melting temperature according to the certain application as different phase change martials caused different values of reduction in heat sink temperature in range of ambient temperature due to difference in melting temperatures of PCMs. The cost of materials depends on the classification of the PCM (organic and inorganic) and quantity of PCMs used in a certain application.

1. Introduction

Micro-channel technology has been increasingly used to advance highly competent heat sink cooling devices. Micro-channel heat sink is represented new cooling devices for removal a large amount of heat from a small region. Generally, heat sink is made from high thermal conductivity materials such as aluminum, brass or copper.

The phase change materials can be used to improve the thermal performance of a micro channel heat sink and used to absorb extra heat through peaks in dissipation power and transient by electronics devices. The heat absorption by a phase change material generally, occurs between the liquid and the solid states.

The successful using of the phase change material is due to a high density of energy storage. Therefore, PCMs used in cooling electronics devices and reducing temperature for preferred applications. There are many researchers in literature studied the performance of heat sink and using of phase change materials.

Hossein Sh. and Ali A. (2010) [1] numerically investigated of the natural convection in a micro-channel fin arrays heat sink and radiation heat transfer. They used two-dimensional to express the problem of governing equations are mass, momentum and energy equations of the fluid along by conduction equations in a micro fin. Their results showed that, the effect radiation change between two nearby fins, between base plate and fin and between ambition and fin. Also, they found that, micro dimensional special effects for the Maxwell's problem when they used velocity slip.

Lavinia G. Socaciu (2012) [2] numerically investigated of effect thermal energy storage with PCM. He used different types of PCMs (organic and inorganic). He studied the problem of radiation and natural convection heat transfer of a micro fin group heat sink. He used the governor equations to solve the problem which is represented by mass, momentum and energy for the fluid with the conduction equation for a micro fin. He observed that, the radiation contributed up to 22% for the heat dissipated, which is a signification effect shouldn't be included from performance study of micro fin groups.

Steven A. Isaacs et al. (2012) [3] experimentally studied of the heat transfer and the flow in pin-fin micro-gaps, pin-fin, height and pitch of 150 μm, 200 μm and 225 μm, respectively, and aspect ratio of 1.33. They used R245 as a working fluid. They studied effect the thermal performances of a heat sink by using temperature measurements and pressure drops. Their results indicated that, the heat flux is increasing and decreasing average heat transfer coefficient. Also, they found that, when increasing vapor quality the average of a heat transfer coefficient is decreasing.

Azeem A. and Shine K. (2013) [4] numerically studied of the thermal performance of several configurations of a fin heat sinks

* Corresponding author.
E-mail address: mushtaq76h@gmail.com (M.I. Hasan).
Peer review under responsibility of Karabuk University.

https://doi.org/10.1016/j.jestch.2018.03.017
2215-0986/© 2018 Karabuk University. Publishing services by Elsevier B.V.

Nomenclature

Cp	specific heat (J/kg.K)
c	volumetric concentration (%)
k	thermal conductivity (W/m.K)
$\dot{m}$	mass flow rate (kg/s)
P	total pressure (Pa)
q	heat transfer rate (W)
T	temperature (K)
u	fluid x-component velocity (m/s)
v	fluid y-component velocity (m/s)
w	fluid z-component velocity (m/s)
W	width (m)
H	height (m)
h	heat transfer coefficient (W/m^2 K)
ΔH	Latent heat (W)
He	Enthalpy of suspension (W)
he	Sensible heat (W)
L	Latent heat of fusion (W)
x	axial coordinate (m)
y	vertical coordinate (m)
Z	horizontal coordinate (m)
ΔP	pressure drop across heat sink (Pa)

Greek Symbols:

ρ	density (kg/m^3)
μ	dynamic viscosity (m^2/s)
β	Melting fraction
φ	Mass fraction

Abbreviation

B	Base
C	Channel
F	Fin
H.S	Heat sink
MCHS	Micro-channel heat sink
n-eicos.	n-eicosane
Paraf.	Paraffin wax
PCM	phase change material
V	volume

with PCM. The configurations included of a fin heat sinks with PCM and without PCM. Their results showed that, the performance unsteady analyses to a record nature transient of problem, the maximum temperature, liquid fraction and heat transfer coefficient for different locations were obtained for different velocity. Also, their results indicated that, the time requirement for a control the temperature of the PCMs to various levels the liquid fraction for a different conditions forced convection is tabulated.

Pakrouh R. et al. (2015) [5] numerically investigated of the thermal performance of a pin fin enhanced heat sinks by phase-change materials design of a cooling electronic devices. They used paraffin RT44 in the pin fin of the heat sink made from the aluminum container, which is selected of that one a higher thermal conductivity. They studied the effects of changed geometrical parameters, containing thickness, number and height of the fins on performance. Their results showed that, the volume expansion for the phase transition such as natural convection in fluid zone, increasing the number, height and thickness of fins leads to a signification decrease in the base temperature such as operating time of the heat sink.

Jesto Th. et al. (2016) [6] numerically studied of the thermal performance of a transferable electronic device by using PCM in heat sink. They used PCM (n-eicosane) with a melting point of 36.5 °C. They discussed that, the influence of the natural convention in the melting and the effect of the natural convention in the melting. Their results showed that, the PCM is melting for increasing ambient temperature and decreasing in the latent heat phase is noted by increasing in the levels for the power input.

In this paper the PCMs is used for enhancement the thermal performance of micro heat sink. Different types of PCMs with different configurations of heat sink have been numerically investigated.

2. Problem description

The model studied in this paper is 3D micro-channel heat sink consists of 3 channels. Fig. 1 shows description of heat sink studied, the length of the heat sink is 25 mm, width 25 mm and height 2.5 mm, the wall thickness of channels is 50 μm, height is 150 μm and width is 250 μm. The material of the heat sink is aluminum with physical properties as listed in the Table 2 [7]. The fins of the heat sink are rectangular cross section and vertically oriented to taking full advantage for a free air flow and melting the PCM placed in the rectangular heat sink. Different configurations of PCMs and heat sink combination have been studied. In order to clarify these configurations extensively, Table 1 and Figures 2–8 describes these configurations according to its case number, noting that the original case of heat sink unit cooled by air is referred to as base case. The following notations system has been used to describe the configurations studied in this paper where the first letter represented the place of PCM followed by its name:

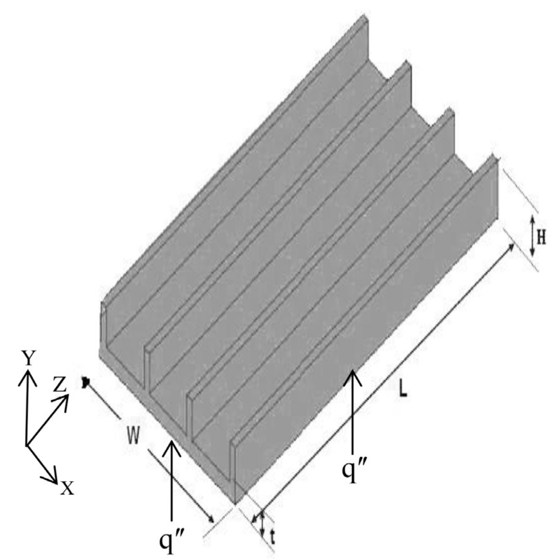

Fig. 1. Schematic of studied heat sink (base case).

C: refer to channel (the PCM is used inside the channels)

B: refer to base of heat sink (the PCM is used as a layer in the base)

F: refer to fin (the PCM is used inside the hollow fin)

3. Governing equations

The governing equations used for solving this model are continuity, momentum and energy which can be written as following [8,9,10,11]:

Please cite this article in press as: M.I. Hasan, H.L. Tbena, Using of phase change materials to enhance the thermal performance of micro channel heat sink, Eng. Sci. Tech., Int. J. (2018), https://doi.org/10.1016/j.jestch.2018.03.017