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Heat Transfer Enhancement Using Nanofluids for Cooling of Electronic Component

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Abstract: This study investigates the applications of nano fluids with an emphasis on their unique thermal properties and their potential to enhance the heat transfer efficiency of systems. Thermal conductivity is an essential factor that effects a fluid's capacity to transport heat. In addition, this research examines the size, shape, and concentration of nanoparticles in order to determine how efficiently nanofluids transport heat. This study investigates the potential use of nano fluids to enhance heat transfer during the cooling of electronic equipment. The findings of this research indicate that MWCNT/water nanofluids have a substantially greater thermal conductivity than Al2O3/water nanofluids, leading to the conclusion that MWCNT/water Nanofluids have a greater heat transfer coefficient. At volume concentrations of 0.1% and 0.7%, the heat transfer coefficients of Al2O3/water nanofluid as well as MWCNT/water nanofluid, respectively, were equivalent. MWCNT/water Nanofluids have a significantly higher heat transmission coefficient than Al2O3/water Nanofluids. Due to the greater thermal conductance of MWCNT nanoparticles compared to Al2O3 nanoparticles, the heat transfer coefficients of MWCNT/water Nano fluids at 0.1%, 0.3%, 0.5%, and 0.7% vol. concentrations were found to be greater in all three test sections. Furthermore, as the diameter of the test section decreases, the heat transfer coefficients increase.

Keywords: Nanofluids, Nanoparticles, heat transfer enhancement, applications of nanofluids, Heat Transfer Efficiency

1. Introduction:

To create nanofluids, particles of metals or metal oxides smaller than 100 nm were dispersed in a base liquid such as water. By employing nanofluids, it is feasible to achieve heat transfer coefficients that are higher than those of conventional liquids. This is made feasible by the dispersion of solid nanoparticles, which have a higher thermal conductivity than the liquids beneath. Nanofluids can be used in a variety of engineering applications, such as absorption refrigeration, micro electromagnetic systems, lubrication of equipment, the production of innovative miniaturized camera lenses, coolant in machine tools, radiator cooling for automobiles, personal desktops, solar water heating, heat condensers, a few medical technologies, nuclear reactors, & numerous aerospace technologies. By suspending nanometer-sized nanoparticles in working fluids, recent developments in materials technologies have made it feasible to create novel heat transfer fluids that might alter the liquids' thermals & transporting characteristics. Nanofluids are solid-liquid composites made of liquid suspending solids nanoparticles no bigger than 100 nm in size (Hussein et al., 2013)

By evenly dispersing & stabilizing the suspensions of nanomaterials in host fluids, nanofluids aim to obtain the best thermal characteristics at the lowest concentrations. A colloidal solvent with scattered nanometer-sized particles (between 1 and 100 nm) is referred to as a nanofluids. One of the biggest technological problems that high-tech sectors like microelectronics, transportations, manufacturing, & metallurgy face is cooling. When utilised as coolants, nanofluids may significantly enhance the thermal characteristics of host fluids (Asst & St, n.d.).

1.1 Applications of nanofluids:

A type of fluid known as a Nanofluid is one in which a base fluid contains nanoparticles with sizes less than 100 nm. They have shown promise as a new class of materials with unique rheological & thermal properties. Due to its exceptional thermal properties, nanofluids offer a broad variety of potential applications. In electronics cooling applications, nanofluids have the possibility of enhancing heat transfer &, as a result, the efficiency of electronic cooling systems. The enhanced cooling capacity could help keep electronic elements from overheating & increase their reliability. Heat exchangers using nanofluids might be more effective overall & at transferring heat, which makes them a good fit for use in air conditioning equipment, power plants, & industrial operations.

Additionally, using nanofluids as imaging agents, drug delivery systems, & therapeutic hyperthermia for the treatment of cancer is being researched. Nanoparticles' small size enables targeted drug delivery to specific body regions, & they can also be used for cancer hyperthermia therapy thanks to their special thermal properties. To improve heat transfer & energy converting efficacy in solar energy platforms, nanofluids can be utilized. To improve the efficiency of energy storage & retrieval, they can also be used in thermal energy storage platforms. To combat the extreme heat conditions in space, nanofluids can be utilized in spacecraft & satellite cooling systems. Nanofluids can be utilised to lubricate mechanical platforms because they reduce wear & friction. Additionally, nanofluids can be used as catalysts in chemical changes to quicken & improve selectivity (Prasad et al., 2017)

Nanofluid Thermal Conductivity Research on the thermal conductance of nanofluids revealed that employing nanofluids may result in significant increases in thermal conductivity. With a particle volume fraction of less than 5%, thermal conductivity increases greater than 20% are possible. These elevated levels exceed predictions made by theoretical models for suspensions with larger particles. This is seen as a sign that there are more nanofluids thermal transport enhancing techniques present.

1.2 Heat Transfer Enhancement:

The enhancement of the thermal performance of any heat transport method, heat exchanges medium, components, devices, or equipment is referred to as heat transfer enhancement, augmenting, or intensifying. The critical heat fluxes for pool boiling heat transfers may have increased, the peak temperatures of a chip hot spot may have decreased, the thermal conductance, specific heat capacity, or latent heat of an energetic storage medium may have increased, and so forth. Improving heat transmission is a method of enhancing heat exchangers' performance. This may be accomplished by increasing a device's capacity for heat transmission or by lowering the pressure losses it produces. This effects may be achieved using a number of approaches, such as creating powerful secondary flows or boosting boundary layers turbulent(Guo, 2020).

1.3 Improving Heat Transfer Efficiency:

In several applications, heat transport is crucial. For instance, for a vehicle to function properly, the heat produced by the primary mover must be evacuated. In a similar manner, electrical devices release heat and need a cooling system. Other heat transfer techniques are also included in heating, ventilation, & air conditioning systems. The primary mechanism in thermal power plants is heat transfer. In additional to this, a lot of manufacturing processes use heat transmission in different ways, such as chilling machine tools, pasteurizing food, or adjusting temperatures to start a chemical reaction. Heat transmission is accomplished in the majority of those applications using heat transfer equipment such heat exchangers, evaporators, condensers, & heat sinks. It would be advantageous to increase the heat transfer efficiencies of those devices since doing so would reduce the area that they take up, that is critical for applications that need compactness. Also, because a pump often circulates the working fluids in heat transfer systems, efficiencies gain in this area may reduce the power requirements. The efficiency of heat transmission may be influenced by increased in a number of ways. Using extending surfaces, vibrating the heat transferring surfaces, & using microspheres were a few techniques. The working fluid's ability to transmit heat may be enhanced by raising its thermo conductance. As comparing to the thermally conductance of solids, often utilized heat transfer fluids like water, glycols, & motor oil has comparatively lower thermal conductivities. Little solid particles may be added to a fluid with a high thermal conductivity to enhance the fluid's thermal conductivity. Multiple inquiries have already examined the viability of employing similar suspensions of solid particles with diameters on the order of 2 millimeters or microns, and significant drawbacks have been identified. These Restrictions prevented the use of particulate suspensions in base fluids as enhanced work fluids in heat transfer applications, that include particles sedimentation, channel blockage, & channel wall erosion(Kumar & Chakrabarti, 2014).

Due to the fast development of micro-electromechanical systems (MEMS) & micro total analysis systems, researchers have also paid close attention to the properties of flow & heat transfers in microchannel & micro tubes. The micro exchangers, bioengineering, the genomics projects, and medicinal engineering are all significantly impacted by those discoveries(Kumar & Chakrabarti, 2014).

Zhixiong Guo, et al., Experimental research was conducted Common nanofluids' thermal properties, recently found or expected improved processes, models used to describe properties including heat transfer characteristics, including the usage of nanofluids to improve heat transfer are all discussed. The concept of artificially neutral networks is elucidated. Application to energy systems as well as building engineering, & cooling technology were described in depth. New solutions for improving heat transmission are required due to advances in technological miniaturization and rising power density. Since the term "Nanofluid" was coined in 1995, Improving heat transfer through the use of Nanofluids have become a prominent research & development subject, primarily because this thermodynamic property of nanofluids has demonstrated superiority or enhanced performance over their base fluids in numerous published reports, but might not be able to satisfy the requires of the current cutting-edge technology. K.r. aglawe, et al., conducted study on the advancement of nanofluids for outcomes in both theory and experiment. Also, several intriguing perspectives on using nanofluids for cooling electrical components were presented. Almost all investigations have shown that, as contrasted with base fluids, nanofluids display the preferable thermal behaviour for electronic cooling. Furthermore, the field's challenges & the path for future improvements are given & addressed. One of the main difficulties with current generation technology is the cooling of electrical gadgets. Because to its remarkable properties, that may be used to efficiently cool devices & increase energy efficiency, nanofluids have increased interest in numerous technical sectors. The use of nanofluids in different equipment & phenomena is being studied by researchers all over the globe, & choosing an appropriate heat transfer fluid is crucial for the proper thermal management of electronics systems. Many investigations have been conducted in the past to learn how different nanofluids flow in various electronic cooling applications affect thermal performances(Aglawe et al., 2020).

Roger R. Riehl, et al., conducted research on to fulfil present demands for both active & passive thermal regulation, improvements in heat transmission, new technologies, & creative solutions are needed. The amount of heat fluxes which need to be dispersed has significantly increased, necessitating alternative design strategies, particularly for those intended for defense. Because of elements including operating in hostile conditions and the large thermal density of electronics which requires its temperatures to be managed, which calls for new designs, traditional designs are not adequate for the growth in heat dissipation demands. In these circumstances, the use of nanofluids may significantly help to allow designers greater creative flexibility to meet the project's needs(Riehl, 2019). This article's focus is on a surveillance system for the military industry that must disperse significant heat loads. In order to facilitate the thermal management of up to 50 kW of heat, which a fan conditioning system is dissipating into the environment, a single stage forced circulating loops has been constructed for the current inquiry. Eric C. Okonkwo, et al., this study looks back on the year 2019 by examining the advancements achieved in the creation of nanofluids & their use in a variety of heat transfer systems, including solar collectibles, heat exchangers, refrigerants, radiator, thermal storage technologies, & electronics. In addition to underlining the difficulties & potential of nanofluids as the next-generation heat transfers fluids, this study seeks to inform readers of current developments(Okonkwo et al., 2021).

Pankaj Khatak, et al., Experimental studies on heat transfers throughout spray cooling were conducted utilising water & a ZnO nanofluids. A spray nozzle infringing fluids normally onto the flat end of a copper-heated surfaces was used in several experimentations (copper cylinder 20 mm diameters). By measuring temperatures gradients along the length of the objective while it is in a steady state, the heat flux & surfaces temperatures were calculated. The water flow rate in these experiments ranged from 15 to 25 ml/min. ZnO nanofluids was sprayed under the identical tests to contrast the outcomes with water and nanofluids at a flow rate of 20 ml/min. The surface temperatures were found to be below the maximal operating temperatures limit of the micro-electronic components at 180 W heat input & 15–25 ml/min flow rates(Khatak & Kumar, 2008). According to Lazarus Godson et al., the distinguishing characteristics of nanofluids include a considerable enhancement in liquid thermal conductance, liquids viscosity, & liquid heat transfers coefficients. It is well knowledge that solid-phase metals have greater thermal conductivities than fluids do at normal temperatures(Godson et al., 2010).

W. Escher, et al., The reduction of high heat fluxes is a significant design problem for electronic gadgets of the future. The popular solution to those large The most effective method for controlling The most effective method for controlling heat fluxes is to directly integrate microchannel arrays into the electrical component that generates the heat. Due to its superior thermal and hydrodynamic transport properties within the requisite operating temperature ranges, water is frequently suggested for use as Combining a single-phase coolant with microchannel heat absorbers to chill electronics. Yet, compared to most metals & metal oxides, water's thermal conductivity is 2 to 3 orders of magnitudes lower(Escher et al., 2011).

Valery Ya et al., examined study on a base fluid & nanoparticles make up the 2 phases of a nanofluids. Water, organic liquids (glycols, oils, biological liquids, etc.), & polymers solutions were examples of common carrier fluids. Typically, chemically stable metal nanoparticles & its oxides make up the scattered solids phases(Rudyak & Minakov, 2018)

2. Methodology:

Methodology of the Experiment to Be Conducted:

The exploratory apparatus includes 3 test sections of 4mm, 9mm, & 13.5mm inner diameter copper tubes.

2.1 For Water:

Fill the reservoir with water first. In the beginning, every valve is closed. At this point allow water to flow through the first test section by opening its valve the 13.5mm inner diameter first test section along with activate the water pump. During this time, the second as well as third test sections' valves are shut. Now adjust the current as well as voltage by adjusting the dimmerstat for the first test section so that the tube (Test Section) receives a constant heat flux. The fluid discharge rates 4 LPM, 6 LPM, 8 LPM, as well as 10 LPM, respectively, are predetermined for experimentation work. Continuous operation is maintained until steady-state conditions are reached. After attaining steady-state conditions, take readings from a Digital temperature indicator (DTI) of the water, the test section's wall temperatures, and its inlet and exhaust temperatures. This process is repeated for different discharge rates.

Now, open the valve of the 9 mm inner diameter second test section so that water can pass through it. During this period, the first as well as third section valves are closed. After steady-state has been reached, remeasure all temperatures at varying flow rates. Repeat for the third test section with a 4 mm inner diameter.

2.2 For Al_2O_3/water:

Utilized are nanofluids of Al2O3/water with vol. concentrations of 0.1%, 0.3%, 0.5%, & 0.7%. Initial passage of Al2O3/water nanofluid with 0.1% vol. concentration through a 13.5 mm inner diameter test section. During this time, the first test section's valves are open while the others are closed. After achieving steady-state conditions, record all readings for varying flow rates. Now identical procedures are repeated for various test sections and concentrations.

2.3 For MWCNT/water:

Use is made of MWCNT/water nanofluids with vol. concentrations of 0.1%, 0.3%, 0.5%, as well as 0.7%. Initial MWCNT/water nanofluid with 0.1% vol. concentration is passed through a 13.5 mm inner diameter test section. During this time, the first test section's valves are open while the others are closed. After achieving steady-state conditions, record all readings for varying flow rates. Now identical procedures are repeated for various test sections as well as concentrations.

Formulas 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,

$Q = (\square_{nf}.U.\ A)\ Cp_{nf}\ (Tout - Tin)$

Mass flow rate $= \square_{nf} x\ (4 \times 10^{-3})/60$

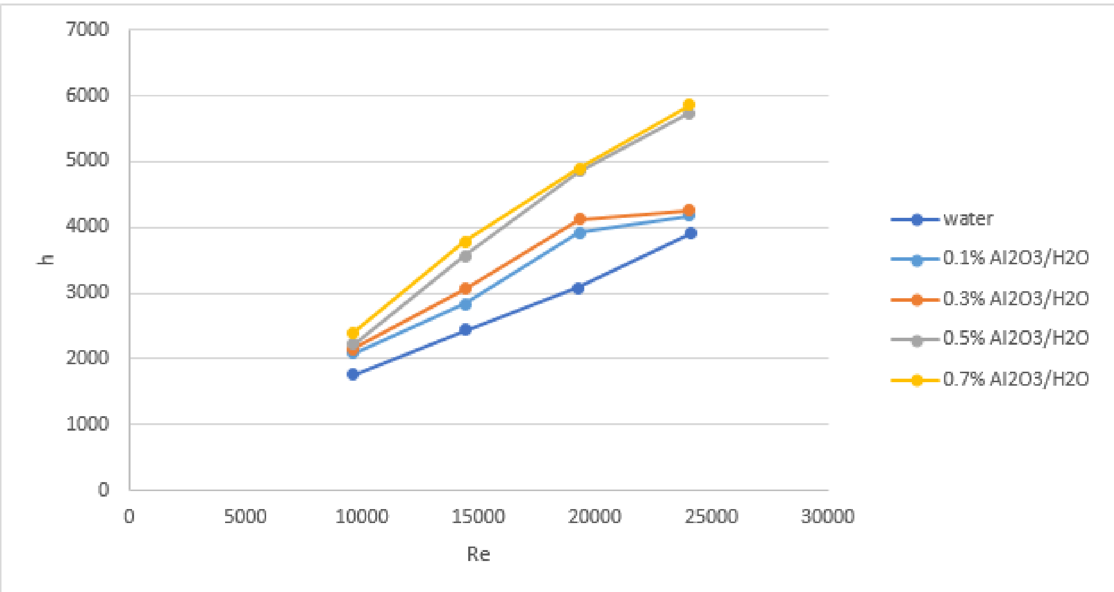
$= 0.066$ kg/s

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

3. Result and discussion

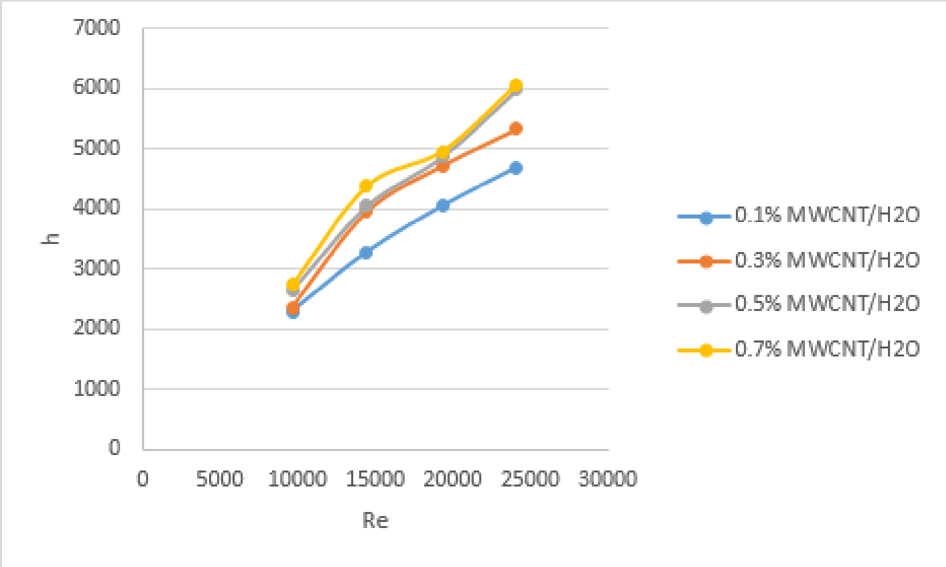
Graphs:

Various diagrams depict the Heat transfer coefficient versus Reynolds number as well as Nusselt number versus Reynolds number were calculated.



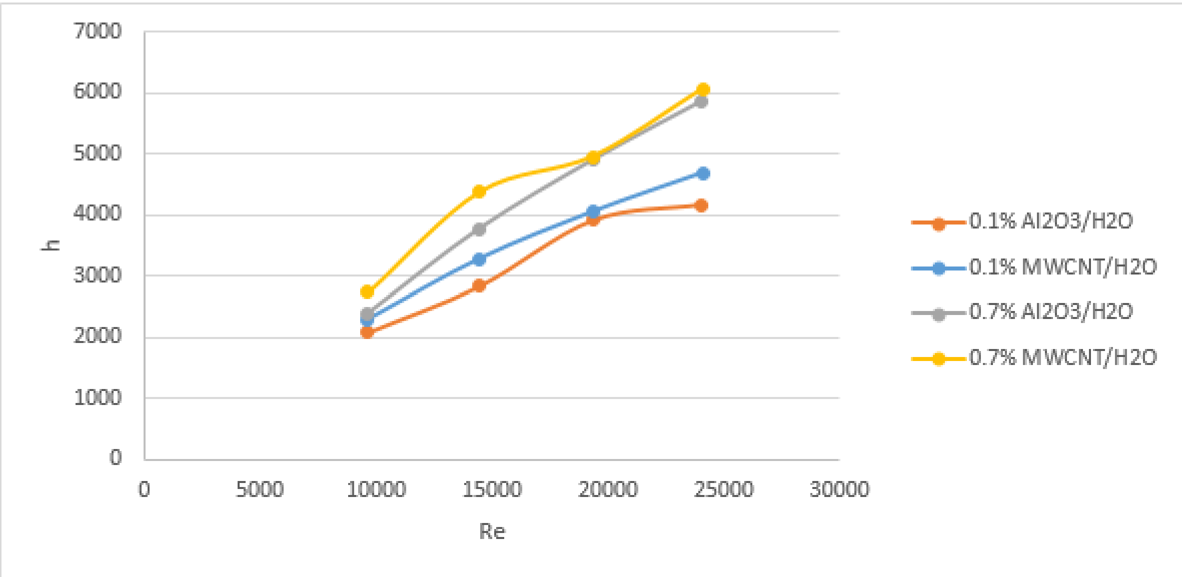
Graph 1 h Vs RE for water and Al2O3/water

As the Reynolds number as well as its nanofluid concentration of Al2O3/water increases, so does its heat transfer coefficient. Moreover, Al2O3/water Nano fluid has a higher heat transfer coefficient than water.



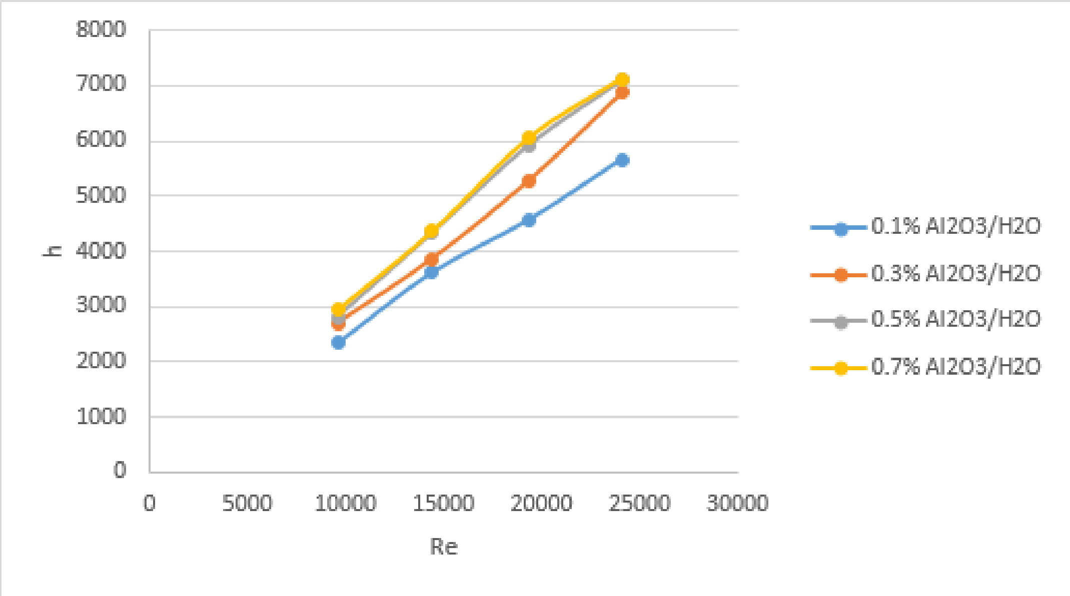
Graph 2 h Vs RE for water & MWCNT/water

similarly, above graph demonstrates that as the volume concentration of MWCNT/water Nano fluid increases, so does the heat transfer coefficient. Because of Brownian motion of nanoparticles, a boost in concentration causes thermal conductivity to increase.



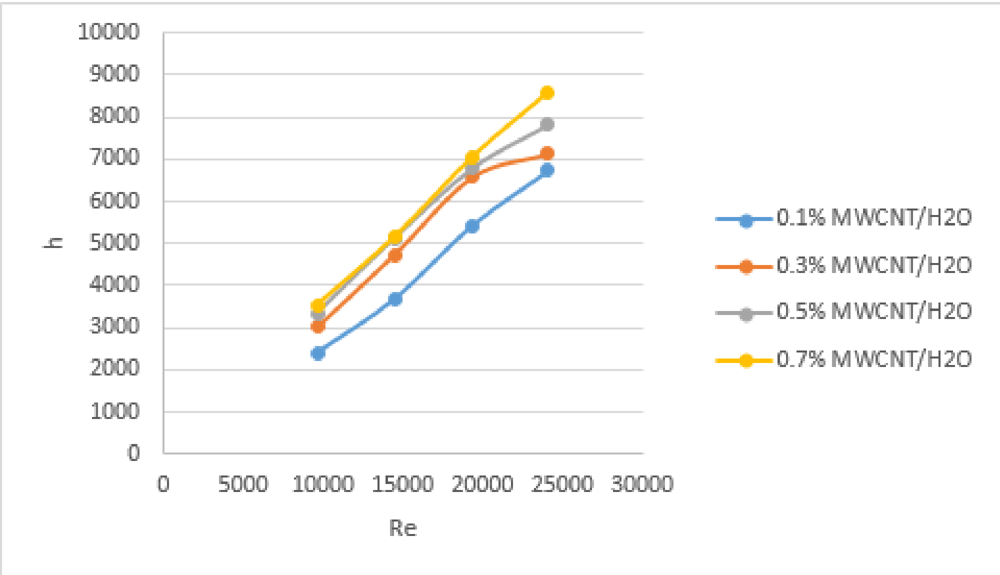
Graph 3 h Vs RE for Al2O3/water and MWCNT/water for 0.1% and 0.7% vol. concentration

Since the thermal conductivity of MWCNT/water Nano fluid is much higher than that of Al2O3/water Nano fluid, the heat transfer coefficient for MWCNT/water Nano fluid is greater.



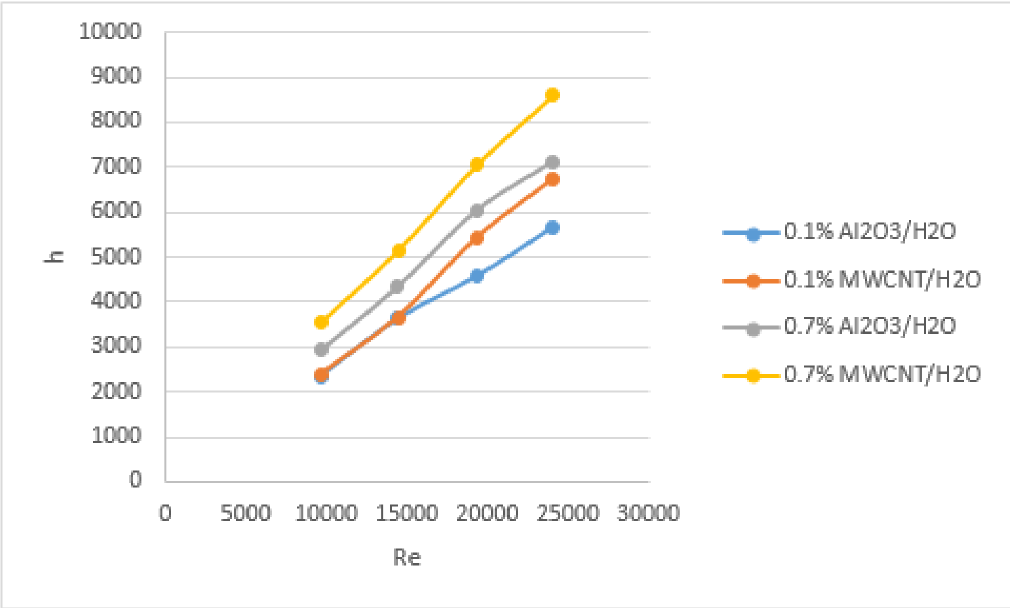
Graph 4 h Vs RE for Al2O3/water

The graph demonstrates Increasing concentrations of Al2O3/water Nano fluid as well as MWCNT/water Nano fluid cause the heat transfer coefficient to increase. The Brownian motion of nanoparticles causes a rise in thermal conductivity as nanoparticle concentration rises.



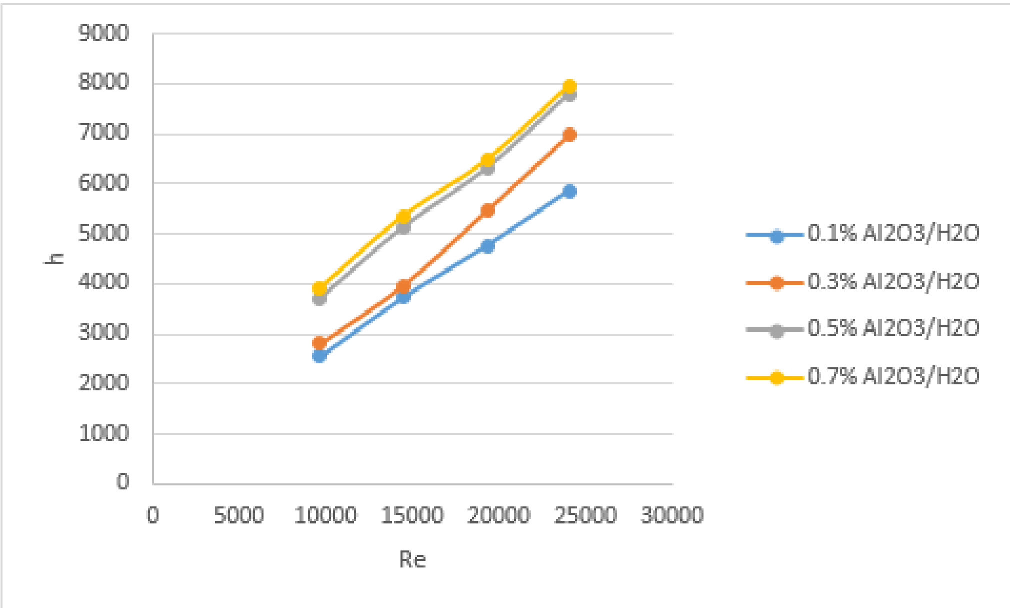
Graph 5 h Vs RE for MWCNT/water

The graph illustrates the heat transfer coefficient of Al2O3/water nano fluid as well as MWCNT/water nano fluid is proportional with the volume concentration. Through Brownian motion, a boost in nanoparticle concentration improves thermal conductivity.



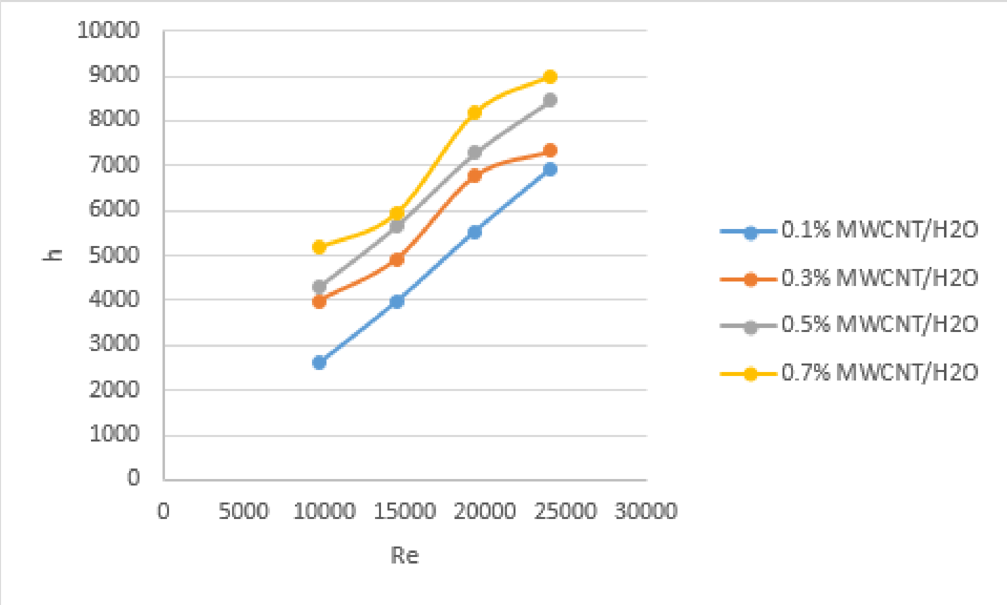
Graph 6 h Vs RE for Al2O3/water and MWCNT/water for 0.1% and 0.7% vol. concentration

The graph above Examines the heat transmission coefficients of 0.1% & 0.7% volume concentrations of Al2O3/water Nano fluid along with MWCNT/water Nano fluid. It demonstrates that the heat transfer coefficient of MWCNT/water nano fluid is higher than that of Al2O3/water nano fluid.



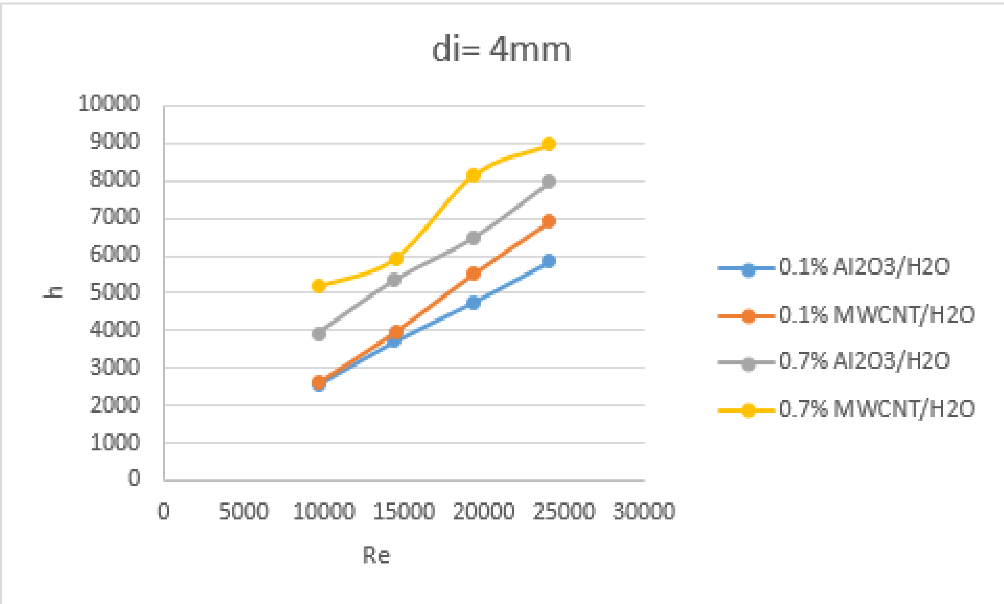
Graph 7 h Vs RE for Al2O3/water

The graph indicates the heat transmission coefficient increases as Reynolds number and Al2O3/water Nano fluid volume concentration increase.



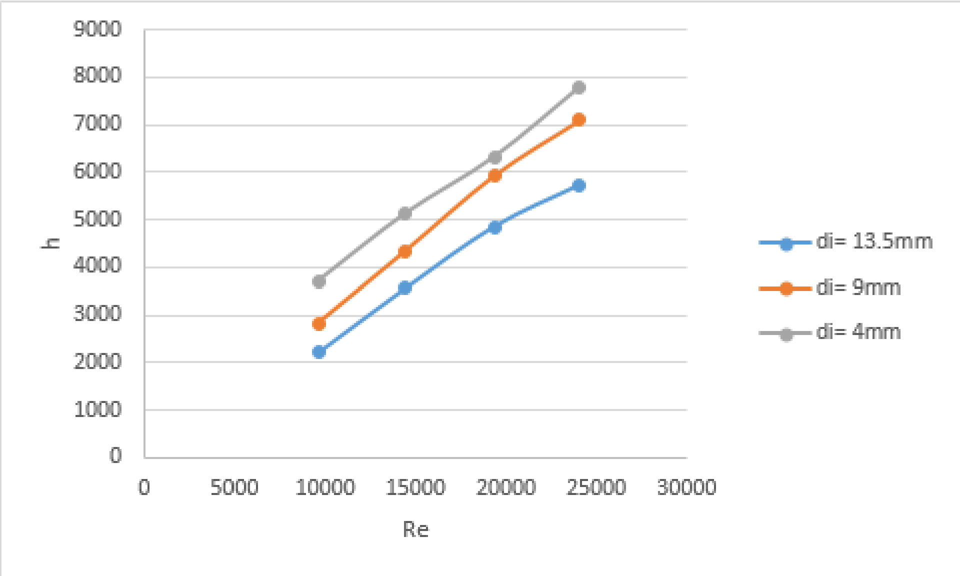
Graph 8 h Vs RE for MWCNT/water

As Reynolds number increases, when the volume concentration of MWCNT/water Nano fluid rises, so too does the heat transfer coefficient.



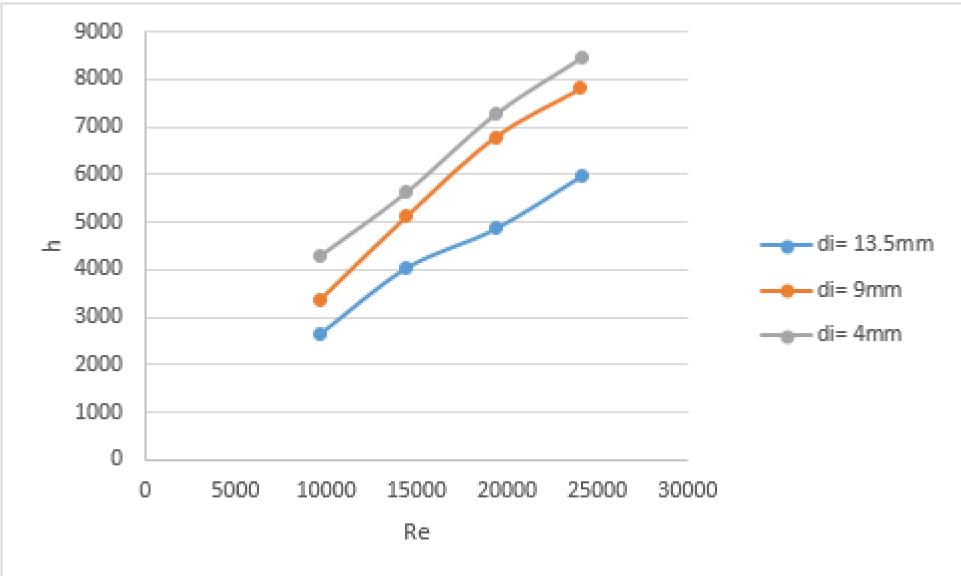
Graph 9 h Vs RE for Al2O3/water and MWCNT/water with 0.1% and 0.7% vol. concentrations.

The above graph illustrates that the heat transfer coefficient of MWCNT/water Nano fluid is Higher than that of Al2O3/water Nano fluid.



Graph 10 h Vs RE for Al2O3/water with 0.5% vol. concentration

The graph depicted above illustrates the influence of tube diameter on thermal conductivity for a 0.5% Al2O3/water Nano fluid concentration. Whenever the diameter of a tube decreases from 13.5 mm to 4 mm, the increase in heat transmission for Reynolds no. 9624.12 is 67.5 percent and for Reynolds no. 24047.95 it is 36.0 percent.



Graph 11 h Vs RE for MWCNT/water with 0.7% vol. concentration

The preceding the graph depicts the effects of tube diameter on the heat transmission coefficient for an Al2O3/water Nano fluid with a 0.7% by volume concentration. Whenever the tube diameter is reduced from 13.5 millimeters to four millimeters, there is a rise in heat transmission for Reynolds no. 9624.12 is 63.6% and for Reynolds no. 24047.95 it is 35%.

4. Conclusion:

The experiment using water, Al2O3 along with MWCNT have been effectively applied to three distinct test sections. As an each of the three test sections, the heat transfer coefficient was estimated for water at various flow rates, Al2O3/water along with MWCNT at corresponding volume concentrations of 0.1%, 0.3%, 0.5%, as well as 0.7%. The testing apparatus consists of three test sections comprised of copper tubes with respective interior diameters of 4 millimeters, 9 millimeters, as well as 13.5 millimeters. Al2O3/water and MWCNT/water are two commonly used nano fluids, with volume contents ranging from 0.1% to 0.7%. First, the 13.5 mm inner diameter of the first test portion is cycled with an Al2O3 that has a vol. concentration of 0.1%. Currently, the valves on the first test segment are open, but they are closed on the other portions. Record each piece of information for each discharge rate after reaching steady-state. The previous processes are now repeated for every single test segment and every single concentration. Due to the significantly greater thermal conductivity of the MWCNT in comparison to the Al2O3, it might be inferred that the latter has a greater heat transfer coefficient. At volume concentrations of 0.1% as well as 0.7%, the heat transfer coefficients for Al2O3 as well as MWCNT, respectively. It has been demonstrated that the heat transfer coefficients of MWCNT and Al2O3 are greater than those of the two. MWCNT has a significantly higher heat transfer coefficient than Al2O3. The effect of conduit diameter on the water content as well as heat transfer coefficient of 0.5% Al2O3 in nanofluids. The increase in heat transmission is estimated to be 67.5% and 36.0% for Reynolds numbers 9624.12 and 24047.95, respectively, if the diameter of the tube is reduced from 13.5 millimeters to 4 millimeters. The influence of conduit diameter on the heat transfer coefficient of a nanofluid containing 0.7% Al2O3 and water. For Reynolds numbers 9624.12 along with 24047.95, the increase in heat transmission is calculated to be 63.6% when the tube diameter is reduced from 13.5 millimeters to 4 millimeters. Due to the greater thermal conductivity of MWCNT nanoparticles than Al2O3 nanoparticles, the heat transfer coefficient was determined to be greater in the MWCNT than in the Al2O3 at vol. concentrations of 0.1%, 0.3%, 0.5%, along with 0.7% across all three test sections. Similarly, whenever the diameter of the test section decreases, the heat transfer coefficient increases.

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Symbols

I	Current (Amp)
V	Voltage (V)
q	Heat Flux (W)
T_b	Properties at bulk mean temperature (^{0}C)
ρ_w	Density of water (kg/m^3)
μ_w	Absolute viscosity (N-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 (^{0}C)
T_{out}	Outlet temperature of Water (^{0}C)
T_w	Average tube surface temperature (^{0}C)
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.