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To study heat transfer analysis of heat sink Minichannel using nanofluids

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ABSTRACT

Water cooling systems have been widely used due to the generation of heat. As technology changes rapidly, there is an urgent requirement of new liquid coolant which leads to increment in heat transfer rate. The thermal conductivity and other properties of nanofluids are promised to increase the heat transfer rate. In this study, the thermal performances of a mini-channel heat sink are investigated experimentally by using pure water, Al2O3-H2O, and CuO-H2O nanofluids. The nanofluids including the volume fraction ranging from 0.1 to 0.5 vol% were used as a coolant which is allow to pass through the small channels of a heat sink. The effects of different flow rates of the various coolants on the complete thermal performances of a mini channel heat sink are investigated experimentally. The flow rate was ranged from 30 LPH to 90 LPH as well as Reynolds no. from 257 to 802. The various coolants were passed through a copper made mini channel heat sink. The experimental result shows the higher improvement of the thermal performances using nanofluids as compared to pure water. The heat transfer coefficient by using Al2O3/Water nanofluid was found to enhance up to 31 % more as compared to pure water. On the other hand, by using CuO/water nanofluid, heat transfer coefficient was found to enhance up to 29% more as compared to pure water. The nanofluid significantly lowered the heat sink base temperature (about 3 °C) by using both the nanofluids as compared to pure water.

Keywords: Minichannel Heat Sink, Nanofluids, Thermal Performances.

I.INTRODUCTION

The heat exchangers play an imperative task in the pitch of energy conversion. It plays an important role in the case of energy conservation and its recovery. As technology changes, day by day electronic industries or electronic devices needs very efficient heat exchangers in order to maintain high heat flux cooling. Many studies concentrate on direct conversion type heat exchanger i.e. recuperator type. In this recuperator type heat exchanger heat transfer between fluids occurs through an unraveling wall or into & out of a wall in a momentary manner. Recently mini and microchannels heat exchanger proving very advantageous devices in order to remove high heat flux from electronics. There is mainly two important phenomena happening inside a heat exchanger, in the first phenomenon fluid flow in channels and in second one heat transfer between channel walls and fluids. Hence in order to have improvement in the heat exchangers, main attention must have to give towards improving the process occurring during those phenomena. The heat transfer rate depends largely upon the surface area to volume ratio. It means smaller channel dimensions of the heat exchanger will give better heat transfer coefficient. On the other hand, heat transfer rate can also be increased by improving the properties of the heat transfer fluids. The thermal conductivity and all other properties of the nanoparticles have promised to enhance the heat transfer rate as compared to conventional fluids such as pure water. Recent developments in the field of nanotechnology have made it easy the production of nano-sized particles. The poor thermal properties of conventional fluid like pure water acts as a barrier to the growth of energy efficient heat exchangers. But as technology changes day by day nanoparticles have been emerging as an important candidate for improvement of heat transfer. By dispersing the nanoparticles in the base fluids, little increment in

The pressure drop occurs but this pressure drop can be accepted by considering the performance improvement of the nanofluid compared to conventional fluids. Currently, microchannel and mini channel heat exchanger are used in industries such as microelectronics, aerospace, biomedical, robotics, telecommunications and automotive Microchannel can be defined as a channel whose hydraulic diameter is below 0.2 mm. These microscale devices, commonly known as MEMS (Micro Electromechanical Systems) are getting more advanced and complex as microelectronics, the microfabrication technology is progressing well with the trend. However, there are two factors that limit the heat transfer coefficients in a micro heat exchanger: the reduction in the channel dimensions was accompanied by higher pressure drop, and the amount of heat transfer was limited by the heat transfer fluid used. The microchannel flow geometry offers a large surface area of heat transfer and a high convective heat transfer coefficient. However, it has been hard to implement in the compact slim design of computers or consumer electronic devices. The major difficulty is driving water with high-pressure head, which is required to pump the coolant fluid through the channels. A normal channel could not give such high heat flux although the pressure drop is very low. Thus, an idea comes into being that water-cooled mini channel can be used in the heat sink with a high heat flux and a mild pressure loss. The mini-channel heat sink can be defined as channels whose hydraulic diameter should be in the range 0.2 to 3 mm. Convective heat transfer and fluid flow in the mini channel and their application in the cooling technology of electronic devices have attracted great attention of researchers in recent years. Many researchers have done experimental studies on improvement of thermal performances of mini-channel heat sink using various fluids. But the number of studies conducted is very limited as per researcher's knowledge. Hence this experimental study will play a vital role in recovering research gap in this field

II. METHODOLOGY AIM AND OBJECTIVE

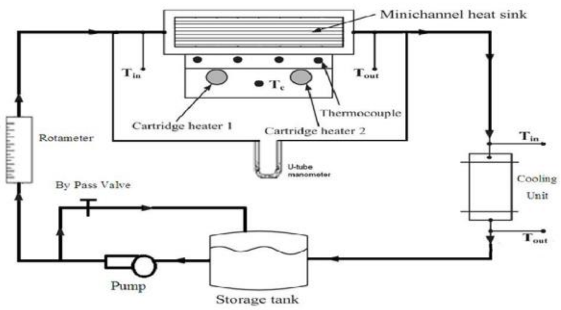
Increasingly smaller electronics requires improvement in performance of cooling systems to keep it operating reliably. The aim of this work is to experimentally investigate the heat transfer enhancement of Minichannel heat sink using nanofluids. Following were the objectives of this study-

1) To experimentally investigate the thermal performances of Minichannel heat sink using nanofluids.
2) To minimize the base temperature as well as the heat source temperature and to hold at a constant level.
3) To compare the results between pure water and nanofluids.

Experimental Set-up Details

Fig. 1 shows experimental setup. The set-up consists of a test section which includes a rectangular mini channel which is used as a heat sink. The copper made mini channel with the dimensions 50 mm x 50 mm x 20mm is fabricated by using wire electric discharge machine. The dimensions of the heat sink taken as- width of the channel 1 mm, the width of the fin 1 mm and height of the channel 2 mm. Total 25 channels are cut by using Wire Electric Discharge Machine. The mini channel through which the flow passes is placed in the box which is made of acrylic material. The heat input is supplied to the base of a mini channel heat sink for which two cartridge heaters is placed below the heat sink. 2 thermocouples is placed in the heat sink to measure the temperature of a heat sink. The heat is supplied to the heat sink by using two cartridge heaters which are placed below the heat sink.

Fig. 1 Experimental Set-up



Minichannel Heat Sink

Fig. 2 shows schematic of a heat sink. A Rectangular mini channel is used as a heat sink. The copper made mini channel with the dimensions of 50mm x 50 mm x 20 mm is fabricated using a Wire Electrical Discharge Machine. The dimensions of a mini channel heat sink as shown in table 1.

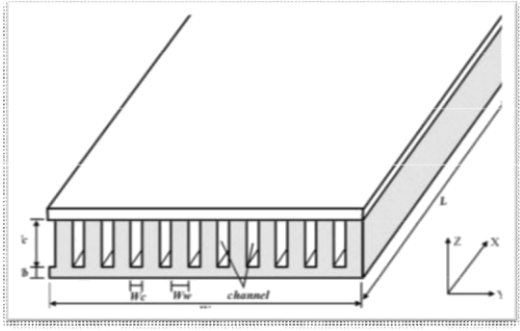


Fig. 2 Schematic of a heat sink

Table for Dimensions of a Minichannel Heat Sink.

Parameters	Dimensions (mm)
Width of the channel, W_{ch}	1
Height of the Channel, H_{ch}	2
Width of the fin, W_{fin}	1

The hydraulic diameter of the fluid flow channel is calculated by formula,

$$D_h = \left(\frac{\text{[illegible]}}{2\,(Wch + Hch)}\right)$$

$$D_h = \left(\frac{\text{[illegible]}}{2\,(1+2)}\right)$$

$$D_h = 1.333 \text{ mm}$$

III. EXPERIMENTAL PROCEDURE

The trial was performed initially by the conventional coolant such as pure water and later by the nanofluids such as Al2O3/water and CuO/water, with the different volume loading and at various flow rates within the test section.

The experimentation was divided into following cases.

a) The case I: Using pure water as a coolant.
b) Case II: Using 0.1 vol. % Al2O3/water as a coolant.
c) Case III: Using 0.3 vol. % Al2O3/water as a coolant.
d) Case IV: Using 0.5 vol. % Al2O3/water as a coolant.
e) Case V: Using 0.1 vol. % CuO/water as a coolant.
f) Case VI: Using 0.3 vol. % CuO/water as a coolant.
g) Case VII: Using 0.5 vol. % CuO/water as a coolant.

The temperature at the various locations as well as at the entry and exit of the test section was measured for the pure water and for nanofluids for all cases with different flow rates. At the same time, the pressure drop within the test section is also measured for the pure water and for nanofluids for all cases with different flow rates. After performing trial for different cases the thermal performances of a mini channel heat sink are calculated experimentally by using pure water as a coolant and then by using Al2O3/water and CuO/water, with the different loading by volume and at various flow rates within the test section. The comparison on the basis of thermal performances made between pure water, Al2O3/water and CuO/water as a coolant.

Preparation of nanofluids

Preparation of nanofluids currently done by using two methods one is single step method and another is two steps method. The oxides form of nanofluids can be made by using two steps methods. In the two-step method, the nanoparticles first mixes with the base fluid. As due to the higher density of the particles first mixing is not done well then it can be overcome by using next step by using magnetic stirrer. Magnetic stirrer makes the proper mixing of nanoparticles with the base fluid by keeping it for 6-8 hours on the stirrer.

Thermophysical properties measurement of nanofluids.
The thermophysical properties of the nanofluids can be measured by using following co-relations. Density of nanofluid, $\rho_{nf} = \varphi.\rho_p + (1- \varphi)\,\rho_w$ Kg/m^3 Viscosity of nanofluid, $\mu_{nf} = \mu_w\ .\ (1+ 2.5\ \varphi)$ Ns/m^2 Specific heat of nanofluid

$$Cp_{nf} = \frac{ø(Cpp.\rho p)+(1-ø)(cpw.\rho w)}{\rho nf}\ \text{J/Kg-K}$$

Thermal conductivity of nanofluid,

$$K_{nf} = \left[\frac{Kp+2Kw+2(Kp-Kw)(1+\beta)3.ø}{Kp+2Kw-(Kp-Kw)(1+\beta)3.ø}\right] \text{x}\ K_w\ \text{W/m-K}$$

Heat Received by the coolant, $q_f = \rho_w \text{ x } Q \text{ x } Cp_w\,(T_{out}-T_{in})$ W

The base temperature of the heat sink, $T_b = \left(\text{Tave} - \frac{qin\,Hb}{Hb.\,Ab}\right)$

Where, A_b = Heat sink base area $A_b = Lch\ N\ (W_{ch}+W_{fin})$
Log Mean Temperature Difference,

$$\Delta TLMTD = \left(\frac{(Tb-Tin)-(Tb-Tout)}{\mathrm{Ln}\left(\frac{Tb-Tin}{Tb-Tout}\right)}\right)$$

The convective heat transfer coefficient, $h = \left(\frac{qf}{\text{Aeff}\,(\Delta TLMTD)}\right)$ W/m^{2}K
Where, $A_{eff} = N\ L_{ch}(W_{ch}+2H_{ch})$ Nusselt number,

$$Nu = \left(\frac{h\,Dh}{Kf}\right)$$

Reynolds number

$$Re = \left(\frac{\rho f\ Um\ Dh}{\mu f}\right)$$

Where, $Um = \left(\frac{Q}{N\,Ac}\right)$ m/s
Convective Thermal Resistance,

$$R_{th} = \left(\frac{\Delta TLMTD}{qf}\right)$$

The Pumping Power,
$P_p = Q \text{ x } \Delta P$ W

CONCLUSION

Experimental investigation of heat transfer enhancement of a mini-channel heat sink using different coolants which include pure water and different nanofluids (Al2O3/Water & CuO/Water) at various volume concentrations have been carried out. The experimental results are concluded as follows:

1. The increase in performance was obtained using Al2O3/Water nanofluid as a coolant as compared to pure water. It was successfully attained to minimize and hold the base temperature at a constant level. On the other hand, CuO/Water nanofluid also minimizes the base temperature of the heat sink to a great extent than pure water.
2. A significant improvement in the heat transfer coefficient i.e. 31 % is achieved using Al2O3/Water nanofluid as compared to pure water. While CuO/water gives around 29 % increment in heat transfer coefficient as compared to pure water.
3. The convective thermal resistance was minimized in a significant manner. By using Al2O3/Water nanofluid, the maximum reduction of 30.35 % in convective thermal resistance was obtained as compared to pure distilled water. While in the case of CuO/water it was reduced to 28.53% as compared to pure water.

It can be concluded that the Al2O3/Water nanofluid and CuO/Water nanofluid applied to the mini channel heat sink has a significant enhancement in heat transfer performances for electronics cooling compared to the pure water.

NOMENCLATURE

Ab = Heat sink base area [m2]
Aeff = Effective area of heat sink [m2]
Dh = Hydraulic diameter of fluid flow [m]
Hch = Height of the channel [m]
Hb = Base of heat sink [m]
Lch = Length of the channel [m]
Wch = Width of the channel [m]
Wfin= Width of the fin [m]
N = Number of channels
Q = Volumetric flow rate [m3/sec]
Um = Mean Velocity [m/s]
Pp= Pumping Power [W]
qf = Total heat absorbed the coolant [W] qin = Heat input [W]
Rth =Thermal Resistance [W/K]
T1 & T2 = Temperatures of Thermocouples inserted in the heat sink [0C]
Tavrg = Average temperatures of thermocouples inserted in the heat sink [0C]
Tin = Inlet temperature of coolant [0C] Tout = Outlet temperature of coolant [0C] Vol. % = Percentage of volume fraction
ΔTLMTD = Log Mean Temperature Difference [0C]
ρ = Density of fluid [Kg/m3]
Cp = Specific heat water at constant pressure [J/Kg-K]
K = Thermal conductivity water [W/m-K]
h = Heat transfer coefficient [W/m2-K]
Re = Reynolds number
Nu Nusslet number
Δp = Pressure drop [N/m2]
μw = Viscosity of the water [N-s/m2]
μnf = Viscosity of the nanofluid [N-s/m2]
kw = Thermal conductivity of water [W/m-K]
kp =Thermal conductivity of nanoparticles [W/m-K]
knf = Thermal conductivity of Nanofluid [W/m-K]
khs = Thermal conductivity of heat sink [W/m-K]
Cpw = Specific heat of water [J/Kg-K]
Cpp = Specific heat of nanoparticles [J/Kg-K]
Cpnf = Specific heat of nanofluid [J/Kg-K]
Φ = Volume concentration of nanoparticles
β = Constant for water (value=0.1)

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