E3S Web of Conferences **399**, 06002 (2023) https://doi.org/10.1051/e3sconf/202339906002
ICONNECT-2023

Investigating the thermal effect of channel heatsink using MWCNTs nanofluids

Arun kumar C M[1*], *Mukeshkumar* P C[2], and *Kavitha* C[3]

[1]Teaching Fellow, Department of Electronics and Communication Engineering, University College of Engineering, Pattukkottai, Tamilnadu, India, 6147014
[2]Assistant Professor, Department of Mechanical Engineering, University College of Engineering, Dindigul, Tamilnadu, India,624622.
[3]Assistant Professor, Department of Mathematics, Sathyabama Institute of Science and Technology, Chennai, Tamilnadu, India,600119.

Abstract. The utilisation of Multi-walled carbon nanotubes (MWCNTs) nanofluids is considered to be a highly efficient approach in the field of thermal engineering, specifically for the purpose of cooling electronic processors. The usage of a microchannel along with an electronic chip for liquid cooling of electronics presents a compelling substitute to the conventional bulky aluminium heat sinks. A minichannel heat sink employing MWCNTs nanofluid as a coolant is further enhanced in thermal and hydraulic performance. In order to analyze the performance of the minichannel heat sinks, a conjugate heat transfer model has been solved using the commercial software ANSYS-CFD. Theoretically, it showed that the presence of MWCNTs reduced thermal resistance and increased the thermal conductivity of liquid cooling system. The results reveal a maximum enhancement of in average heat transfer coefficient (h) for minichannel heat sink using MWCNTs as a coolant at volume 40%, 46%, and 52% concentrations of 0.25%, 0.5% and 0.75%. The performance evaluation shows that the overall performance of the minichannel heat sink using MWCNTs cooled minichannel heat sink at 0.75% volume concentration is roughly enhanced more as compared to water.

1 Introduction

Researchers and scientists have been actively investigating thermal dissipation materials for high-power electronic devices. In addition to advancements in device density and processing speed, improving thermal dissipation is crucial. One approach to enhancing cooling system efficiency is by exploring new materials and configurations that improve heat transfer performance within the working fluid without modifying mechanical designs or key components. Nanofluids have emerged as a topic of interest in recent studies, referring to fluids that contain suspended nanoparticles to enhance their thermal properties. These nanoparticles can be made from a variety of materials including metals, oxide ceramics, nitride ceramics, carbide ceramics, semiconductors, carbon nanotubes, and composite

* Corresponding author: cmarunkumar@gmail.com

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materials. Compared to conventional heat transfer fluids like oil, water, and ethylene glycol, nanofluids exhibit improved thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients. For example, carbon nanotubes (CNTs) have exceptionally high thermal conductivity compared to materials like silver. Methods such as ultrasonication, surfactant treatment, or functionalization can disperse multi-walled carbon nanotubes (MWCNTs) in specific solutions. This presents possibilities for utilizing MWCNT-based liquids in thermal dissipation systems for computer processors and other high-power electronic devices. The focus of this work is on the application of MWCNT-based liquid for an electronic chip.

1.1 Methodology

To address this problem through numerical analysis, the equations of continuity, momentum (accounting for the Lorentz force), and energy have been formulated. The model assumes a 2D laminar steady-state flow and considers thermodynamic and chemical equilibrium between water and MWCNT. Therefore, the equations that govern the system, including continuity, momentum, and energy equations, can be represented as follows:

Continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

Momentum equation:

$$\rho_f\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial \rho}{\partial x}+\mu_f\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right) \tag{2}$$

$$\rho_f\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=-\frac{\partial \rho}{\partial y}+\mu_f\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right) \tag{3}$$

$$\rho_f\left(u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial \rho}{\partial z}+\mu_f\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right) \tag{4}$$

Where ρ_f and μ_f are the density and dynamic viscosity of the coolant, respectively, and p is the coolant pressure.
Energy equation for the coolant

$$\rho_f C_{p,f}\left(u\frac{\partial T_f}{\partial x}+v\frac{\partial T_f}{\partial y}+w\frac{\partial T_f}{\partial z}\right)=K_f\left(\frac{\partial^2 T_f}{\partial x^2}+\frac{\partial^2 T_f}{\partial y^2}+\frac{\partial^2 T_f}{\partial z^2}\right) \tag{5}$$

2 Geometry details and numerical model

As previously mentioned, the thermal and hydraulic properties of a minichannel heat sink are assessed and compared using water and MWCNT as working fluids. The specific design details of the minichannel heat sink used in the investigation are shown in Figure 1. Aluminum is utilized to construct the heat sink channels in order to improve heat dissipation from the surface of the electronic chip. Figure 2 displays the heat sink with its channels, which are protected by a glass cover to prevent any potential leakage.

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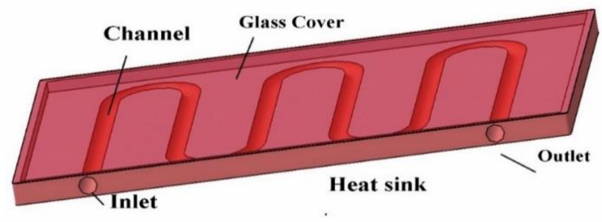

Fig. 1. Schematic view of mini-channel Heatsink

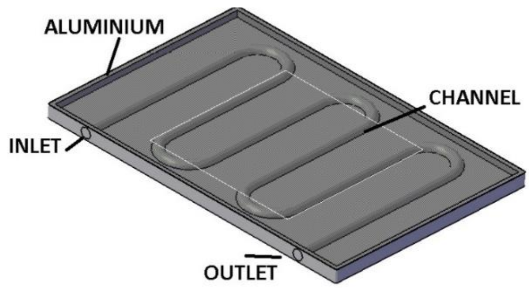

Fig. 2. Schematic view of mini-channel Heatsink with closed glass cover.

3 Results and Discussion

In this research, the performance of a channel heat sink model is analyzed using computational fluid dynamics (CFD) simulations. The study compares the performance of two different coolants: water and nanofluids containing multi-walled carbon nanotubes (MWCNTs). The focus is on evaluating the impact of various volume concentrations of MWCNTs, specifically 0.25%, 0.5%, and 0.75%. The objective is to assess and compare parameters such as heat transfer coefficient, Reynolds number, Nusselt number, thermal resistance, friction factor, power consumption, and reliability for different volume fractions of nanoparticles in comparison to water.

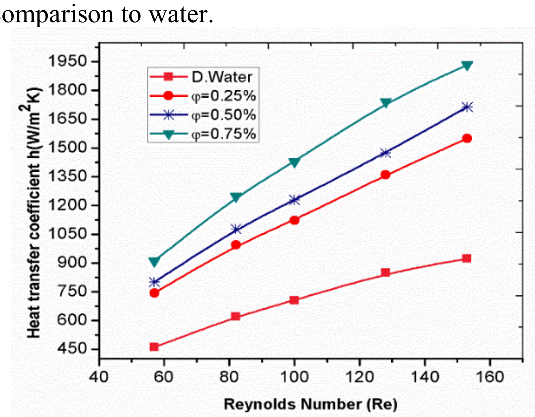

Fig. 3. Relationship between the heat transfer coefficient and Reynolds number is studied for nanofluids

The study's results reveal a significant improvement in the heat transfer coefficient of MWCNT-water nanofluids compared to pure distilled water. At volume concentrations of φ=0.25%, φ=0.5%, and φ=0.75%, the heat transfer coefficient increases by approximately 40%, 46%, and 52% respectively. This enhancement is depicted in Figure 3, which showcases the heat transfer coefficient of MWCNT nanofluids at different Reynolds numbers. The improved heat transfer coefficient is attributed to the higher thermal conductivity of nanofluids and the presence of a larger quantity of nanoparticles dispersed in the base fluids.

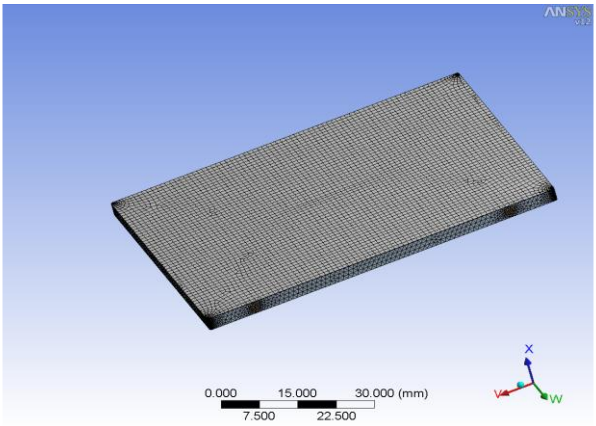

Fig. 4. Top view of Channel Heatsink Mesh Structure

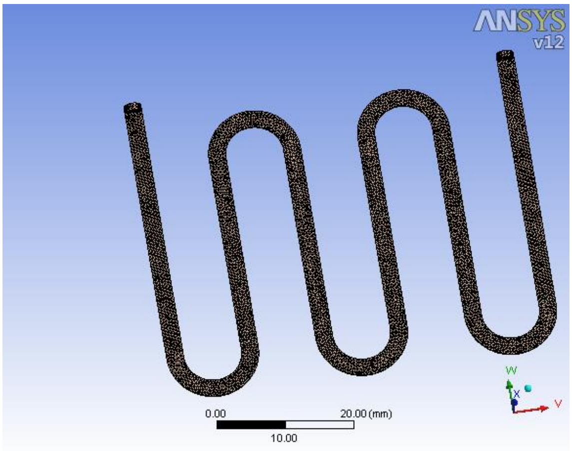

Fig. 5. Mesh Structure for channel

3.1 Mesh Independence

The process of discretizing solid and fluid domains is executed in ANSYS- CFD through the utilisation of structured blocking, which facilitates the creation of hexahedral mesh elements. The process of meshing holds significant importance in the ANSYS computational fluid dynamics simulation procedure. Meshing is an essential component of simulations, particularly for intricate geometries. When analysing a heat sink with a channel, the total number of elements and nodes that has been produced is 246898 and 1017904, respectively. Figure (4) and (5) shows the mesh view of channel heat sink using the ANSYS Computational Software.

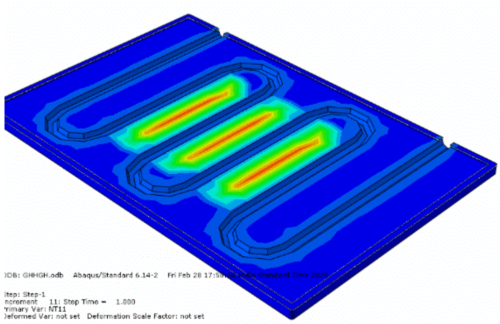

Fig. 6. Simulation output of channel heatsink

3.2 Temperature Distributions

Figure.6 illustrates the temperature contours of microchannel heatsink using MWCNT nanofluids with an 0.75% volume fraction. As depicted in Figure.7 demonstrates that the utilization of MWCNT as a coolant results in a significant area of blue coloration, which signifies that the temperature of the electronic chip decreases. Figure. 8 illustrates how the surface temperature of the channel heat sink varies with relation to the input velocity of 0.50% volume concentration of coolants. This data was collected and plotted so that it could be visualised. It has been discovered that increasing the volume flow rate would result in a drop in the surface temperature of the electronic chip that is employing the channel heatsink and coolants. In contrast to the other coolants, it was discovered that the surface temperature dropped by 35 % when 0.50% volume concentration of MWCNTs nanofluids was utilised. As shown in the figure.8, the simulation output of the results for the inlet and outlet can be seen. Simulated results (figure.9) indicate that the water in the channel heatsink has a lower degree of blue coloration and exhibits less heat dissipation than nanofluids.
Figure.6 demonstrates that the utilization of nanofluids improves the temperature uniformity in the MWCNT/Water. This is attributed to the higher thermal conductivity of nanofluids in comparison to pure water. Consequently, it leads to an extension of the device's lifespan.

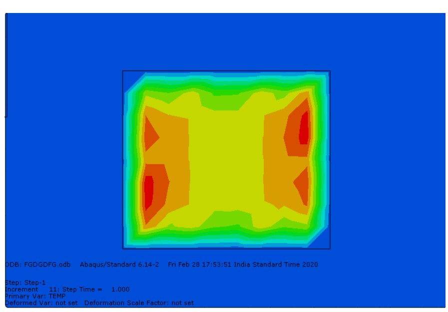

Fig. 7. Simulation results of electronic chip using MWCNT/Water nanofluids

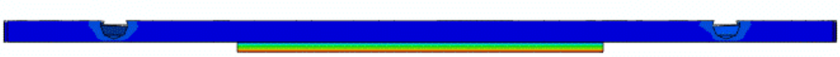

Fig. 8. Simulation results of input and output channel

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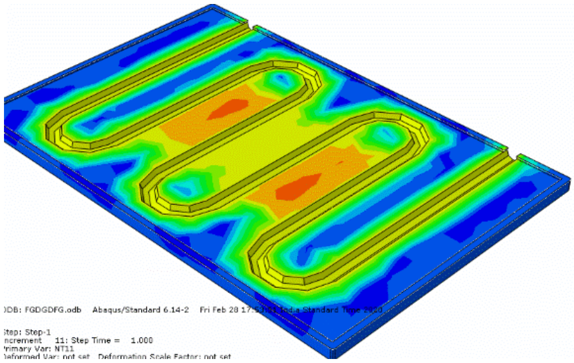

Fig. 9. Simulation results of channel heatsink using distilled water.

3.3 Nusselt Number Characteristics

The Nusselt number's variation is depicted in Figure 10, which is based on distinguished Reynolds numbers and MWCNT nanoparticle volume concentrations. In the channel heatsink, both distilled water and MWCNT /water nanofluid exhibit an increase in Nusselt number with increasing velocity. MWCNT /water nanofluid has a higher Nusselt number than distilled water, as shown in the graph. As compared with distilled water, the Nusselt number of nanofluid was enhanced by 40%, 45 %, and 51 % at volume concentrations of 0.25%, 0.50%, and 0.75%, respectively. Reynolds number and a variation in nanoparticle volume concentration are responsible for the remarkable changes in the Nusselt number.

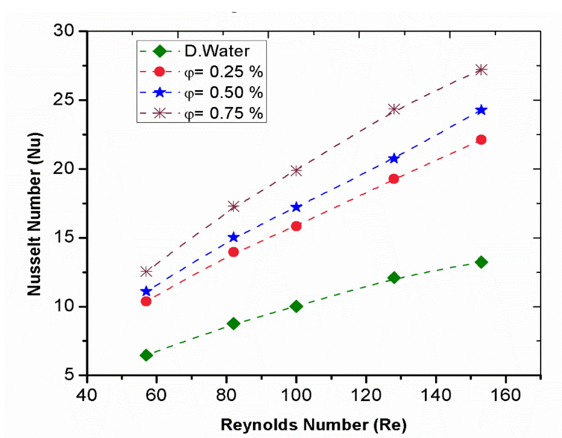

Fig. 10. Nusselt number (Nu) for different Reynolds number.

4 Conclusions

This study explores a novel approach for improving the thermal and Performance efficiency of a minichannel heat sink through the utilization of MWCNTs nanofluids. The MWCNTs /water nanofluid exhibits a superior heat transfer coefficient in comparison to alternative coolants due to its elevated thermal conductivity, as has been noted through observation. The utilisation of MWCNTs /water nanofluids in a micro channel heat sink has been found to enhance its cooling performance in comparison to the use of distilled water. This is attributed to the higher thermal conductivity exhibited by MWCNTs nanofluids. The maximum wall temperature, fluid temperature, and thermal resistance all drop as the flow rate increases. Higher fluid average velocity and enhanced thermal dispersion effects are responsible for the decrease in these values.

References

1. P. K. Schelling, L. Shi, and K. E. Goodson, "Managing heat for electronics," Materials Today, **8**, 6 (2005).
2. Y.-H. Hung, J.-H. Chen, and T.-P. Teng, "Feasibility assessment of thermal management system for green power sources using nanofluid," Journal Nanomaterials, ArticleID 321261, 11 (2013).
3. W. Nduku, M. Njane, and O. D. Makinde, "Combined effect of Buoyancy force and Navier slip on MHD flow of a nanofluid over a convectively heated vertical porous plate," The Scientific Worl d Journal, Article ID 725643, (2013).
4. Handbook of Chemistry and Physics, Section12, CRC, 90th edition, (2010).
5. S. Berver, Y. K. Kwon, and D. Tom anek, "Unusual high thermal conductivity of carbon nanotubes," Physical Review Letters, **84** (2000).
6. D. J. Yang, Q. Zhang, and G. Chen, "Thermal conductivity of multiwalled carbon nanotubes," Physical Review B, **66**, Article ID 165440, (2002).
7. Z.-M. Dang, L. Wang, and L.-P. Zhang, "Surface functionalization of multiwalled carbon nanotube with trifluorophenyl," Journal of Nanomaterials, 2006, ArticleID83583, (2006).
8. B.H.Thang,P.N.Hong,P.H.Khoi,andP.N.Minh,"Application of multiwall carbon nanotubes for thermal dissipation in a micro-processor," Journal of Physics, **187**, ArticleID012051, (2009).
9. B.H.Thang,P.N.Hong,P.V.Trinhetal.,"Simulation of thermal dissipation in a μ-processor using carbon nanotubes based composite," Computational Materials Science, **49**, 4 (2010).
10. R. Saidur, K. Y. Leong, and H. A. Mohammad, "A review on applications and challenges of nanofluids," Renewable and Sustainable Energy Reviews, **15**, 3 (2011).
11. V. Vasu, K. R. Krishna, and A. C. S. Kumar, "Heat transfer with nanofluids for electronic cooling," International Journal of Materials and Product Technology, **31**, 1 (2009).
12. N. Singh, G. Chand, and S. Kanagaraj, "Investigation of thermal conductivity and viscosity of carbon nanotubes-ethylene glycol nanofluids," Heat Transfer Engineering, **33**, 9 (2012).
13. H. Xie and L. Chen, "Review on the preparation and thermal performances of carbon nanotube contained nanofluids," Journal of Chemical and Engineering Data, **56**, 4, (2011).
14. L.Godson, B.Raja, D.MohanLal, and S. Wongwises,"Enhancement of heat transfer using nanofluids—an overview," Renewable and Sustainable Energy Reviews, **14**, 2 (2010).
15. H. Xie and L. Chen, "Review on the preparation and thermal performances of carbon nanotube contained nanofluids," Journal of Chemical and Engineering Data, **56**, 4, (2011).

16. N. Singh, G. Chand, and S. Kanagaraj, “Investigation of thermal conductivity and viscosity of carbon nanotubes-ethylene glycol nanofluids,” Heat Transfer Engineering, **33**, 9 (2012).
17. T.S. Senthilkumar1, S. Rathinavel, S. Senthil Kumar, A. Ganesh babu, Tierärztliche Praxis, **41** (2021).
18. A. Parthiban, S. Sathish, R. Suthan, T. Sathish, M. Rajasimman, V. Vijayan, J. Jayaprabakar, Environmental Research, **220** (2023).
19. M. Ramesh, D. Jafrey Daniel James, G. Sathish kumar, V. Vijayan, S. Raja Narayanan and Aklilu Teklemariam, Bioinorganic Chemistry and Applications, Article ID 6344179 (2022).
20. Siranjeevi Ravichandran, Rajesh Jegathaprathaban, Jeyalakshmi Radhakrishnan, R. Usha, V. Vijayan and Aklilu Teklemariam, Bioinorganic Chemistry and Applications, Article ID 2335443 (2022).
21. SR. Parthiban, M. Loganathan, R. Venkatesh, V. Vijayan, V, Journal of Scientific & Industrial Research, **80**, 7 (2021).
22. R. Yokeswaran, V. Vijayan, T. Karthikeyan, B. Suresh Kumar, G. Sathish Kumar, Journal of New Materials for Electrochemical Systems, 22, 1 (2019).
23. R. Yokeswaran a, S. Siva Chandran b, V. Sathish kumar c, M. Loganathan d, B. Veluchamy, Materials today: proceedings, 69, 3 (2022).
24. R. Yokeswaran1, V. Vijayan, T. Karthikeyan, M. Loganathan and A. Godwin Antony, Journal of New Materials for Electrochemical Systems, 23, 4 (2020).