Convective performance of 0.1 % volume fraction of TiO2/water nanofluid in an electronic heat sink

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Abstract

Heat dissipation is critical issue in modern electronic component due to rise heat flux and decrease the feature size. This present work TiO2/water nanofluids of only one volume fraction 0.1% are prepare by dispersing the nanoparticle in distil water. Fluid pass through a thin channelled copper water block of overall dimension (94×94×20) mm with flow rate of 1.0, 1.25, 1.50 l/min used for the analysis. The base temperature of water block was minimum for nanofluid compare with water. The heat transfer coefficient found maximum improved 18.91 % compare with water.

Keywords: Nanofluid, water block, heat transfer coefficient

1. Introduction

The electronic chips integration and compaction rise at high level with technological advances recently. Due to electronics chip more component and offer more processing power than ever before. Increase the power dissipation

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electronics chip more component and offer more processing power than ever before. Increase the power dissipation per unit area from few past decades [1, 2].

| Nomenclature | Description |
|--------------|-------------|
| A            | area (m²)   |
| H            | Height of channel (m) |
| n            | number of channels |
| R            | thermal resistance (K/W) |
| W            | Channel width (m) |
| b            | base |
| Q            | heat generation (W) |
| h            | Heat transfer coefficient (W/m².K) |
| L            | Channel length (m) |
| T            | temperature (K) |

Huang, Weng [3] investigated the thermal performance of a thermoelectric water-cooling device for electronic equipment. They developed a novel analytical model of a thermal analogy network to predict the thermal capability of the thermoelectric device. Peng and Peterson [4] experimentally showed the single-phase forced convective heat transfer and flow characteristics of water in microchannel structures/plates with small rectangular channels. The results indicated that the geometric configuration had a significant effect on the single-phase convective heat transfer and flow characteristics for both laminar and turbulent flow. Heat transfer improvement can be made by increasing either heat transfer area or heat transfer co-efficient [5]. Selvakumar and Suresh [6] passed CuO-water nanofluid through the water block; they found the maximum rise of heat transfer coefficient 29.63 % for 0.2 vol. % compare with water. Roberts and Walker [7] study on water block with alumina based nanofluid, they observer the enhancement of heat transfer up to 1.5 vol.% of nanofluid. Putra, Yanuar [8] investigate the heat pipe liquid block combined with the thermoelectric system has a significant effect on heat transfer from the CPU by using alumina and titania (TiO₂) nanoparticle with water as base fluid.

This study focuses on the effect of volume concentration of nanoparticles on flow rates, heat transfer coefficient, and thermal resistance for a water block heat sink.

2. Methodology

Pure 99.50% Titania (TiO₂) nanoparticles (21 nm) were received from manufactured by Sigma Aldrich, USA. Nanofluids of 0.10 vol. % with water as the base fluid of pure distilled. Used Sonic Dismembrator System (FB505, Fisher Scientific, USA) for cell disruption and homogenization applications. Ultrasonicated continued for 2 hours without adding any surfactant.

The schematic diagram of the experimental set up is depicted in Fig. 1, which is a closed loop for cooling of electronic system consisting of water block, cooling fluid loop and data acquisition system. The experimental apparatus is also shown in Fig. 2.

![Fig. 1. Schematic diagram of experimental set up.](image)
The connection within the piping system and the test section are designed such that parts can be changed or repaired easily. The closed loop consists of storage tank, pump, flow meter, and air cooled radiator. First, working fluid is chilled by the surrounding air. After the fluid is cooled to the desired level, a pump (model: XSPC X20 750) is used to pump it out of the storage tank, and then is passed through a flow meter, water block The coolant absorbs the heat from the heat sink and becomes hot. An air-cooled radiator type cooler (model: SSPC RS360) is used to cool down the coolant before entering the storage tank for recirculation. The flow rates of the coolant are controlled by adjusting the flow meter. A pressure transducer is also installed across the heat sink to measure the pressure drop.

The base temperature of the water block is calculated using Eq. (1) where the base height effect is considered.

\[
T_b = T_{b,(av,tc)} - \left( \frac{QH_b}{k_b A_b} \right)
\]  

(1)

Where, the area of base of water block is obtained by Eq. (2)

\[
A_b = \ln(W_{ch} + W_{fin})
\]  

(2)

The thermal resistance is defined by Eq. (3).

\[
R_{th} = \frac{T_h - T_{nf,in}}{Q}
\]  

(3)

From the collected data of temperatures and mass flow rates, the convective heat transfer coefficient of the heat sink \((h)\), can easily be determined based on the heat balance equation of the latter, which is written as follows Eq. (4):

\[
\]
\[ h = \frac{Q}{A_s (T_h - T_{m,nf})} \]  
(4)

Where, mean temperature of nanofluid is determined using Eq. (5).

\[ T_{m,nf} = \frac{(T_{nf,in} + T_{nf,out})}{2} \]  
(5)

The surface area available for heat transfer is counted by Eq. (6).

\[ A_{sf} = nW_{ch}L + 2n\eta H_{ch}L \]  
(6)

Where, \( n \) is the number of cooling channels and fin efficiency is 100% due to high thermal conductivity of copper. Fin efficiency of water block was computed by Eq. (7) and (8). The fin efficiency (\( \eta_{fin} \)) is calculated by Eq. (7) and (8).

\[ m \times H_{ch} = \frac{2h}{k_{hs}W_{fin} \times H_{ch}} \]  
(7)

Where, \( k_{hs} \) is thermal conductivity of the copper microchannel heat sink.

\[ \eta_{fin} = \frac{\tanh(m \times H_{ch})}{m \times H_{ch}} \]  
(8)

3. Result and discussion

The base temperature measured between the heated and water block is an indication of performance of the cooling system. The effect of TiO\(_2\)/water nanofluids of volume concentrations 0.1% on base temperature at different volume flow rate of water and nanofluids is shown in Fig. 3. It is clear from the figure that the interface temperature reduces with increasing volume flow rate of the water and TiO\(_2\)/water nanofluids. The volume flow rate of the water and nanofluids are varied from 1.0 LPM to 1.5 LPM. At the minimum volume flow rate of 1.0 LPM the temperature gain obtained for 0.1% volume concentration TiO\(_2\)/water nanofluids compared to water are 6.40 °C. At a maximum volume flow rate of 1.5 LPM, the base temperature obtained for 0.1% volume concentration TiO\(_2\)/water nanofluid is 64.18 °C which is 2.17 °C lower than the temperature obtained for water. It can be understood from the values of base temperature that the nanofluids remove more heat from the heated block compared to water and keep the base temperature minimum.
The thermal resistance decreases with the rise of flow rate and nanoparticle volume fraction compared with water as demonstrated in Fig. 4. The minimum thermal resistance was found at 1.50 l/min flow rate for 0.1 vol. %. The maximum reduction of thermal resistance (17.76 %) occurred at 1.5 l/min flow rate for 0.1 vol. % of TiO₂-water nanofluid. This significant reduction in thermal resistance, acts as a motivation to use nanofluid as an electronics coolant.

The heat transfer coefficient augmented with the nanoparticle volume fraction compare with water. In fig. 5 it is shown that the maximum heat transfer coefficient enhancement was found to be 18.91% for 0.1 vol. % at 1.0 l/min flow rate compared with water as the base fluid. The results indicate that the trend are increasing with the rise of flow rate.
4. Conclusion

The effect of TiO$_2$/water nanofluid in water block with studied with different flow rate. As a result of base temperature of water block reduction by nanofluid rather than water. Also the heat transfer coefficient improves 18.91%. It indicates that nanofluid is good candidate of coolant for cooling of electronics devices.

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