Scholars LITERATURE

Nanotechnology and Nanomaterials Research

Research Article

DOI: https://doi.org/10.47275/2692-885X-120
Volume 4 Issue 1

A Numerical Study on the Performance of Water Based Copper Oxide Nanofluids in Compact Channel

Shiva Singh*, Gurpreet Singh Sokhal and Gurprinder Singh Dhindsa

Department of Mechanical Engineering, Chandigarh University, Gharuan, Punjab, India

Abstract

Heat can be transferred through nano-sealed particles by suspending them into a base fluid. Many experimental data have shown that nanofluids have much more thermal conductivity than conventional fluid. The main objective is to evaluate the role of copper oxide nanofluid in a channel that is compact and used for the application of heat. The evaluation of heat transfer performance has been calculated and the heat transfer rate of the compact channel goes above with an increase in the concentration of a base fluid of nanoparticles. At the same condition, if there is a nanofluid whose temperature is less at some factor, then the heat transfer rate is approximately 24% increases than base fluid.

Keywords: Nanofluids, Thermal conductivity, Temperature, Heat transfer, Nanoparticles

Correspondence to: Shiva Singh, Department of Mechanical Engineering, Chandigarh University, Gharuan, Punjab, India; E-mail: shivapratapsingh9838@gmail.com

Citation: Singh S, Sokhal GS, Dhindsa GS (2023) A Numerical Study on the Performance of Water Based Copper Oxide Nanofluids in Compact Channel. Nanotechnol Nanomater Res, Volume 4:1. 120. DOI: https://doi.org/10.47275/2692-885X-120

Received: July 21, 2023; **Accepted:** September 13, 2023; **Published:** September 15, 2023

Introduction

The standard arrangement essentials for present-day heat transfer equipment are less in size and high thermal execution. In the last decades, valid research has committed to coming over of cutting-edge for up-gradation of heat. One-stage and two-stage techniques are intended for little and enormous scope combinations separately [1]. Size in nanoscale and enormous explicit space of nanoparticles show higher thermal conductivity, consistency alongside the heat absorption. There is a lot of research is there on the properties of nanofluids, but the main concern is that the heat transfer should be maximum on side of particles whose size does not vary much more than nanoscale [2]. Comparing a base fluid that is pure and that colloidal suspension is strong with the performance of a low active particle, then the whole properties will change, and thermal conductivity will be higher than that of it. In the heat exchanger, the performance of different types of nanofluids whose concentration is at less volume, then the transfer of heat performance of nanofluids is large on compared with base fluid [3]. The application of heat transfer, on the addition of various types of nanofluids in the base fluid, increases the efficiency of heat transfer properties. The fluid properties can be changed by the enhancement of the cooling rate. In heat transfer systems like heat exchangers, nanofluids are used as a coolant [4]. The presentation of the minimal channel is altogether higher than that of the compact channels. The heat flux and temperature profiles of nanofluids have been decreased with the increasing thermal relaxation parameters. The study of heat transfer performance in nanofluids through the compact channel is numerically studied. To make it low in the size of a heat transfer device, it is important that the pipe has a compact size. This feature helps in increasing the transfer performance and minimum pressure drop in the airside. Heat transfer can be enhanced with the flow of another type of fluid in entropy generation [5]. The thermal conductivity of silver particles based nanofluid is much higher than other nanofluids. The effect of particle shape on thermal conductivity is also an important factor for example the thermal conductivity of cylindrical nanoparticles provides a good way other than spherical nanoparticles (Figure 1). The heat exchanger is a type of device which is used to transfer heat between two or more fluids. Both heating and cooling processes can be done by this process. If two or more fluids are indirect contact, then they can be separated by a solid wall with the help of fluids. This type of exchanger can be used in space heating power stations, chemical plants, and many more [6]. If we see in the case of industry the cooling-heating can be done on a large scale with the help of a heat exchanger. If we see in many industries a lot of energy is going to be wasted and it can recover with the help of heat exchanger. In this process, we put the fluids in a heating region by the different stream in the process [7].

Literature Review

There are many researchers who have worked on nanofluids. Nanofluid is a vast area and in this area, there are many articles that have been published in which the efficiency has been reported for heat transfer devices. It has always been a challenge to select the optimal heat exchanger. If we don't know about system designers or equipment, then we cannot select an appropriate heat exchanger. There are always limitations in the design, so we have to first consider the criteria for the selection which is suitable for the work. Some important selection criteria: high and low-pressure limits, variation of temperature, pressure drop [8].

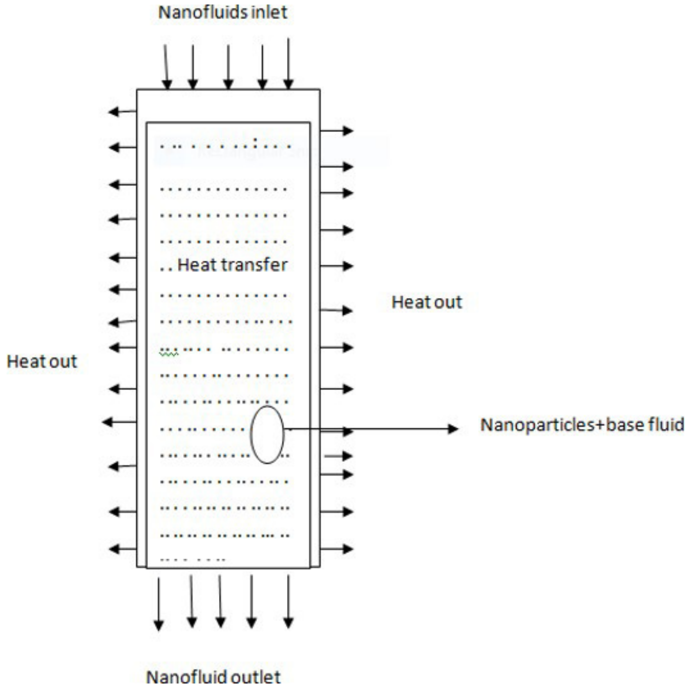

Figure 1: Heat transfer mechanism in compact tube.

The technology is used with the help of small diameter coils and is also popular in a modern refrigeration system which can produce a better rate of heat transfer than the conventional sized condenser. In turbulent flow, the heat transfer is more intense than cooling. This design study shows that the pressure drops at various factors such as the inlet and outlet nozzle, the cross-drift phase, the flow's angle, and the go-drift velocity can affect the heat transfer. It was noted that both single and two-stage approaches expected comparative stream fields, however, the thermal field forecast was changed [5]. Increment in convective heat transfer of nanofluids over distilled water was measured in this study. It has been derived that convective heat transfer increases astoundingly with the development of nanoparticles obsession under different Reynolds numbers. Results revealed that the convective heat transfer increases with the development in both Reynolds number and volume concentration. The pressure drop of Al_2O_3/water nanofluids is generally the same as those of rough water in the given condition [9]. The particle volume portion similarly expects a huge occupation as for the thermal conductivity of nanofluids. It has been seen that by increasing the particle volume, the thermal conductivity of nanofluids increases, and by a rise in the temperature the consistency of nanofluids decreases [10]. The low temperature was used to display the substantiality of nanofluids disregarded areas. The creator uncovered that the consistency of nanofluids increases with an increase in the volume ratio. The temperature oppositely affects the consistency of the copper oxide nanofluids [11]. It has been revealed that as the temperature assembles the consistency of the copper oxide nanofluids diminishes randomly. It has been moreover seen that the volume segment expects a critical occupation in thermal conductivity. It has been seen that the thermal conductivity increases with an increase in the volume ratio [12].

It has been found that both the thickness and thermal conductivity of nanofluids increases with nanoparticles volume concentration. It has been seen that the thermal conductivity of Al_2O_3/water nanofluids has a straight association with the volume concentration [13]. From the above boundary, conditions gathered that if the Rayleigh number is identical to 103 then the normal Nusselt number is extended by growing the volume part. In any case, if Rayleigh's number is more noticeable than or identical to 104, then the normal Nusselt number decreases [14]. It has been assumed that both the thermal conductivity and consistency increases with an increase in the atom molecule centre. The writer moreover revealed that the event of particle completion also expects a huge occupation in heat move improvement for example it depends upon the zeta ability of nanoparticles in the suspension process [15]. From the above boundaries' conditions, it has been resolved that the conductivity of nanofluids increases with an increase in nanofluids temperature and decreases with an increase in nanoparticles size for instance the conductivity is generally raised for the atom which has the smallest apparent distance across [16]. Colloidal suspensions of nanoparticles that are present in a base fluid are called nanofluids. These nanofluids are highly efficient heat transfer fluids. This enhanced heat transfer of the fluid is due to the presence of an ordered molecular layer around each particle, many physical mechanisms that include the Brownian motion, and also the aggregation and clustering of the particles. However, several disparate mechanisms are still not found out. It is known that the thermal conductivities of most of the solid materials are higher than those of liquids and hence the thermal conductivities of particles and mixtures are anticipated to increase. Fluids suitable for thermal management applications are fluids that have higher thermal conductivities [12]. For many existing heat transfer devices like the miniature devices with small component sizes and passages, nanoparticles mixtures are suitable as heat transfer takes place in a variety of movements as they have very small sizes of suspended particles. Due to the small sizes of these miniature devices, the nanoparticles act as a medium of lubrication when they come in contact with other solid surfaces [17]. The increase in the effective thermal conductivity with the enhancement of heat transfer was due to the reduction in the thickness of the thermal boundary layer. The liquid-vapor phase change also tends to reduce the thickness of the gas layer present near the wall. These fluids with heating and cooling properties are of major importance to industrial sectors which include electronics, transportation, energy supply, and production [9]. In the development of energy-efficient heat transfer equipment, a major role is played by the thermal conductivity of the fluids. Regardless, compared to most solids, conventional heat transfer fluids have poor heat transfer properties. Even after all the research and development on industrial heat transfer requirements, the rate of improvement of the heat transfer capabilities is quite low. Because of which there is still a need to develop new plans for the improvement of conventional heat transfer fluids [18]. With this, there is also a need for a more comprehensive theory that explains the behavior of nanofluids.

The clogging and settlement of microchannels are not easy but the thermal conductivity of nanofluids can be decreased by the agglomeration process. Analyze the factors of nanofluids, the property should be stable and follow a proper mechanism. It is found that obtained nanofluids are stable than other nanofluids which are in stable positions without sedimentation [19]. According to composition the degree of continuity between the fluids and nanoparticles the phase of interface decreases. The particle size in the nanoparticle is less than zero (approximately negligible) and the concentration of the nanoparticle is very small so this type of fluid can be considered homogenous. In this type of study, we neglect the gravity force, and the gravity force is less as compared to the viscous drag force. The thermophysical properties of nanofluids are important when it came to the application of nanofluids in heat transfer. The preparation of nanofluid should ensure appropriate scattering of nanoparticles in the liquid and component. The thermal conductivity of nanofluid is highly dependent upon the volume part and properties of nanoparticles. For the transfer of heat, the production of metallic and non-metallic should be of crystalizing size and less than 100 nm. Nanofluids can be used for cooling and also used to solve some common problems such as sedimentation, clogging, and increase pressure drops. To enhance the thermal properties of coolant as equipment of heat transfer such as heat exchanger, it is primarily used. The ability to design materials at the nanoscale level with some innovation and technology and manipulating nanomaterials at a nanoscale level can enhance the properties of nanofluids. It is important to know the real concentration and physical properties of manufactured nanoparticles under real conditions so that easily get to know the behavior of that nanofluids. If a material changes its phase in nanoparticles, then it can increase effective thermal conductivity and also increase specific heat of that fluid [20]. If there is an increment in specific surface area, then heat transfer surface between particles and fluids will be more. The advantage of nanofluids is to reduce clogging as compared to others and enhance the system miniaturization. variation in concentrating particles of nanofluids can change the chemical and physical properties of fluids [11].

Methodology

The clogging and settlement of microchannels are not easy but the thermal conductivity of nanofluids can be decreased by the agglomeration process. If we analyze the factors of nanofluids, the property should be stable and follow a proper mechanism. It is found that obtained nanofluids are more stable than other nanofluids which are in stable positions without sedimentation. According to composition the degree of continuity between the fluids and nanoparticles the phase of interface decreases (Figure 2) [21].

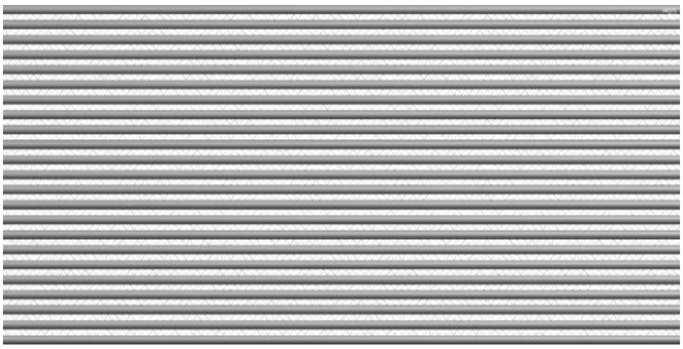

Figure 2: Shows the front view of the radiator tubes and zigzag fins of the radiator.

The computational fluid dynamics software ANSYS-fluent 14.5 and the conservation equation 1, 2, and 3 were used.

Continuity equation: $\nabla . V = 0$ (1)

Energy equation: $\rho_{nf} C_{pnf} \left(\nabla . V \right) T = k_{nf} \nabla^2 T V$ (2)

Momentum equation: $\rho_{\text{nf}} \left(\nabla . V \right) V = -\nabla P + \left(\mu_{nf} + \mu^t \right) \nabla^2 V$ (3)

Results and Discussion

It is because the specific heat of base fluids is less than that of other nanofluids. The important criterion for heat transfer application of nanofluid is thermal conductivity. The estimation of the thermophysical properties plays an important role in the heat transfer applications of the nanofluids. The estimation of the different thermophysical properties i.e., specific heat capacity, density, thermal conductivity, and viscosity are done with the well-developed models only. For heat transfer applications of nanofluids, thermal conductivities are considered to be an important parameter. With the increase in fluid inlet temperature and addition of nanoparticles, there is an increase in the thermal conductivity of nanofluids [10]. The increase in the thermal conductivity of base fluid leads to heat transfer enhancement which is caused by the increase in nanoparticles concentration. Since the thermal conductivity of nanoparticles is higher than the base fluid, it leads to thermal conductivity enhancement (Figure 3).

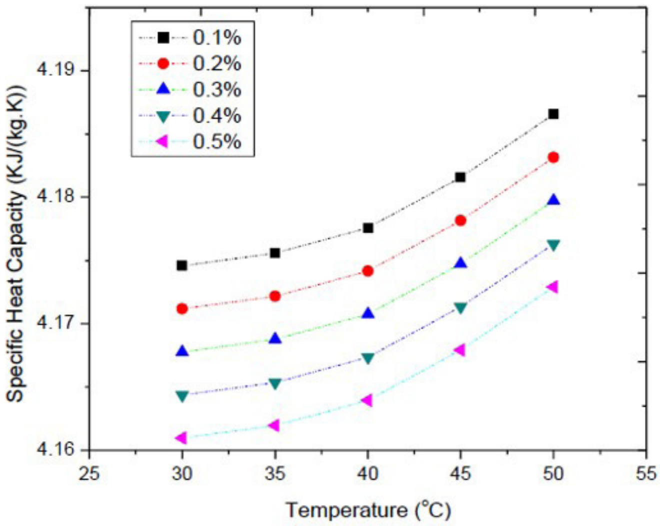

Figure 3: Variation of specific heat of nanofluids with variation in fluid temperature and particle concentration.

In Numerical calculation and correlation, the average error in between is 12.23%. With the increase in volumetric concentration and Reynolds number then the coefficient of heat transfer also increases [9]. An increment in Nusselt number results in an increment in heat transfer (Figure 4).

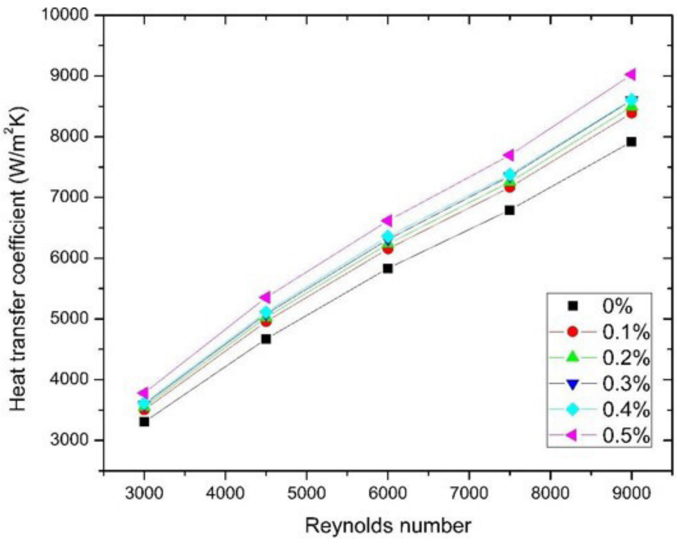

Figure 4: Variation of heat transfer coefficient with different volumetric concentration of nanoparticles based in water at a temperature of 45 °C.

Conclusion

The thermophysical properties of nanofluids are important when it came to the application of nanofluids in heat transfer. In some results, it has been shown that the decrease in specific heat with increment concentration of particles then it will increase with temperature.

References

1. Stewart JE, Dohme JA (2005) Automated hover trainer: Simulator-based intelligent flight training system. Int J Appl Aviat Stud 5: 25-40.
2. Eastman JA, Choi US, Li S, Thompson LJ, Lee S (1996) Enhanced thermal conductivity through the development of nanofluids. MRS Online Proc Lib 457: 3. https://doi.org/10.1557/PROC-457-3
3. Wen D, Ding Y (2004) Experimental investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions. Int J Heat Mass Transf 47: 5181-5188. https://doi.org/10.1016/j.ijheatmasstransfer.2004.07.012
4. Eastman JA, Choi SUS, Li S, Yu W, Thompson LJ (2001) Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles. Appl Phys Lett 78: 718-720. https://doi.org/10.1063/1.1341218
5. Reddy MCS, Rao VV (2013) Experimental studies on thermal conductivity of blends of ethylene glycol-water-based TiO_2 nanofluids. Int Commun Heat Mass Transf 46: 31-36. https://doi.org/10.1016/j.icheatmasstransfer.2013.05.009
6. Das SK, Putra N, Thiesen P, Roetzel W (2003) Temperature dependence of thermal conductivity enhancement for nanofluids. J Heat Transf 125: 567-574. https://doi.org/10.1115/1.1571080
7. Jana S, Salehi-Khojin A, Zhong WH (2007) Enhancement of fluid thermal conductivity by the addition of single and hybrid nano-additives. Thermochim Acta 462: 45-55. https://doi.org/10.1016/j.tca.2007.06.009
8. Priya KR, Suganthi KS, Rajan KS (2012) Transport properties of ultra-low concentration CuO-water nanofluids containing non-spherical nanoparticles. Int J Heat Mass Transf 55: 4734-4743. https://doi.org/10.1016/j.ijheatmasstransfer.2012.04.035
9. Kole M, Dey TK (2011) Role of interfacial layer and clustering on the effective thermal conductivity of CuO-gear oil nanofluids. Exp Therm Fluid Sci 35: 1490-1495. https://doi.org/10.1016/j.expthermflusci.2011.06.010
10. Zhu H, Han D, Meng Z, Wu D, Zhang C (2011) Preparation and thermal conductivity of CuO nanofluid via a wet chemical method. Nanoscale Res Lett 6: 1-6. https://doi.org/10.1186/1556-276X-6-181
11. Saterlie M, Sahin H, Kavlicoglu B, Liu Y, Graeve O (2011) Particle size effects in the thermal conductivity enhancement of copper-based nanofluids. Nanoscale Res Lett 6: 1-7. https://doi.org/10.1186/1556-276X-6-217
12. Murshed SMS, Leong KC, Yang C (2005) Enhanced thermal conductivity of TiO_2-water based nanofluids. Int J Therm Sci 44: 367-373. https://doi.org/10.1016/j.ijthermalsci.2004.12.005
13. Patel HE, Das SK, Sundararajan T, Nair AS, George B, et al. (2003) Thermal conductivities of naked and monolayer protected metal nanoparticle based nanofluids: manifestation of anomalous enhancement and chemical effects. Appl Phys Lett 83: 2931-2933. https://doi.org/10.1063/1.1602578
14. Zhu HT, Zhang CY, Tang YM, Wang JX (2007) Novel synthesis and thermal conductivity of CuO nanofluid. J Phys Chem C 111: 1646-1650. https://doi.org/10.1021/jp065926t
15. Akoh H, Tsukasaki Y, Yatsuya S, Tasaki A (1978) Magnetic properties of ferromagnetic ultrafine particles prepared by vacuum evaporation on running oil substrate. J Cryst Growth 45: 495-500. https://doi.org/10.1016/0022-0248(78)90482-7
16. Wei X, Zhu H, Kong T, Wang L (2009) Synthesis and thermal conductivity of Cu_2O nanofluids. Int J Heat Mass Transf 52: 4371-4374. https://doi.org/10.1016/j.ijheatmasstransfer.2009.03.073
17. Lee S, Choi SS, Li SA, Eastman JA (1999) Measuring thermal conductivity of fluids containing oxide nanoparticles. J Heat Transf 121: 280-289. https://doi.org/10.1115/1.2825978
18. Hong J, Kim D (2012) Effects of aggregation on the thermal conductivity of alumina/water nanofluids. Thermochim Acta 542: 28-32. https://doi.org/10.1016/j.tca.2011.12.019
19. Barbés B, Páramo R, Blanco E, Casanova C (2014) Thermal conductivity and specific heat capacity measurements of CuO nanofluids. J Therm Anal Calorim 115: 1883-1891. https://doi.org/10.1007/s10973-013-3518-0
20. Lee D, Kim JW, Kim BG (2006) A new parameter to control heat transport in nanofluids: surface charge state of the particle in suspension. J Phys Chem B 110: 4323-4328. https://doi.org/10.1021/jp057225m
21. Teng TP, Hung YH, Teng TC, Mo HE, Hsu HG (2010) The effect of alumina/water nanofluid particle size on thermal conductivity. Appl Therm Eng 30: 2213-2218. https://doi.org/10.1016/j.applthermaleng.2010.05.036