THINK INDIA JOURNAL

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Experimental Investigations of Mini-Channel Heat Sink Working on Nano Fluid

Ashish Kumar Patel[1*],Palak Gupta[2], Mayank Dotiyal[3],Neeraj Yadav[4], Ashish Jain[5]
[1] Lovely Professional University, Phagwara,
[2] Lovely Professional University, Phagwara,
[3]Lovely Professional University, Phagwara, India

Abstract

The following experiment investigates the effect of nanofluid on a mini-channel heat sink in comparison to pure distilled water. TiO_2 nanoparticles of 99.9% purity and having mean diameter between 10-20 nanometers were used. They were dissolved in pure distilled water to form two nanofluid solutions having 5% and 10% concentration by weight. The work piece was an aluminium plate with dimensions of 45mm x 45mm x 6mm. Since mini-channel heat sinks can have channels with hydraulic diameter as high as 3mm, square grooves of same dimensions were cut off the plate. The workpiece was heated and then heat transferred was calculated among pure distilled water and the two nanofluid solutions. The flow rate was varied between 1.8 L/hr to 3.6 L/hr. The nanofluid was able to not only reduce the heat sink temperature by nearly 23^0C but also
improved the heat transfer to enormous lengths (well in excess of 200%). The thermal resistance offered by nanofluid was up to 65% lower at 10% concentration than what distilled water offered.

***Keyword**: Coolant, Heat Sink, Magnetic Stirrer, Mini-channel, Nanofluid, Nanoparticles, Sonic Heater*

1.1 Introduction

A heat exchanger is a thermal device which is used in exchanging heat between two or more solutions, the fluids have a solid barrier between them to prevent it from mixing. They are used in industries like electronics industry, space industry, chemical industry, etc. Those particles which have a dimension of at least a side less than 100 nm is called a nanoparticle. Nanoparticles are currently used in many industries like electronic chip industry, optics, medical research etc. The most common thing used in today's advancing world is electronic chips. Starting from a small alarm clock to a truck, these chips play an important role. As these chips produce a lot of heat due to which there is a need of cooling agent or coolant. Hence the nanofluids were invented to cool down these systems and prevent it from any hazards. The nanoparticle, when blended with a fluid base, shows a phenomenal spike in the thermal conductivity of the nanofluid. As the nanoparticles are very small, they are used in the miniaturization of the cooling systems, which is a great benefit to the microchips.

Nowadays, the use of mini channel (hydraulic diameter ranging from 200 micrometers to 3mm) heat exchanger has increased drastically and continuous research is done in this field to make the heat exchanger more efficient by any means. The minichannel heat sync has shown a remarkable use in the field of electronic chips. With the direct cooling of the electronic chips there can be many problems one of which is improper heat dissipation. As the cooling agent is made to flow through the mini channel, there has been a noticeable change in heat dissipation.

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019

1.2 Literature Review

It has been found that, for heat transfer applications the performance exhibited by nanofluids are much better as compared to distilled water. Sohel at el. [1] explained about the coefficient of heat transferwas enhanced by 18%. The nanofluid was successfully be able to lowered the base temperature of heat sink by 2.7^{o}Cand it also possessed 15.72% less value of thermal resistanceat 0.25 vol.%. Hemant Kumar and S.S.Sehgal [2] explained needs and uses in recent microelectronics. This paper explained about size, weight and cost as main factors for the usage of mini-channels for cooling the electronic chips. Mass flow rate and pressure drop were varied to obtain relationship with other factors like volume friction, heat transfer rate and density. In this experiment, distilled water with flow rate from 0.4 L/min to 1 L/min with corresponding Reynolds number from 385 to 1851 was used to cool the heat sink.Lazarus Godson at el. has explained different features of the nanofluids including their enhancement in the rate of heat transfer and thermal conductivity. Das et al. [8] did research on the effect of temperature on the rate of heat transfer in nanofluids.Ho and Chen [9] performed an experiment on mini-channel heat exchanger using Al_2O_3–H_2O as a nanofluid. The rate of heat transfer characteristicsby using TiO_2–H_2O nanofluid in a rectangular mini-channel were investigated by Naphon and Nakharintr [10]. They received a significant enhancement in thermal performance, without increasing the considerable amount of pumping power.

1.3 Experimental setup

A system flow diagram for the mini-channel heat sink is presented in the Fig1. The close loop comprises of the following four components: mini-channel heat sink, a heat exchanger, a pump and a nanofluid storage tank. The pump sends the desired quantity of prepared nanofluid to the heat sink from the storage tank to absorb the heat generated by the heat source. After the absorption of the heat, the nanofluid is made to exchange the heat with the coolant in the heat exchanger so that it can be recirculatedin the loop. Another pump controls the quantity of the coolant, so that the temperature of the nanofluid at the exit of heat exchanger is exactly equal to the temperature at the inlet of heat sink. The square mini-channels were produced by milling operation. An aluminum block of dimensions 45 mm × 45 mm × 6 mm was used as the heat sink. There were total five equally spaced channels each of width and depth 3 mm. The heating coil of 1000 watts was placed below the heat sink to heat the plate. The temperatures were measured using five Linear Active Thermistor IC sensors with an accuracy of ±2°C and sensing temperature from -40^{0}C to +125^{0}C. Two temperature sensors were placed below the heat sink to analyse the coil temperature and other three temperature were placed at the inlet, outlet of heat sink and the outlet of the heat exchanger, respectively. Two 12V DC Peristaltic pumps with flow rate 19-100 mL/ min were used in the experiment, one between storage tank and the heat sink and the other one to pump the coolant in and out in the heat exchanger.

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019

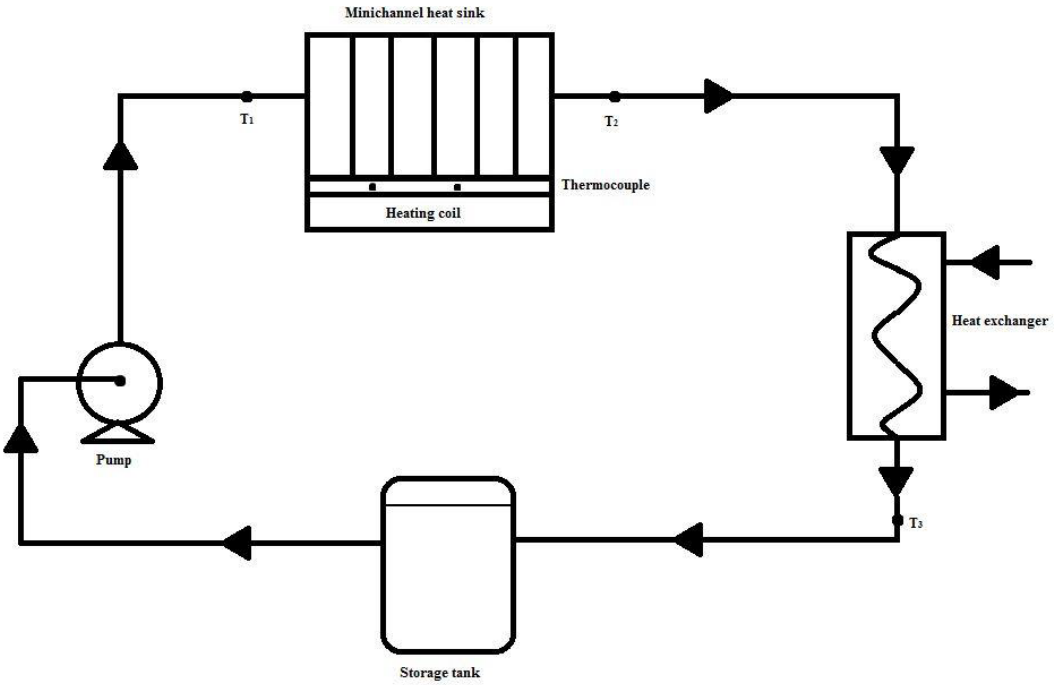


Fig 1 A system flow diagram for the mini-channel heat sink

1.4 Methodology

Nanofluid preparation

Currently, there are two ways to prepare nanofluid from nanoparticles, (i) Single step preparation process or VEROS (Vacuum Evaporation onto a Running Oil Substrate) technique and (ii) Two step preparation process. Metal oxides are generally prepared by two-step preparation process. In this process, firstly, the nanoparticles are simply dispersed in the base fluid but this dispersion is not good enough. After that, sonication of nanofluid was done using an ultrasonic homogenizer to make a homogeneous nanofluid. The nanoparticles used in the experiment were received from Nano Labs, Jamshedpur. Physical and chemical properties of the nanoparticles:

1. Nano-particles: Titanium Oxide (TiO2)
2. Purity: 99.9%
3. Avg. Particle Size: 10-20 nm
4. Density (at 20^0C) : 4.01×10^3 kg/m^3
5. Thermal conductivity of the nano-particle: 4.8 W m-1 K-1
6. Molar mass: 79.8658 g/mol
7. Specific heat: 685 J/kg.K
8. Melting point: 1830-1850^{0}C
9. Boiling point: 2500-3000^{0}C

Steps involved in the preparation of nanofluid:

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Weighing: The nanoparticles were weighed 10 grams and 20 grams to prepare twoconcentrations of 5% and 10% by mass in a total solution of 200mL, respectively.

Manual Stirring: The weighted nanoparticles were then added to the distilled water to prepare 200 mL solution of nanofluid and then manually stirred by stirrer.

Magnetic Stirring: The beaker, with nanofluid, was mounted over the magnetic stirrer to stir the solution constantly at average speed of 800-900 RPM for 1.5 hrsat constant temperature.

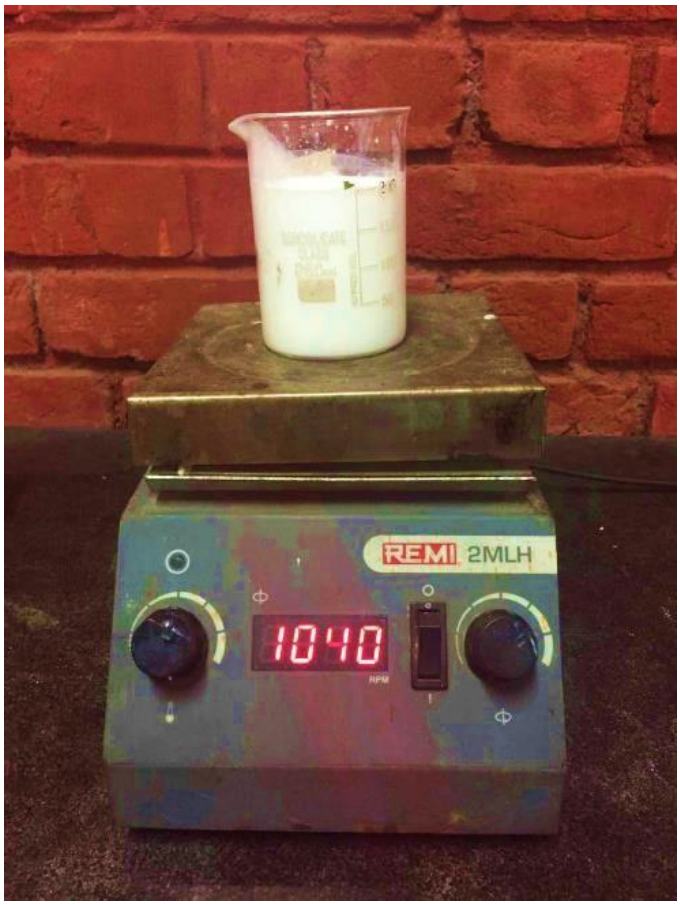


Fig 2The TiO_2-H_2O nanofluid solution being stirred

Sonication Process: After stirring process, the solutions were placed in the sonication machine to mix the TiO_2-H_2O nanofluid properly. These nanofluid solutions were kept in the sonication machine for 11 cycles. (1 cycle = 480 sec)

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019



Fig 3Sonication process

1.5 Results and Discussion

In order to properly judge the difference between heat transfers in case of water and the nanofluid, the experiment was conducted at three different discharges.

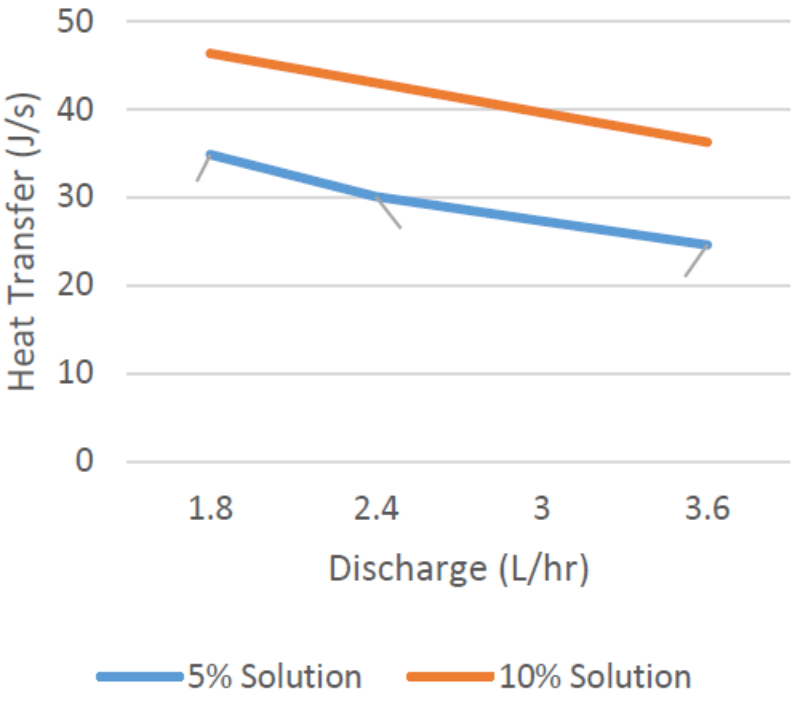


Fig 4 Discharge vs Heat Transfer

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019

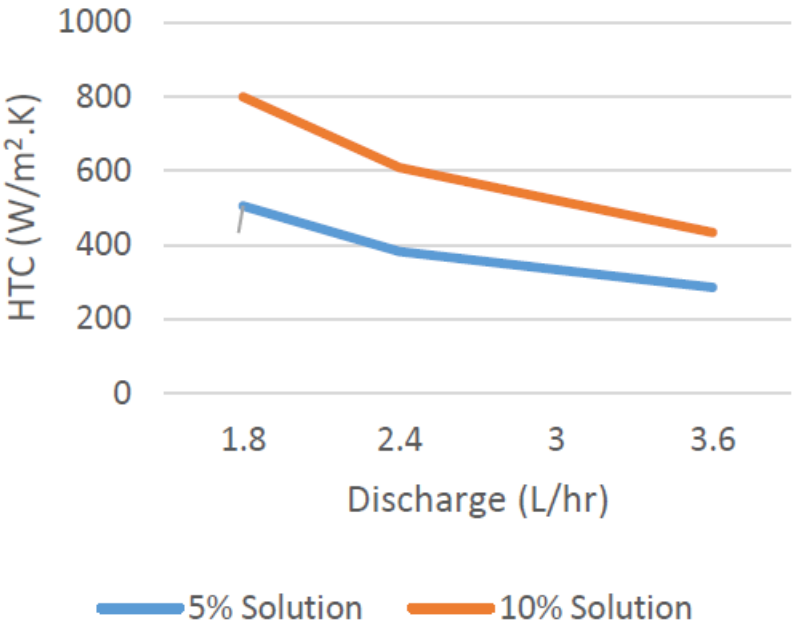


Fig 5 Discharge vs Heat Transfer Coefficient

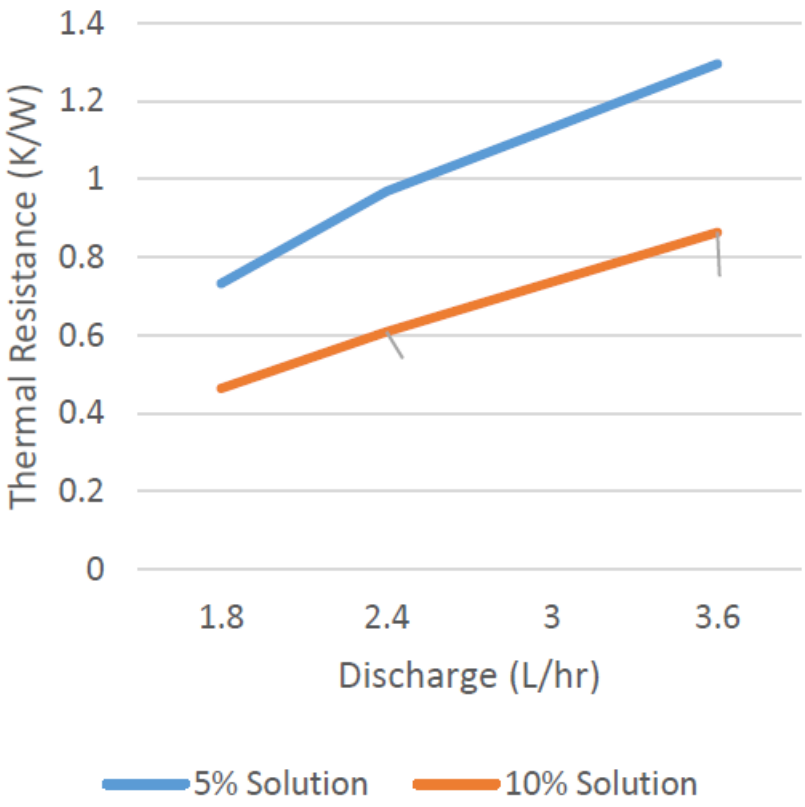


Fig 6 Discharge vs Thermal Resistance

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Comparison of parameters for 5% and 10% nanofluid.

• It is pretty evident from the graph that as discharge increases, the amount of heat transfer decreases. With increase in discharge there is an increase in the velocity of nanofluid flowing through the system. This in-turn decreases the time of contact between the system and fluid. So, it is obvious that heat transfer would be less if time of contact of the two is less. As discharge increases, the difference in the heat transfer between the two concentrations increases, from 33% at 1.8 L/hr to 41% at 2.4 L/hr to 49% at 3.6 L/hr.

• It is also seen that the thermal resistance increases with the increase in discharge. The thermal resistance increases slowly initially but afterwards, a steep rise is observed. However, as discharge increases, the separation between the two concentrations decreases.

• Since thermal resistance and heat transfer coefficient are inversely proportional to each other the similar pattern is observed in case of heat transfer coefficient except it decreases with increase in discharge. It is seen that the fluid with higher nanoparticle content provides lesser resistance. Also, the increase in resistance, with increase in discharge, is less for 10% solution than 5% solution.

1.6 Conclusions

In this experimental work, the heat transfer performances of a mini-channel heat sink were investigated using TiO_2–H_2O based nanofluid at different flow rates. The thermal performances were compared against pure distilled water. The concluded results are as follows:

A better performance was found using TiO_2–H_2O nanofluid as compared to the pure distilled water. Minimization and holding of the base temperature of the heat sink at a constant level was attained. The heat transfer coefficient was improved by using the nanofluid as compared to the distilled water. The overall heat transfer coefficient was calculated by performing log mean temperature difference analysis. The convective resistance was reduced in a significant manner. When we use the same system, we found 136% to 248% better heat transfer capacity of TiO_2 nanofluid. But for the same amount of heat transfer TiO_2 setups can be as much as **40-55%** smaller in size.

References:

1. M.R. Sohel, S.S. Khaleduzzaman, R. Saidur, A. Hepbasli, M.F.M. Sabri, I.M. Mahbubul (2014)An experimental investigation of heat transfer enhancement of a minichannel heat sink using Al2O3–H2O nanofluid. International Journal of Heat and Mass Transfer volume 74: 164-172

2. Hemant Kumar and S.S.Sehgal (2013) Study of fluid flow and heat transfer through Mini-channel heat sink. Volume 2 No.2 July-December 2013 pp 25-28

3. Lazarus Godson, B. Raja, D. Mohan Lal, S. Wongwises (2009) Enhancement of heat transfer using nanofluids. Renewable and Sustainable Energy Reviews 14(2):629 641 · February 2010

4. Kaufui V. Wong and Omar De Leon (2009) Applications of Nanofluids: Current and Future.

5. Sayantan Mukherjee, SomjitParia (2013) Preparation and Stability of Nanofluids: A review.

Copyright ⓒ 2019Authors

ISSN:0971-1260
Vol-22-Issue-37-December -2019

6. Xiang-Qi Wang, Arun S. Mujumdar (2006) Heat transfer characteristics of nanofluids.

7. S.K. Das, N. Putra, P. Thiesen, W. Roetzel, Temperature dependence of thermal conductivity enhancement for nanofluids, J. Heat Transfer 125 (2003) 567– 574.

8. C.J. Ho, W.C. Chen, An experimental study on thermal performance of Al2O3/ water nanofluid in a minichannel heat sink, Appl. Therm. Eng. 50 (2013) 516– 522.

9. P. Naphon, L. Nakharintr, Heat transfer of nanofluids in the mini-rectangular fin heat sinks, Int. Commun. Heat Mass Transfer 40 (2013) 25–31.

10. M. KeshavarzMoraveji, R. MohammadiArdehali, A. Ijam, CFD investigation of nanofluid effects (cooling performance and pressure drop) in mini-channel heat sink, Int. Commun. Heat Mass Transfer 40 (2013) 58–66

11. P. Selvakumar, S. Suresh, Convective performance of CuO/water nanofluid in an electronic heat sink, Exp. Therm. Fluid Sci. 40 (2012) 57–63. [24] B.C. Pak, Y.I. Cho, Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles, Exp. Heat Transfer 11 (1998) 151– 170.

12. Y. Xuan, W. Roetzel, Conceptions for heat transfer correlation of nanofluids, Int. J. Heat Mass Transfer 43 (2000) 3701–3707.

13. R.L. Hamilton, O.K. Crosser, Thermal conductivity of heterogeneous twocomponent systems, Ind. Eng. Chem. Fundam. 1 (1962) 187–191.

14.] W. Yu, S.U.S. Choi, The role of interfacial layers in the enhanced thermal conductivity of nanofluids: a renovated Maxwell model, J. Nanopart. Res. 5 (2003) 167–171.

15. C.T. Nguyen, F. Desgranges, N. Galanis, G. Roy, T. Maré, S. Boucher, H. AngueMintsa, Viscosity data for Al2O3–water nanofluid—hysteresis: is heat transfer enhancement using nanofluids reliable?, Int J. Therm. Sci. 47 (2008) 103–111.

16. M. Corcione, Rayleigh–Bénard convection heat transfer in nanoparticle suspensions, Int. J. Heat Fluid Flow 32 (2011) 65–77.

17. A. Ijam, R. Saidur, P. Ganesan, Cooling of minichannel heat sink using nanofluids, Int. Commun. Heat Mass Transfer 39 (2012) 1188–1194.

18. C.J. Ho, L.C. Wei, Z.W. Li, An experimental investigation of forced convective cooling performance of a microchannel heat sink with Al2O3/water nanofluid, Appl. Therm. Eng. 30 (2010) 96–103.

19. H.W. Coleman, W.G. Steele, Experimentation, Validation, and Uncertainty Analysis for Engineers, John Wiley & Sons, New York, 2009.

Copyright ⓒ 2019Authors