IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 10, Issue 2 Ver. III (Mar. – Apr. 2018), PP 13-17
www.iosrjournals.org

A Comparative Evaluation of Thermo physical Properties of Nanofluids for Industrial Applications

Supreeti Das
Department of Physics,Gargi College, University of Delhi
Corresponding Author: Supreeti Das

Abstract: *In the present paper we investigate the heat transfer characteristics of nanofluids. This is a new class of fluids which is prepared by suspending a small quantity of nanoparticles in base fluids like water. It has the potential to be used as an efficient heat removing material. In particular , nanofluids can be used in the automobile industry as a coolant. In the present era of miniaturization in the electronic industry, nanofluids can be used in devices for quick removal of the enormous heat generated in these devices like laptops. Similarly nanofluids can also find applications in fire extinguishing industry,in the manufacturing industry and also as a medium in heat exchangers. Due to the enhanced heat transfer properties, smaller volume of heat exchange fluid will be required. Nanofluids, therefore have the potential to cut costs wherever conventional fluids like water, ethylene glycol or oil are presently in use as heat transfer fluids. It is therefore important to understand the mechanisms and the heat transfer properties of nanofluids for designing efficient heat removal material. Since addition of nanoparticles to the base fluid enhances the heat transfer, in the present paper we focus on the changes produced in the thermophysical properties of base fluid in the presence of nanoparticles. We will calculate and analyze the thermophysical properties of nanofluids which will be formed by dispersing metal oxide nanoparticles in water and ethylene glycol. Evaluation of properties like thermal conductivity, viscosity and specific heat and investigating their dependence on temperature , will be of immense significance for potential applications of nanofluids in the industries as efficient heat removal will improve the performance of the devices.*

Date of Submission: 28-03-2018 Date of acceptance: 14-04-2018

I. Introduction

Nanofluid is a term coined by Choi in 1995 [1] which is obtained by forming a suspension of nanoparticles in fluids. The special property of this class of fluids is the anomalous increase in the thermal conductivity due to which they are potential heat removing fluids. The growth in technology in the past few decades has certainly been enormous. However these technological advancements have also resulted in a crisis for thermal management. While miniaturization solves storage problems but it also generates a lot of heat in the devices. Similarly our manufacturing industry, petroleum industry(nanofluids can be used for cooling the apparatus which work under high friction like the drilling machines), food processing industry, automobile industry (nanofluid can be used as a coolant) all have a requirement for efficient removal of heat. Thus nanofluids with its property of enhanced thermal conductivity can be the new generation material for efficient heat removal in the above mentioned industries. Using suspensions with micro particles for heat removal is certainly not novel. Also increasing the surface area for heat transfer for example by extending surfaces with fins have been used in Mechanical Engineering but using nanotechnology for increasing the surface area and therefore increasing the heat transfer is a novel concept. Nanotechnology can result in dispersing smaller particles in the base fluid broadly of diameter ranging between 1-100 nm[2]. There are quite a few advantages of this. As the particles are smaller, they will not clog the channnels through which they flow. Being lighter, the wear and tear of the walls of the tube are highly reduced when such a fluid is used as a coolant[3,4]. Since the thermal conductivity is anomalously enhanced, the quantity of the fluid used will be much smaller resulting in lighter heat exchangers. Replacing base fluids by nanofluids for heat removal will certainly cut costs as the quantity of fluid required will be lesser and the heat exchangers will be more compact and lighter.

The main factors on which the heat transfer depends are a) the size of the nanoparticle b) volume concentration c) base fluid used d) material of the nanoparticle. The excitement that this new material has generated has resulted in various experimental groups studying the heat transfer characteristics of nanofluids[5]. The base fluids that are employed both as coolants and as heat removal fluids are water, ethylene glycol and oil none of which are characterized by high thermal conductivity. Understanding the mechanisms of heat transfer in nanofluids which result in the increase in the thermal conductivity therefore is very important. This study can lead to designing efficient heat removal materials. The most important step towards this is to understand the alterations in the thermophysical properties produced due to the addition of nanoparticles. In the present work , our focus therefore is investigation and comparison of the thermophysical properties of nanofluids formed by nanoparticles dispersed in the base fluid (ethylene glycol(EG)) .

II. Descriptions and Equations

We will be comparing the thermophysical properties of nanofluids formed by suspending (a)Titanium di oxide, (b)Silica and (c) Alumina nanoparticles. In the present work we are concentrating on the oxide nanofluids as they are more stable. There is a limitation to the volume fractions that should be computationally explored. Experimentally it is found that [6,7] volume fractions above 5%-8% result in agglomerations and sedimentations and therfore the nanoparticles will not remain suspended in the fluid and the fluid will not be a nanofluid .We confine our calculations to a range of 0.1% to 8% volume fraction for the nanoparticles. We have used the correlations generated empirically for the determination of the viscosity, density, thermal conductivity and the specific heat capacity[8,9,10,19]. The nanoparticles are considered to be small, and assuming there is a thermal equilibrium between the nanoparticles and base fluid we treat the system as a single phase with solid nanoparticles moving with same velocity as the fluid. The properties are determined by its constituents nanoparticles and base fluid. The basic assumption of the single phase is that the fluid is considered as homogeneous.

$$\mu_{nf} = \mu_f(1+\varphi) \qquad (1)$$

with μ_{nf} and μ_f as the viscosities of the nanofluid and base fluid respectively and φ is the volume fraction of the nanoparticles.

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_p \qquad (2)$$

where ρ_{nf} , ρ_f and ρ_p are respectively the densities of the nanofluid, base fluid and the nanoparticles.

$$k_{nf} = k_f\left[k_p + 2k_f - 2\varphi\left(k_f - k_p\right)\right]/\{k_p + 2k_f + \varphi\left(k_f - k_p\right)\} \qquad (3)$$

where k_{nf} , k_f and k_p are the thermal conductivities of the nanofluid,base fluid and nano particle respectively.

$$c_{p_{nf}} = [(1-\varphi)\rho_f c_{p_f} + \varphi\,\rho_p c_{p_p}]/\,\rho_{nf} \qquad (4)$$

where $c_{p_{nf}}$, c_{p_f} and c_{p_p} represent respectively the specific heat of nanofluid, base fluid and nanoparticle.

III. Methodology

The nanofluids to be used as a heat exchanger fluid will have to be subjected to temperature variations. The thermophysical properties are temperature dependent[11] . Our idea is to the compare the variation of these properties with temperature for the given nanofluids. In the present work therefore we study the variation of thermal conductivity with the volume fraction. The nanoparticles under consideration are Alumina, Silica and TiO_2. The base fluid used in this work is ethylene glycol[21]. While a lot of experimental data is available for nanofluids with water as the base fluid not much work is reported for ethylene glycol as the base fluid. Our aim is also to consider the viscosity dependence on the volume fraction[12]. We will finally compare the percentage enhancement in thermal conductivity of these nanofluids[13] formed by alumina,silica and titanium di oxide nanoparticles.

Table 1:

Nanoparticle	ρ_p (Kg/m^3)	$k_p(\frac{W}{mK})$	$c_{p_p}(\frac{J}{Kg\,K})$
Al_2O_3	3970	40	765
SiO_2	2220	1.380	745
TiO_2	4250	8.95	686.2

IV. Results

Using equations (1)-(4) , we evaluate thermophysical properties of the nanofluids using the mixture models. We find that the thermal conductivity increases with the volume fraction. However we must note that we have a limit of increasing the volume fraction(Fig.1). While the thermal conductivity increases but with higher volume fraction,chances of clustering and sedimentation increase . Thus some kind of optimization will be required. Fig. 2 is a graphical representation of the dependence of the thermal conductivity of the nanofluid on the temperature[14,15]. While equations (1)-(4) are used for calculating the thermophysical properties of the nanofluid using the values of its constituents but the temperature dependence of these properties cannot be ignored as the nanofluids will always be used for heat removal therefore these values will continuously vary with the temperature[18]. Fig. 3 represents the percentage change in the thermal conductivity as the volume fraction is changed for the 3 nanofluids. Fig 4 is a display of the dependence of specific heat on volume fraction while Fig. 5 represents the variation of viscosity with volume fraction. Viscosity plays a very important role in the transfer of heat[15,16]. Fig. 6 compares the relative change in thermal conductivity for TiO_2 nanofluids with two base fluids water[11,22] and ethyl glycol[17] at different volume fractions.

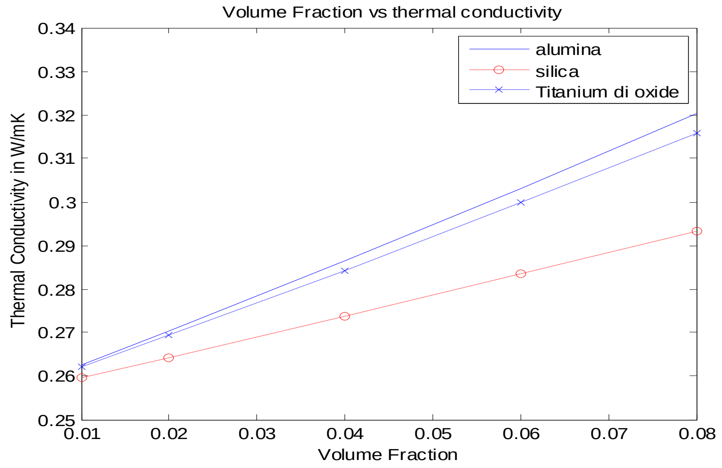

Fig. 1 Thermal Conductivity as a function of volume fraction

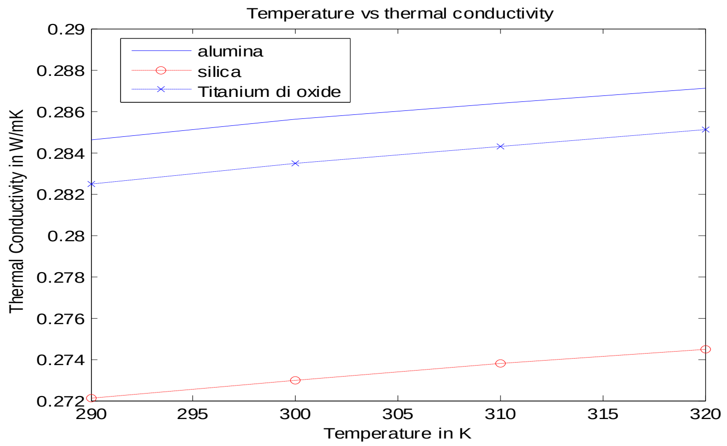

Fig. 2 Thermal Conductivity as a function of Temperature

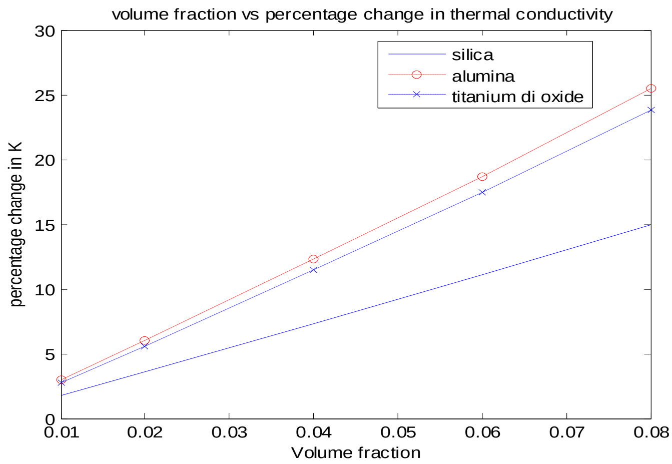

Fig 3 Percentage change in thermal conductivity as a function of volume fraction

DOI: 10.9790/4861-1002031317

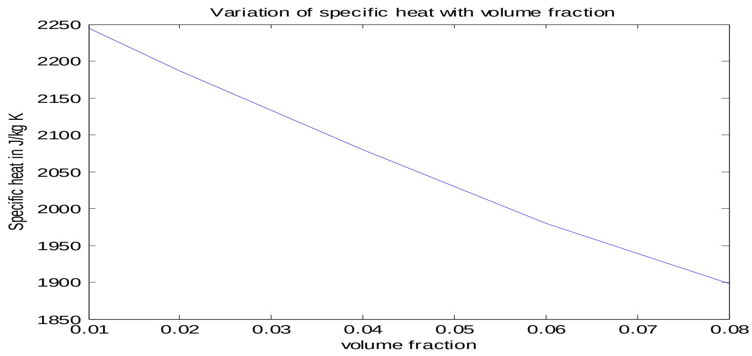

Fig.4 Specific heat as a function of volume fraction

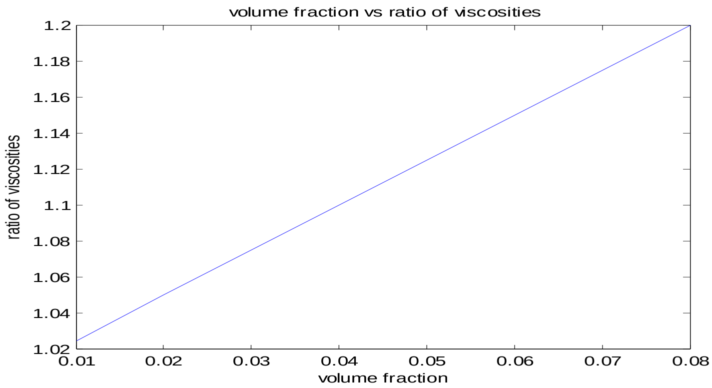

Fig. 5 Ratio of nanofluid viscosity and base fluid viscosity as a function of volume fraction

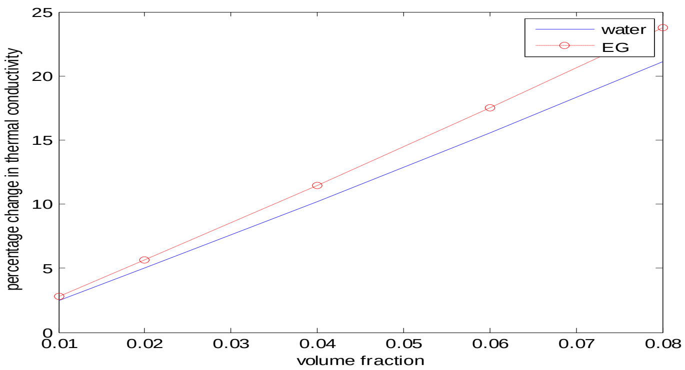

Fig. 6 Comparison of percentage change in thermal conductivity with water and EG as base fluid for Titanium dioxide nanofluid

V. Conclusion and Future Applications

In this paper we have studied the thermophysical properties of Alumina-EG, SiO_2-EG and TiO_2-EG nanofluids[16,17,21]. The thermal conductivity increases in all the nanofluids with volume fraction and temperature . We have also found that the relative change in thermal conductivity remains almost a constant with temperature and is a function only of the volume fraction. The percentage increase in thermal conductivity for a given volume fraction is highest for alumina nanofluid followed by Titanium di oxide nanofluid . The percentage increase is least for silica thermal conductivity. However silica being more abundant and cheaper may be a good substitute for the base fluid in heat exchangers. The increase in volume fraction increases the viscosity of all the nanofluids as is evident from the graph. Increasing viscosity always increases the pumping power costs for the fluid. This once again sets a limit to the increase of the volume concentration of the nanoparticle. From Fig 6 we find that for a given volume fraction , the relative increase in thermal conductivity is higher for ethylene glycol as base fluid in comparison to water. Thus using EG as a base fluid will produce more efficent nanofluids for heat management purposes. This is a a very important result for the automobile industry where presently only EG water mixture is used. Addition of small amounts(6%-8%) of nanoparticles can increase the thermal conductivity by about 20%.

For the nanofluid to be used in industries as the next generation working fluid for an efficient thermal management ,the most important factor is stability and non-agglomeration[16]. Clustering of the nanoparticles will have to be completely avoided ensuring that the nanoparticles remain suspended in the base fluid. Clustering always results in a decrease of effective surface area. It will result in microsuspensions which does not have the properties of nanofluids. Further larger particles always result in sedimentation due to gravity and the fluid cannot be treated as homogeneous and the single phase approach will not be valid. As this limitation is overcome , nanofluids will open new opportunities for a diverse set of industries where further developments and innovations are restricted due to the challenges of heat management. Flowing of nanofluids through microchannels in heat sinks can be used for cooling electronic equipment. The question to be addressed in future is what will cause stability of the nanofluid without affecting the anomalous increase in the thermal conductivity and the heat transfer characteristics. For future research it is very important to factor in the size of the nanoparticles for investigating the thermophysical properties. For industrial applications, more experimental work on dynamic models is required so as to validate the convection models studied. The present work focusses only on heat transfer through conduction while there is a requirement for studying the heat transfer both by conduction and convection.

Acknowledgement

This work is a part of the UGC minor project "Designing Efficient Thermal flow nanofluids" . The author would like to thank the UGC for providing the grant for carrying out this work.

References

[1] S.U.S. Choi , Enhancing thermal conductivity of fluids with nanoparticles, Developments and Applications of Non-Newtonianflows,99, ASME, 1995.

[2] P.Keblinski, S.R.Phillipot, S.U.S.Choi, J.A.Eastman, Mechanisms of heat flow in suspensions of nanosized particles(nanofluids), International J. Heat and Mass Transfer,45, 2002,855-863 .

[3] Y.Xuan, Q.Li, Heat Transfer Enhancement of Nanofluids, Int.J.Heat&Fluid Flow, 21, 2000, 158-164.

[4] T.Pradeep ,A textbook of Nanoscience and Nanotechnology,McGrawhill Education(2nd reprint 2016)

[5] Elena V Timofeeva, Wenhua Yu, David M France, Dileep Singh, Jules L Routbort , Nanofluids for heat transfer : an engineering approach, Nanoscale Research Letters ,2011,6:18 http://www.nanoscalereslett.com/content/6/1/182

[6] Sarit Kumar Das, Stephen U. S. Choi, Heat transfer in Nanofluids— a review, Heat transfer engineering, 27(10), 2006, 3–19.

[7] X.Q. Wang, A.S. Mujumdar, Heat transfer characteristics of Nanofluids: a review , Int. J. Therm. Sci. 46 , 2007, 1–19 .

[8] Bilal Elhajjar , Glades Bachir , Abdelkader Mojtabi, Chakib Fakih, Marie Catherine Charrier-Mojtabi , Modeling of Rayleigh–Bénard natural convection heat transfer in nanofluids , Comptes Rendus Mecanique 338 , 2010 , 350-354.

[9] S.Lee, S.U.S. Choi, J.A.Eastman, Measuring thermal conductivity of fluids containing oxide nanoparticles, J. Heat Transfer Trans, ASME1999, 121, 280-289.

[10] Rashmi et al, Preparation, Thermophysical properties and heat transfer enhancements of nanofluids , Material Research Express 2014, 032001.

[11] Supreeti Das ,Nanofluids for heat transfer, an analysis of thermophysical properties, IOSR, J of Applied Physics, vol7,2015, 34-40 eISSN:2278-4861

[12] Pastoriza-Gallego et al. Thermal conductivity and viscosity measurement in ethylene glycol based alumina nanofluids, Nanoscale Research Letters 2011, 6:221 http://www.nanoscalereslett.com/content/6/1/221

[13] Pak B.C. and Cho I.Y., Hydrodynamic and heat transfer study of dispersed fluids with sub-micron metallic oxide particles, Experimental Heat Transfer, Vol.11, 151-170, 1998.

[14] Xuan Y., Roetzel W., Conceptions for heat transfer correlation of nanofluids, International Journal of Heat and Mass Transfer, Vol.43, 3701-3707, 2000.

[15] Brinkman H.C., The viscosity of concentrated suspensions and solution, Journal of Chemistry and Physics,1952,20, 571.

[16] Maiga S.E., Palm S.J., Nguyen C.T., Roy G. andGalanis N., Heat transfer enhancement in turbulent tube flow using Al2O3 nanoparticle suspension, International Journal of Numerical Methods for Heat and Fluid Flow, Vol.16, 2007,No.3, 275-292.

[17] Duangthongsuk W. and Wongwises S., Heat Transfer Enhancement and Pressure Drop Characteristics of TiO2-Water Nanofluid in a Double-Tube Counter Flow Heat Exchanger, International Journal of Heat and Mass Transfer, Vol.52, 2009, Nos.7-8, 2059-2067.

[18] Lazarus Godson Asirvatham ,Nanofluid heat transfer and Applications , Journal of Thermal Engineering http://eds.yildiz.edu.tr/journal-of-thermal-engineering/Articles Yildiz Technical University Press, Istanbul, Turkey Vol. 1, No. 2, 2015 ,113-115.

[19] Mohamed H. Shedid, M. A. M. Hassan , Numerical Investigation of Heat Transfer Characteristics for the Annular Flow of Nanofluids using YPlus, Journal of Fluid Flow, Heat and Mass Transfer Volume 3, 2016 Journal ISSN: 2368-6111.

[20] Mohamoud Jama,Tejvir Singh, Seifelislam Mahmoud Gamaleldin, Muammer Koc, Ayman Samara, Rima J. Isaifan,and Muataz A. Atieh , Critical Review on Nanofluids: Preparation,Characterization, and Applications , Journal of Nanomaterials,Vol 2016, Article ID 6717624,Hindawi publications.

[21] S. Akilu, A. T. Baheta, K.V. Sharma and S. K. Vandragi ,Properties of Silica nanofluid in Glycerol, Ethylene Glycol mixture as base liquid, ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 22, Nov 2016 , ISSN 1819-6608.

[22] Supreeti Das,Nanofluids for Heat Transfer, Energy Research and Environmental Management:An Innovative Approach, Feb 2015, 115-117

Supreeti Das "A Comparative Evaluation of Thermo physical Properties Of Nan fluids for Industrial Applications" IOSR Journal of Applied Physics (IOSR-JAP) , vol. 10, no. 2, 2018, pp. 13-17.