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NANOFLUIDS-BASED MODELLING FOR HEAT TRANSFER ENHANCEMENT FOR COOLING OF ELECTRONIC COMPONENTS

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Abstract:

The effectiveness of fluids for heat transmission may be enhanced by a comparatively new class of substances called Nanofluid. Researchers first looked at using nanoparticles to increase the thermal conduction of fluids in the 1990s, which is when this study's background of Nanofluid for heat transfers started. And the uses for nanofluids are many including electronic cooling, heat exchangers, biomedical applications, solar energy systems, aerospace, and energy storage. The performance can be improved by Nanofluid' improved heat transfer characteristics and efficiency of these systems, leading to reduced energy consumption and environmental impact, scope of research on nanofluids is extensive, covering topics such as nanoparticle synthesis, dispersion, and stability, in addition to the basic ideas of fluid mechanics & heat transmission. The heat transfer coefficient rises with rising Reynolds number as the Al2O3/water nano fluid volume concentrations increase the influence of tube diameter on heat transfer coefficient for 0.5% vol. concentration of Al2O3/water Nano fluid. If the tube diameter is reduced from 13.5 mm to 4 mm, it is discovered that the heat transfer enhancement for Reynolds numbers 9624.12 and 24047.95 is 67.5% and 36.05 percent, respectively. For the purposes of validation & assessment, the findings of the present experimental work were matched with the findings of the earlier analytical & numerical work in addition to the instances of the earlier experimental works.

Keywords: Nanofuids, Heat transfer, Heat exchangers, Nanoparticles. Electronic cooling.

1. Introduction:

The Nanofluid has great potential for enhancing heat transmission. One reason is that the Nano fluid's thermal conductivity is greatly increased as a result of the ultra-fine particles floating inside it. The volume fraction, shape, size, & properties of the nanoparticles have an impact on the thermally conductivity of Nanofluid. Despite the fact that several strategies are used to improve heat transfers, low thermal conduction of the process fluid prevents high compactness & efficiency of heat exchanged. Enhancing the thermal characteristics of energy transmitting fluids may prove to be an effective method for increasing heat transfer. Enhancing heat transfer using nano fluids is an emerging study subject in the realm of cooling electronic components. The purpose the primary objective of this research is to improve the efficiency of cooling systems for electronics components especially for high power density devices. Nano fluids, in this application, are suspensions of nanoscale particles in a fluid base that have demonstrated promising results in boosting heat transfer rates when compared to traditional cooling fluids(Xuan & Li, 2000)

Enhancing a liquid's thermal properties is the main justification for introducing solid particles smaller than 100 nm; The term "Nanofluid" is coined to describe those novel fluids. Particles, whether metallic or nonmetallic, that are suspended in water, ethylene glycol, or glycerol have lately attracted attention. Thermo fluid systems have several uses, including vehicle cooling systems. For many years, as common coolants in radiators, Water, ethylene glycol, and glycerol were the base fluids utilized;however, they provided poor thermal conductivity, prompting researchers to seek fluids with better thermal conductivity than typical coolants(Hussein et al., 2014a).

1.1 Nano fluids:

Engineering equipment in the domains of power & chemical engineering, medicines, electronics, & other human endeavors employ nanofluids, a mix of base fluids with a small concentration of nano-sized metal or metal oxide particles. The ability to improve heat & mass transfers because of the lower concentration of nanoparticles & the ability to manipulate the transport mechanisms which might be employed, for example, in drag delivery systems, are the key drivers behind the wide range of Nanofluid applications. In recent years, research into using nanofluids to cool electronic components had shown promise. The development of high-performance electronic devices has increased because of how important it is to have modern cooling equipment. The use of nanofluids for cooling electronic components can provide several benefits, including improved heat transfer performance, reduced size and weight of cooling systems, and lower energy consumption(Sheremet, 2021).

1.1.1 History of nano fluids for heat transfer:

Nanofluids were created as a consequence of studies to boost the thermal conductivity of liquids. The breakthrough notion of incorporating solid particles into HTFs to boost heat conductivity is credited with the development of nanofluids. Maxwell proposed this novel concept in 1873. Huge efforts are being made to enhance the fluids' ability to transmit heat. Several solid metallic & non-metallic materials have well-known thermal conductivities which are far greater than those of typical HTFs. So, since Maxwell first proposed it, the attempt to increase heat conductivity by adding solid particles to HTFs is a novel one. Many efforts were made to create combinations from the beginning(Uddin et al., 2016).

1.2 Applications:

Nanofluids have several uses in the area of convection since it is a relatively new and unique technology; for example, it is used for conditioning inside vehicle engines, heavy equipment, generating power microwave tubes, etc. Also, the nanofluid is made to flow even from the very little gap or hole to transfer the heat in any devices. It is also used in a transportations purpose in a manufacturing industry for supply materials and proper assessment. Some of common uses of nanofluids in heat exchanging fields such as in power plant industries is boilers, also in the cooling of electronics system, microsystem(K R et al., 2014).

Prasad Mangalkar et al., conducted study on improvement of heat transfer cooling electrical equipment utilizing Nanofluid Microprocessor heat dissipation is always rising. Because of the expansion of information technology, there is a greater need for microprocessors with advanced computational capabilities. High end CPUs dissipate between 110 and 140 W of heat, which is too much to be removed by standard air-cooling methods. So, other improved thermal management approaches will need to replace this technology for a variety of applications.

Husam Abdulrasool Hasan et al., investigated Mathematical research on the effect of using different nanofluids as a CPU cooling fluid on the enhancement of heat transfers and fluids flow were conducted Al_2O_3, CuO, SiO_2, & ZnO are 4 distinct kinds of nanoparticles that have been employed. Their nanoparticle dimensions vary from 20 nm to 50 nm. Water has also been used for cooling purposes with volume fractions of 1%, 2%, 3%, & 4% of various kinds of nanofluids. In comparison to traditional heat transfer fluids, this research demonstrated how crucial it is to use nanofluids to improve heat transmission (water). Research on the characteristics of nanofluids, including its manufacture, heat transfer methods, enhancing conduction & convection heat transfer, etc., was given by Shanthi R et al. The paper also outlines the theoretical & experimental research on pool boiling in nanofluids & its applications(Hasan et al., 2018).

Colloidal suspensions of metals or ceramics nanoparticles in a base fluid, such as water, ethylene glycol, or oil, were known as nanofluids. Nanofluids, according to its better thermal transporting properties, offer a huge potential to boost the original fluid's heat-transfer efficiency. The goal of Nanofluid research is to create nanofluids with superior transport properties by synthesizing them using new techniques that improve upon existing synthesis techniques.

Roger R. Riehl, et al., examined a thermal managing system utilizing copper oxide (CuO)-water heat pipes & a single-phase forced circulation loop to help with the thermally planning of up to 50 kW of heat produced by several combinations of digitalisation components, Nanofluid were created. and dissipated to the environments by a fan cooling system. The heat pipes draw heat from distant electronics and reject it into the cold plates of the primary single-phase forced circulation loops(Riehl, 2019).

T Balaji, et al., investigates the different cooling methods, particularly the liquid cooling systems, used nanofluids, a unique sort of fluid with nanometer-sized particle dispersal. By focusing on thermal properties including heat transfer coefficients, thermal resistivity, thermally conductivity, interface temperatures, etc., this research quantifies the different types of nanofluids utilised for cooling electronics along with their thermal performances(Balaji et al., 2021).

M. A. Khattak, et al., The fact that nanofluids improve heat transmission makes them significant. Colloidal mixes of metallic or ceramic nanoparticles in a base fluid, like water, ethylene glycol, or oils, were known as nanofluids. Due to their superior thermal transporting characteristics, nanofluids have a tremendous potential to increase the original fluid's capacity for heat transmission. The initial crucial step in using Nano phase particles to alter the heat transfer performance of conventional fluids is the preparation of nanofluids(Huminic & Huminic, 2012).

Adnan M, et al., TiO2 & SiO2 Nano powders suspended in clear water are used to improve heat transfer. The test setup contains a vehicle radiators, & laminar flow conditions were used to examine the impacts on heat transfer enhancement during operational settings. The Nanofluid volume concentrations, inlet temperature, & volume flow rate was 2-8 LPM, 60-80 °C, & 1-2%, correspondingly. & Experimental analysis was used to assess the impacts of various Al2O3 nanoparticle concentrations on the radiator of an automobile's ability to transmit heat(Hussein et al., 2014b).

Samy Joseph Palm, et al., This work investigates the ability of coolants with suspended metallic nanoparticles to promote heat transfers in conventional radial flowing cooling systems was analysed quantitatively. The temperature-dependent characteristics of those nanofluids have been used to study the laminar forced convective flow between 2 coaxial & paralleled discs having central axial injections. Additionally, even with extremely modest particle volume fractions, the use of nanofluids may greatly improve the heat transfers capacities of radial flowing cooling methods. In addition, it was discovered that the modelling employing temperature-dependent nanofluids characteristics led to higher accurate predictions of heat transfer enhancements and lower wall shear stresses than when consistent parameters were included across the domains(Samy, 2006).There are a number of benefits that nanofluids were considered to offer over most traditional heat transfer fluids. More than ten years ago, researchers concentrated on identifying & modelling the efficient thermal conductivity & viscosity of nanofluids. Nanoparticles utilised in nanofluids have been synthesised using physical & chemical techniques from a variety of materials(Kakaç & Pramuanjaroenkij, 2009).

Dr. v.m. kriplani et al., investigated the use of nanofluid as the working fluids for a heat pipe liquid block in conjunction with thermoelectric cooling. Nanofluids of alumina-water & alumina-water was utilised as working fluids. Mehdi Bahiraei et al., In response to the rise in heat created by new electronics components, a combination of Nanofluid & minichannel properties had emerged as a hot research issue. This technique may lead to additional downsizing of electronics equipment & the improvement of energy efficiency(Mangalkar & Krip, 2017).

M raja et al., Showed that When utilised as coolant for a single cylinder diesel engine, the heat transfer properties of ALO. /Water nanofluids were investigated in a shell & tube heat exchanger under laminar flow conditions. The two-step process is used to create nanofluids. 0.5. 115. 14. Se quantities are present. In conditions of laminar flow, the impact of Peclate number & different volume concentrations on her CASOS pressure drop is examined.

1.3 Scope of the research

"Heat Transfer Enhancement Using Nanofluids for Cooling of Electronic Components" study covers a wide variety of subjects and methodologies. The study's fundamental goal is to investigate the possibilities of employing nanofluids - fluids containing nanoparticles to enhance the cooling performance of electronic components. To attain this aim, researchers will need to get a thorough grasp of the basic concepts of heat transfer and fluid mechanics, including the many modes of heat transmission and fluid characteristics. They will also need to do extensive research on the qualities and behaviour of nanofluids, such as their thermal conductivity, viscosity, stability, and other physical and chemical aspects.

Methodology:

3.1 Objective:

Microprocessor heat dissipation is always rising. Because of the expansion of information technology, there is a greater need for microprocessors with advanced computational capabilities. High end CPUs dissipate heat at a rate of 110–140 W. Conventional air-cooling methods are insufficient to remove this much heat. So, other improved thermal management approaches would need to replace this technology for a variety of applications. Nanoparticle-sized solid particles may now be produced because to advances in nanofabrication & procedures. There are many nanofluids are available, but proper selection of nanofluids gives good results for heat enhancement. The oxide forms of nano-powders are most in use by many researchers such as Al2O3, MWCNT, Ti oxide etc. In this experimentation, Al2O3 nanoparticles with water as base fluid are used.

3.2 Procedure of Experiment to be Performed:

Experimental setup consists of three test section of copper tubes of inner diameter of 4mm, 9mm & 13.5mm.

3.2.1 For Water:

Firstly, fill tank with water. Initially all valves are closed. Now open the valve of first test section so that water flows through first test section of 13.5mm inner diameter and start the water pump. During this, valves of second and third test section is closed. Now set proper current and voltage by varying dimmerstat for first test section so that it gives constant heat flux to the tube (Test Section). Then adjusting the flow rates of fluids which is fixed for experimentation work are at 4 LPM, 6 LPM, 8 LPM & 10 LPM. The setup run continuously up to steady state conditions achieve. Initially take readings for water, after achieving steady state conditions take readings of wall temperatures of test section and then inlet and outlet temperature of test section from Digital temperature indicator (DTI). This procedure is repeated for varying flow rates.

3.2.2 For Al_2O_3/water:

Al_2O_3/water nanofluid with vol. concentration of 0.1%, 0.3%, 0.5% and 0.7% is used. Initially Al_2O_3/water Nanofluid with vol. concentration of 0.1% is passed through first test section of inner diameter 13.5 mm. During this valve of first test section is open and other are closed. Note all readings for varying flow rates after attaining steady state condition. Now same steps are repeated for various test section and for various concentrations.

3.3 Primary Components:

3.3.1 Reservoir:

The tank/Reservoir used in the setup is of 4-5 litre capacity and made of stainless-steel materials.

3.3.2 Pump:

The pump used in the set up for flowing purposes is specification as 1/30 HP.

3.3.3 Copper tube:

The copper tubes used are of inner diameter 4 mm, 9mm and 13.5 mm in test section.

3.3.4 Rotameter:

The Acrylic type rotameter used for experimentation with the range of 0-25 litre per minute is of standard size.

3.3.5 Heating coil:

The heating coil is main elements in setup for heating the tube and nichrome coil used of 1000 Watts wound through out tube and total length is about 2 meters.

3.3.6 Dimmerstat:

The dimmerstat used to supply power input for heating the test sections and power can vary with the help of dimmerstat.

3.3.7 Insulation:

The Insulation used in setup for preventing the heat losses from test section so that Glass wool insulation used in setup.

3.3.8 Cooling unit:

The cooling unit provided in setup to cool the fluid coming out from the test section and it is an important element of the setup.

3.3.9 Thermocouples:

Thermocouples used in setup of K-type which is fitted at different locations of test section and also at inlet & outlet of test section.

3.3.10 By-Pass Valve:

The by-pass valve used to control fluid supply and fitted after the pump so that only requirement amount of fluid supply to test section and remaining fluid back to reservoir.

3.3.11 Digital temperature indicator:

Digital temperature indicator used to show different temperatures readings of copper tube (test section) and inlet & outlet fluid temperatures.

3.3.12 Nano powders:

Al_2O_3 were selected for the experimentations work.

Table 3.1 Properties of Al2O3 Nano powders

Properties	**Al_2O_3**
Diameter (nm)	10-20
Density (kg/m3)	1500
Sp. Heat (J/kg-K)	880
Thermal Conductivity (W/m-K)	46

3.3.13 Base Fluid:

That basic fluid utilized inside this experiment is pure water. That foundation fluid was combined with Al2O3 at various volume strengths, namely 0.1%, 0.3%, 0.5%, and 0.7%.

Equations for Nano fluids:

Density of Nanofluid, $\rho_{nf=(\emptyset \times \rho_{np})+(1-\emptyset)\rho_{bf}}$

Viscosity of Nanofluid, $\mu_{nf} = \mu_{bf}(1 + 2.5\emptyset)$

Specific heat of nanofluid, $Cp_{nf} = \frac{\emptyset(Cp_{np}\times \rho_{np})+(1-\emptyset)(Cp_{bf}.\rho_{bf})}{\rho_{nf}}$

Thermal conductivity of nanofluids, $K_{nf} = K_{bf}\left[\frac{K_{np}+2K_{bf}+2(K_{np}-K_{bf})(1+\beta)^3.\emptyset}{K_{np}+2K_{bf}-2(K_{np}-K_{bf})(1+\beta)^3.\emptyset}\right]$

Heat gained by nanofluid,

Q = (□$_{nf}$.U. A) Cp_{nf} (Tout - Tin)

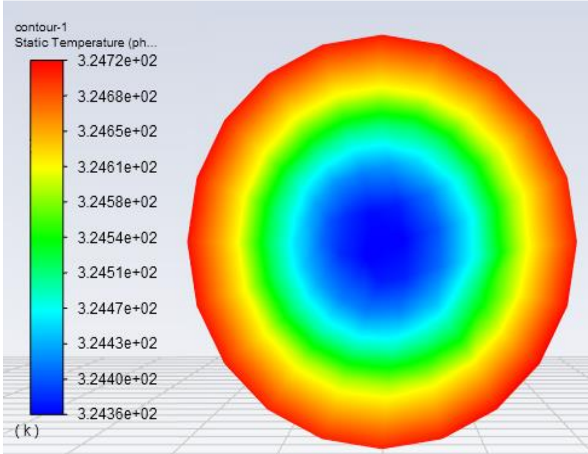
Mass flow rate = □$_{nf}$x (4 x 10^{-3})/60

= 0.066 kg/s

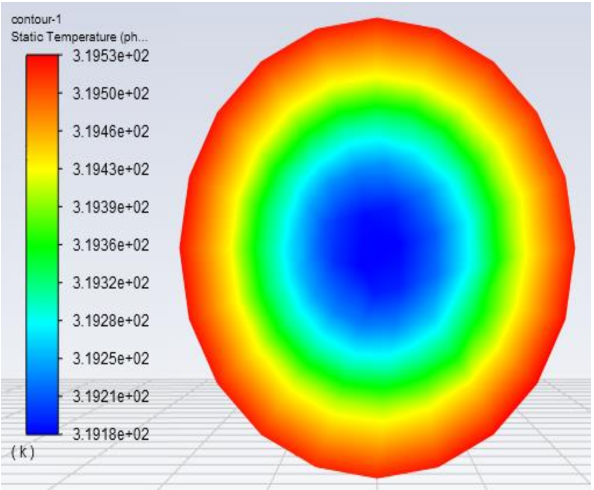
Convection heat transfer rate, Q = h_{nf} A_s (T_w - T_b)

Results for Al2O3

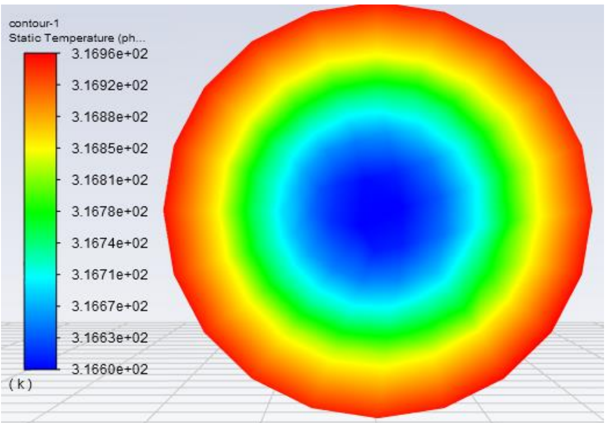
<u>Tube Diameter = 4 mm</u>



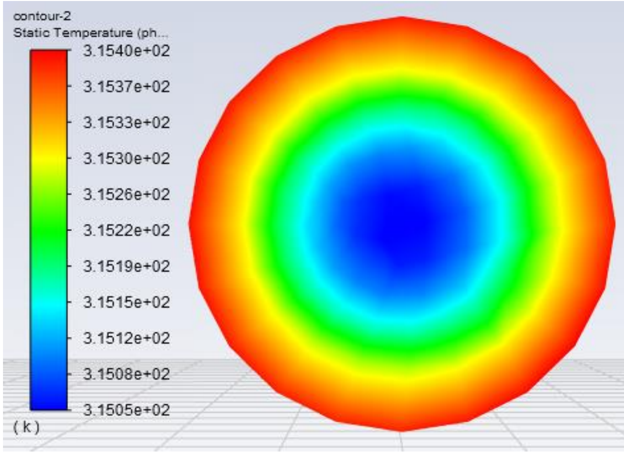
Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 4 mm and Discharge = 4 LMP



Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 4 mm and Discharge = 6 LMP

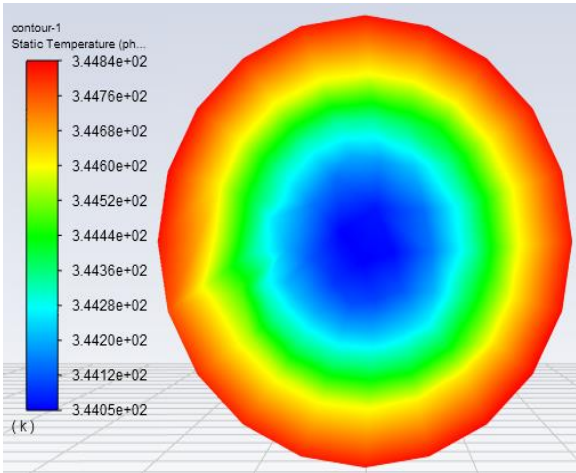


Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 4 mm and Discharge = 8 LMP

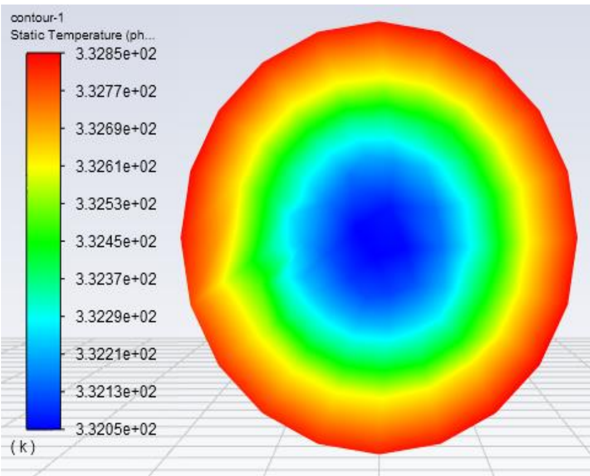


Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 4 mm and Discharge = 10 LMP

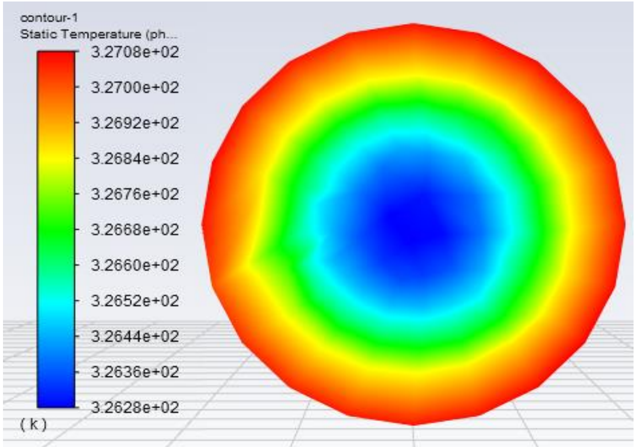
<u>Tube Diameter = 9 mm</u>



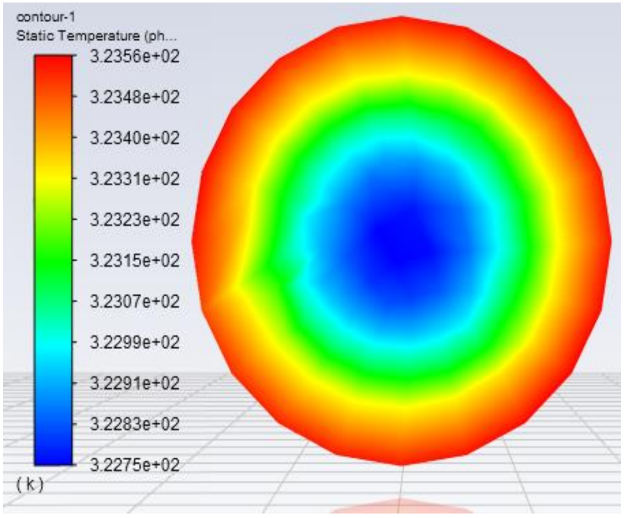
Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 9 mm and Discharge = 4 LMP



Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 9 mm and Discharge = 6 LMP

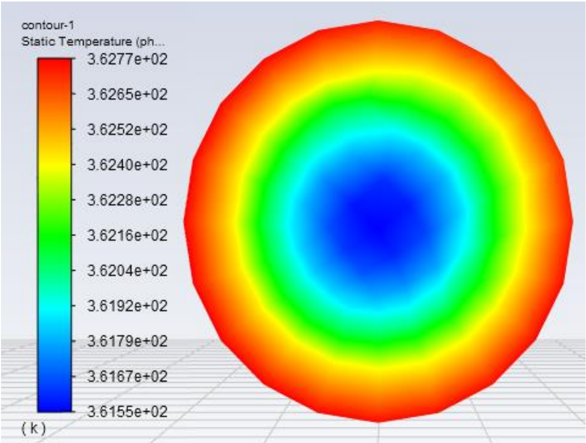


Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 9 mm and Discharge = 8 LMP

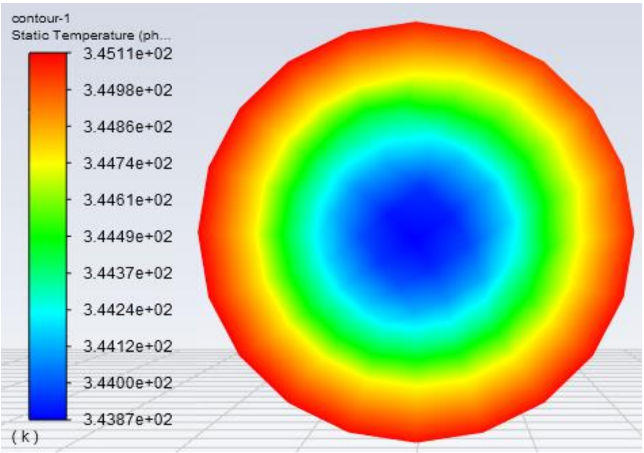


Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 9 mm and Discharge = 10 LMP

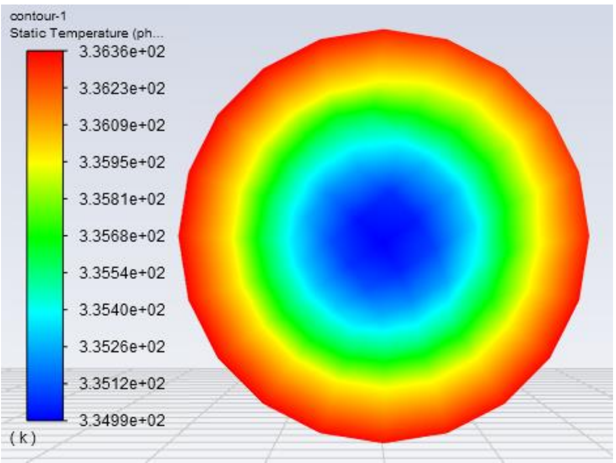
Tube Diameter = 13.5 mm



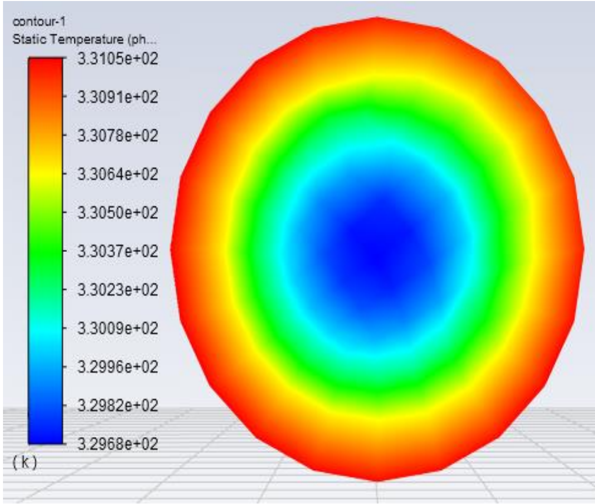
Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 13.5 mm and Discharge = 4 LMP



Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 13.5 mm and Discharge = 6 LMP



Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 13.5 mm and Discharge = 8 LMP



Temperature Contour of Water with 0.7% Al_2O_3 at Outlet for Tube Diameter = 13.5 mm and Discharge = 10 LMP

Results & Discussion:

5.1 Graphs:

Various graphs are plotted for calculated results of heat transfer coefficient Vs Reynolds number, Nusselt number Vs Reynolds number.

Reynolds number, Nusselt number Vs Reynolds number.

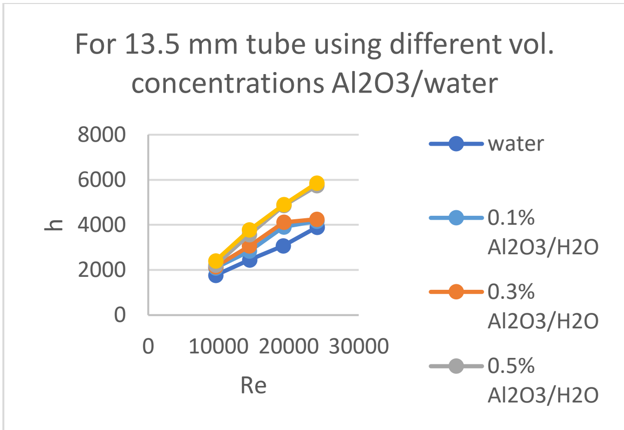


Fig. 5.1 Heat transfer coefficient Vs Reynolds no. for water and Al_2O_3/water for all concentrations

The graph above demonstrates how, when we raise the volume concentration of Al2O3/water Nano fluids, the heat transfer coefficient rises along with an increase in Reynolds number. Al2O3/water Nanofluid also has a greater heat transfer coefficient than water.

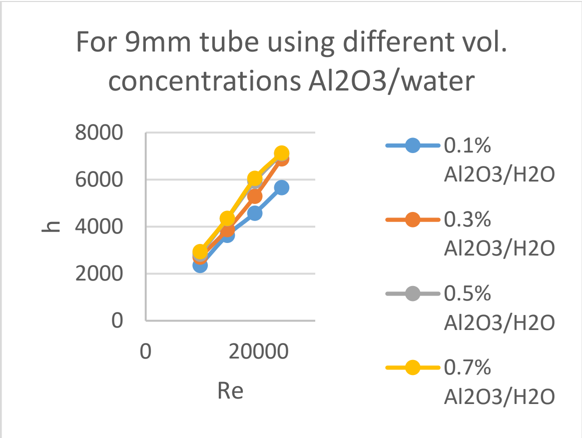


Fig. 5.4 Heat transfer coefficient Vs Reynolds no. for Al_2O_3/water for all concentrations.

Above graph and Fig 5.5 shows that the heat transfer coefficient increases with increase in volume concentration of Al_2O_3/water Nano fluid and MWCNT/water Nano fluid respectively. Increase in concentration increases the thermal conductivity due to Brownian motion of nanoparticles.

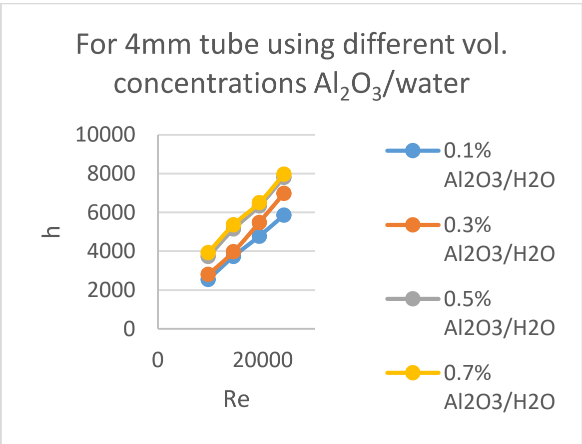


Fig. 5.7 Heat transfer coefficient Vs Reynolds no. for Al_2O_3/water for all concentrations

The graph above & Fig. 5.8 show that the heat transfer coefficients rise with a raise in Reynolds numbers when we increased the volume concentrations of Al2O3/water Nano fluids.

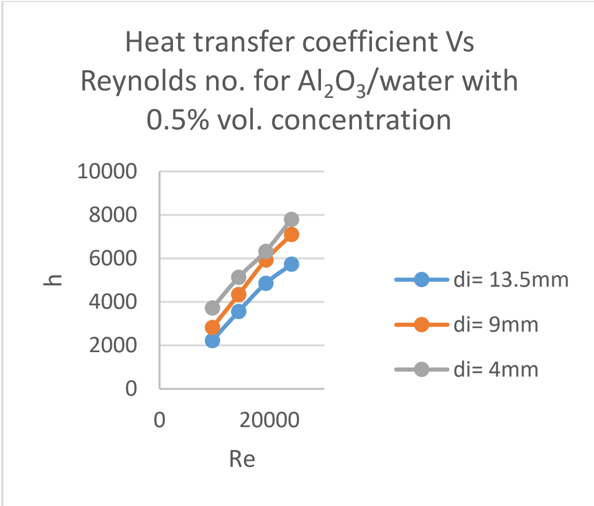


Fig. 5.10 Heat transfer coefficient Vs Reynolds no. for Al_2O_3/water with 0.5% vol. concentration

Above graph shows the effect of tube diameter on heat transfer coefficient for 0.5% vol. concentration of Al_2O_3/water Nano fluid. It is found that heat transfer enhancement for Reynolds no. 9624.12 is67.5%and for Reynolds no.24047.95 is36.05% if tube diameter is decreased from 13.5 mm to 4 mm.

Conclusion:

Al2O3 nanoparticles with water as the base fluid are employed in this experiment. Three test sections of copper tubes with inner diameters of 4mm, 9mm, and 13.5mm comprise the experimental setup. The flow rates of fluids that are set for experimentation work are 4 LPM, 6 LPM, 8 LPM, and 10 LPM. The Al2O3/water Nano fluid is utilized in concentrations of 0.1%, 0.3%, 0.5%, and 0.7%. When the concentrations of Al2O3/water nano fluid volumes grow, the heat transfer coefficients increase with the Reynolds number. Furthermore, the heat transfers coefficients of the Al2O3/water nano fluids are greater than that of water. The heat transmission coefficient grows as the volume's concentrations of the Al2O3/water Nano fluids increases. The thermal conductance of nanoparticles rises with concentration as a result of Brownian motion. When the concentration of the Al2O3/water nano fluids increases, the heat transfer coefficients increase along with the Reynolds numbers. the influence of tube diameter on heat transfer coefficient for 0.5% vol. concentration of Al2O3/water Nano fluid. If the tube diameter is reduced from 13.5 mm to 4 mm, it is discovered that the heat transfer enhancement for Reynolds numbers 9624.12 and 24047.95 is 67.5% and 36.05

percent, respectively. For the purposes of validation & assessment, the findings of the present experimental work were contrasted with the findings of the earlier analytical & numerical work in addition to the instances of the earlier experimental works.

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Symbols:

I	Current (Amp)
V	Voltage (V)
q	Heat Flux (W)
T_b	Properties at bulk mean temperature (^0C)
ρ_w	Density of water (kg/m^3)
μ_w	Absolute viscosity ($N\text{-}s/m^2$)
K_w	Thermal conductivity of water (W/m-K)
Cp_w	Specific heat of water (J/kg-K)

A	Area of tube (m^2)
m	Mass flow rate (kg/sec)
V	Velocity (m/s)
Q	heat transfer rate (W)
h	heat transfer coefficient (W/m^{2}-K).
A_s	Heat transfer surface area (m^2)
T_{in}	Inlet temperature of Water (^0C)
T_{out}	Outlet temperature of Water (^0C)

T_w	Average tube surface temperature (^0C)
Nu	Nusselt No.
ρ_{nf}	Density of Nano fluid (kg/m^3)
μ_{nf}	Viscosity of Nano fluid (N-s/m^2)
Cp_{nf}	Specific heat of Nano fluid (J/kg-K)
K_{nf}	Thermal conductivity of Nano fluids (W/m-K)
Re	Reynolds No.