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Nano Fluids for Heat Exchanger

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Abstract- Ultrahigh performance cooling is one of the important needs of many industries. However, low thermal conductivity is a primary limitation in developing energy-efficient heat transfer fluids that are required for cooling purposes. Nanofluids are engineered by suspending nano particles with average sizes below 100 nm in heat transfer fluids such as water, oil, diesel, ethylene glycol, etc. Innovative heat transfer fluids are produced by suspending metallic or non-metallic nanometer-sized solid particles. Experiments have shown that nanofluids have substantial higher thermal conductivities compared to the base fluids. These suspended nanoparticles can change the transport and thermal properties of the base fluid. The aim of this project is to summarize recent developments in research on nanofluids, and to carry out cfd analysis for four different nano fluids and the result is analysed, two fluids are selected for experimentation work and finally the experimented result is compared with the cfd results to draw out the conclusion. The different nano fluids used for cfd analysis are Magnesium oxide-water, cupper oxide-water, Titanium oxide-water, and Iron oxide-water. For experimentation nanoparticle's sizes are varied in the range of 70 to 230 nm for preparing nanofluids, and to observe enhancement in the thermal conductivity.

Keywords: **CO, HC, NOx, SO2, NOx, SOX.**

I. INTRODUCTION

The idea behind development of nanofluids is to use them as thermo fluids in heat exchangers for enhancement of heat transfer coefficient and thus to minimize the size of heat transfer equipments. Nanofluids help in conserving heat energy and heat exchanger material. The important parameters which influence the heat transfer characteristics of nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of nanofluids also depend on operating temperature of nanofluids. Hence, the accurate measurement of temperature dependent properties of nanofluids is essential. Thermo physical properties of nanofluids are prerequisites for estimation of heat transfer coefficient and the Nusselt number. Lee et al (1998), Das et al. (2000), Xuan and Roetzel (2003), and Choi et al. (2003) have investigated on properties of nanofluids containing metals and metal oxides nanoparticles. They have studied the parameters which influence nanofluid properties. The aim of this project is to summarize recent developments in research on nanofluids, and to carry out cfd analysis for four different nano fluids and the result is analyzed, two fluids are selected for experimentation work and finally the experimented result is compared with the cfd results to draw out the conclusion. The different nano fluids used for cfd analysis are Magnesium oxide-water, cupper oxide-water, Titanium oxide-water, and Iron oxide-water. For experimentation, nanoparticle's sizes are varied in the range of 70 to 230 nm for preparing of nanofluids, and to observe enhancement in the thermal conductivity.

II. LITERATURE SURVEY

[1]. L.B mapa et al: Measured enhanced thermal conductivity of Cu- Water based Nano fluid using a shell and tube heat exchanger. Where the dimensions of heat exchanger is 240X24X0.25mm, using 37 tubes. The outcome of analysis is rate of heat transfer is increases with increasing flow rate and also its concentration. By nanoparticle dispersed into de-ionized base fluid a better enhancement is achieved.

[2]. J.Koo et al: Investigated the nano particle collision and deposition in the surface wall with the help of micro channel heat sink. Which has the dimension of 1cm X 100micrometerX300micrometer; water-Cu and Cu-ethylene nanofluid are through micro channel heat sink. They are investigated the base fluid should posses high prandtle number and get enhanced heat transfer rate by minimize particle – particle, particle-wall collision. Viscous dissipation is important of narrow channel because Nusselt number high for high aspect ratio.

[3]. Shung-Wen Kang et al: Studied about the relation between thermal resistance- size of nanoparticle with the help of 211 micrometer X 2187 micrometer sized and deep grooved circular pipe and heat pipe maintain 40 temperature. They are finalized thermal resistance is directly proportional to the size of the nanparticle. Maximum reduction of the thermal resistance by using 10nm sized particle. Because particle size is increasing the wall

temperature also increases. So small sized particle suitable for enhanced heat transfer rate. Thermal resistance is decreases with the increasing heat and concentration of nanoparticles.

[4] Shuichi Tori: Investigated convective heat transfer coefficient of diamond based nanofluid by using heat tube apparatus. Specification of tube is 4.3mm,4mm outer and inner diameter respectively, and applied 100W power uniformly. They are showed the heat transfer coefficient is increases with increasing concentration and Reynolds numbert ofn Nano fluid, but at the same time increased the pressure drop with increasing concentration of nano particle.

[5]. S.J Kim et al: Investigated formation of porous layer and wet ability of nanofluid using critical heat flux experiment and SEM images. They are used three different types of nanoparticles with different diameters such as Al2O3 (110-220nm) SiO2(20-40nm) Zno(110-210nm). They are showed boiling is main factor to affect the heat transfer rate of nanofluid. Due to nucleate boiling nanoparticle deposited on wall, so the porous layer is formed on the wall. Porous layer directly consequence for creating wettablity, cavity and roughness of surface wall. So heat transfer rate decreased due to boiling of nanofluid.

[6]. Paisam Naphon et al: Investigated the thermal efficiency of heat pipe using titanium –alcohol Nanofluid, heat pipe dimensions are 60mm and 15mm length and outer diameter respectively. The Thermal efficiency increases with increasing tilt angle within 600 angle and concentration of nanoparitcle.

[7]. Anilkumar et al: Studied the heat transfer enhancement of fin, using Al2o3- water nano fluid analyzed using CFD. Reyleigh number increases due to Brownain motion, ballistic phonon transport, and clustering and dispersion effect of nanoparticle. At high Rayleigh number flow rate at center circulation is increasing, so temperature is drop from center of fin. Volume of the circulation increases the velocity at centre is increases as the result of increasing the solid fluid heat transportation. Low aspect ratio fin is suitable for heat transfer enhancement, because heat affected zone is less

[8]. Yu-Tung Chen: Investigated the thermal resistance of heat pipe using Al2O3 water nanofluid, heat pipe made as 200cmX3mm length and thickness respectively. Heat resistance is increases with increasing concentration of nano fluid up to 50ppm. Due to wet ability of nanoparticle various geometry wick is created on heat pipe.

[9]. Eed Abdel Hafez Abdel-hadi et al: Investigate the heat transfer analysis of vapour compression system using Cuo-R134a Nano fluid, test section made of copper horizontal tube and heat is applied 10-40 Kw/m Heat flux concentration and size particle is important factor to enhance the heat transfer rate of nanofluid. Heat transfer rate increases with increasing heat flux, upto 55% of concentration of nanofluid and upto2.5nm sized particles.

III. STATEMENT OF THE PROBLEM

Behaviour of nanofluids and modeling during heat transfer is still in the early stages of development and therefore has not been fully investigated. Research is needed to advance nanotechnology and to determine heat transfer applications for nanoparticles/nanofluids. Research will help to understand the relationship of nanofluids and heat transfer rates at various operational conditions. Experiments will also help to understand the relationship of deposition of nanoparticles and its effect on heat transfer rates. The research being conducted in this study to analyse the behavior of four types of nanofluids at different concentrations, temperatures, and at different flow rates, using CFD simulation software and Experiments are carried out for Two nanofluids in double pipe heat exchanger. The purpose of this project is to determine the effect nanoparticles have on heat transfer rates along with the effect deposition has on heat transfer rates using nano fluids at different concentrations, different flow rates, and at different temperatures.

IV. EXPERIMENTAL SETUP

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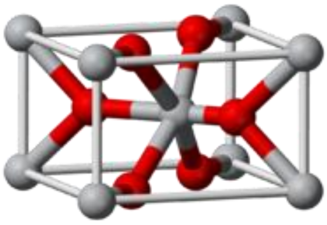
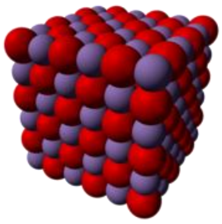
Apparatus for double pipe heat exchanger is shown in the above figure. The outer pipe is made up of steel having inner diameter and length of 0.0275m, and 2m respectively. The inner pipe is made-up of cupper having inner diameter, outer diameter, and length as 0.0085m, 0.014m and length 2m respectively. Cladding of mineral wool is carried out which acts as insulation over outer pipe. Two valves are provided on each pipe which can be open and closed alternatively for counter flow and parallel flow operation. Two water tanks viz (1) cold water and (2) hot water are provided with separate water pumps to circulate cold and hot water through pipes respectively. Heater are provided to heat the water from hot water tank. Thermocouples are provided to measure the temperatures of hot and cold water at inlet and outlet. The digital temperature indicators are used to indicate these temperatures.

A. Titanium dioxide

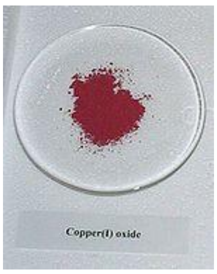
Titanium dioxide, also known as titanium (IV) oxide or titania, is the naturally occurring oxide of titanium, chemical formula TiO2. When used as a pigment, it is called titanium white, Pigment White 6 (PW6), or CI 77891. Generally it is sourced from ilmenite, rutile and anatase. It has a wide range of applications, from paint to sunscreen to food coloring. When used as a food coloring, it has E number E171.

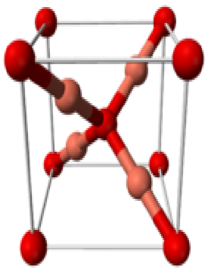
B. iron oxide

Iron oxide or ferrous oxide is the inorganic compound with the formula FeO. Its mineral form is known as wüstite. One of several iron oxides, it is a black-colored powder that is sometimes confused with rust, which consists of hydrated iron oxide (ferric oxide). Ironoxide also refers to a family of related non-stoichiometric compounds, which are typically iron deficient with compositions ranging from Fe0.84O to Fe0.95O.[2]

C. Copper oxide





Copperoxide or cuprous oxide is the inorganic compound with the formula Cu2O. It is one of the principal oxides of copper. This red-colored solid is a component of some antifouling paints. The compound can appear either yellow or red, depending on the size of the particles. Copper oxide is found as the reddish mineral cuprite. Cuprous oxide is commonly used as a pigment, a fungicide, and an antifouling agent for marine paints. Rectifier diodes

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based on this material have been used industrially as early as 1924, long before silicon became the standard. Copper oxide is also responsible for the pink color in a positive Benedict's test.

D. Magnesium oxide
Magnesium oxide (MgO), or magnesia, is a white hygroscopic solid mineral that occurs naturally as periclase and is a source of magnesium (see also oxide). It has an empirical formula of MgO and consists of a lattice of Mg2+ ions and O2− ions held together by ionic bonding. Magnesium hydroxide forms in the presence of water (MgO + H2O → Mg(OH)2), but it can be reversed by heating it to separate moisture.

V. METHODOLOGY

A. One-step method
To reduce the agglomeration of nanoparticles, Choi et al. developed a one- step physical vapour condensation method to prepare Cu/ethylene glycol nanofluids. The one- step process consists of simultaneously making and dispersing the particles in the fluid. In this method the processes of drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized and the stability of fluids is increased. The one step processes can prepare uniformly dispersed nanoparticles and the particles can be stably suspended in the base fluid. The vacuum - SANSS (submerged arc nanoparticle synthesis system) is another efficient method to prepare nanofluids using different dielectric liquids. The different morphologies are mainly influenced and determined by various thermal conductivity properties of the dielectric liquids. The nanoparticles prepared exhibit needle- like, polygonal, square and circular morphological shapes. The method avoids the undesired particle aggregation fair well. One- step physical method cannot synthesize nanofluids in large scale and the cost is also high, so the one- step chemical method is developing rapidly. However there are some disadvantages for one-step method. The most important one is that the residual reactants are left in the nanofluids due to incomplete reaction or stabilization. It is difficult to elucidate the nanoparticle effect without eliminating this impurity effect.

B Two-step method
Two- step method is the most widely used method for preparing nanofluids. Nanoparticles, nanofibers, nanotubes or other nanomaterials used in this method are first produced as dry powders by chemical or physical methods. Then the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation , high - shear mixing, homogenizing and ball milling. Two- step method is the most economic method to produce nanofluids in large scale, because nanopowder synthesis techniques have already been scaled up to industrial production levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of nanoparticles in fluids is the use of surfactants. However the functionality of the surfactants under high temperature is also a big concern, especially for high temperature applications. Due to the difficulty in preparing stable nanofluids by two- step method, several advanced techniques are developed to produce nanofluids, including one- step method. The two steps are explained as follows

VI. RESULT AND DISCUSSION

A. Properties of Titanium(Tio$_2$) oxide Nano fluid

Sl No.	Weight of Titanium oxide nano particles added to water	Weight of Base fluid (water)	Volume concentration factor($\varnothing$) %	Density of Nano fluid (ρ_{nf}) Kg/ m^3	Specific heat of Nano fluid(Cp_{nf}) Kj/kg °K	Thermal conductivity of Nano fluid(K_{nf}) W/m^{0}K	Viscosity of the Nano fluid(μ_{nf}) kg/m-sec
1	1gm	100gm	0.001798	1008.28	4171.72	0.6313	0.0006024
2	2gm	100gm	0.003627	1016.7	4165.33	0.634	0.0006034
3	3gm	100gm	0.005486	1025.2	4158.84	0.638	0.0006062

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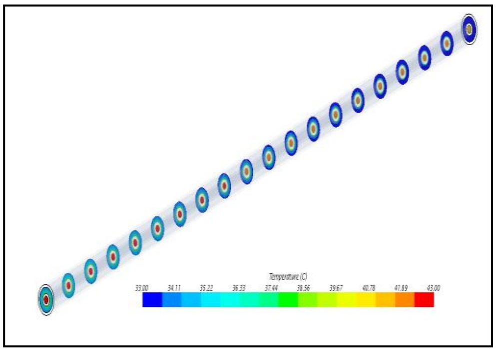
B. B.CFD

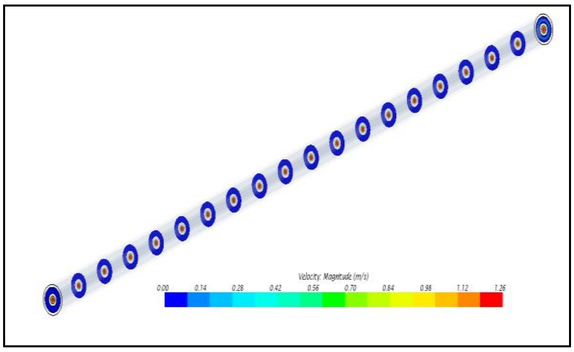
Numerical methods are extensively used to analyze the performance of the behaviour and also to design the micro channels heat exchanger. Computational Fluid Dynamics (CFD) is a computer-based numerical tool used to study the fluid flow, heat transfer behaviour and also its associated phenomena such as chemical reaction. A set of mathematical model equations are first developed following conservation laws. These equations are then solved using a computer programme in order to obtain the flow variables throughout the computational domain. Examples of CFD applications in the chemical process industry include drying, combustion, separation, heat exchange, mass transfer, pipeline flow, reaction, mixing, multiphase systems and material processing.

Copper oxide analysis

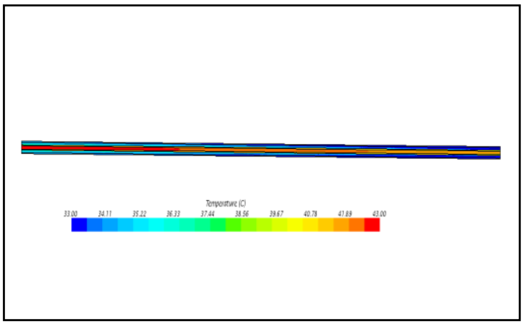
Nano fluid with 1% nano particles



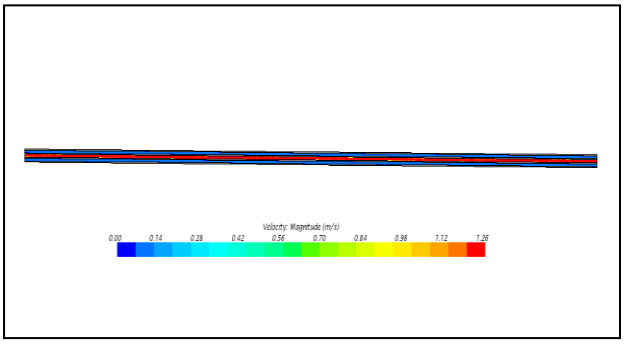
Plot 1.1 Temperature variation along the length length of heat exchanger



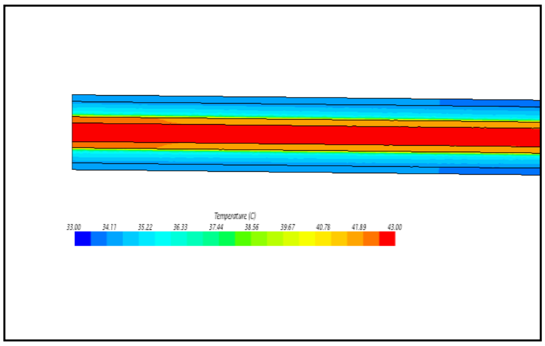
Plot 1.2 Velocity variation along the of heat exchanger

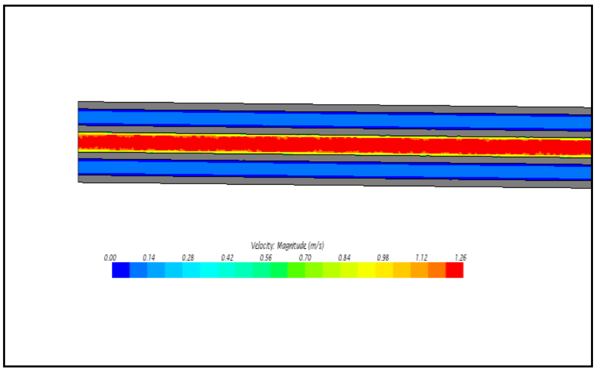


Plot 1.3. Temperature profile of nano fluid along the entire length of heat exchanger



plot 1.4. Velocity profile of nano fluid along the entire length of heat exchanger





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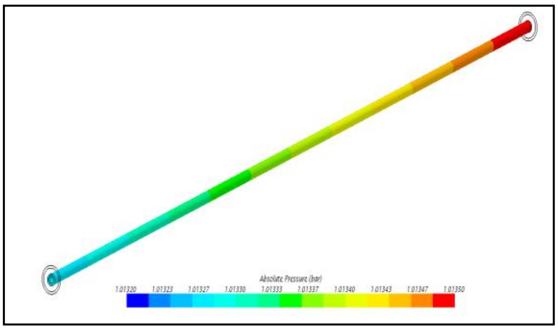
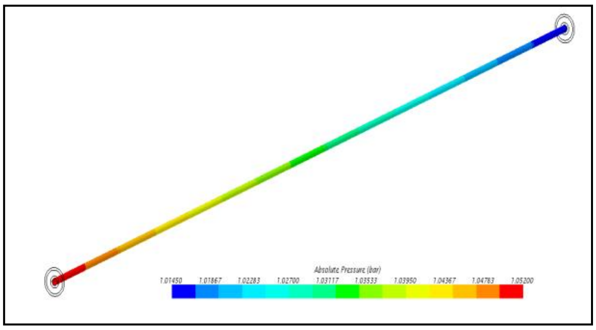
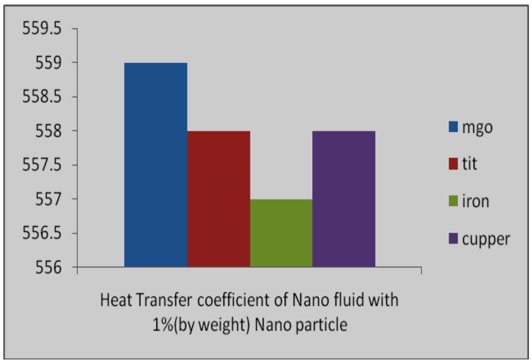
Plot 1.5. Temperature profile at the entrance **Plot no 1.6. Velocity profile at the entrance**

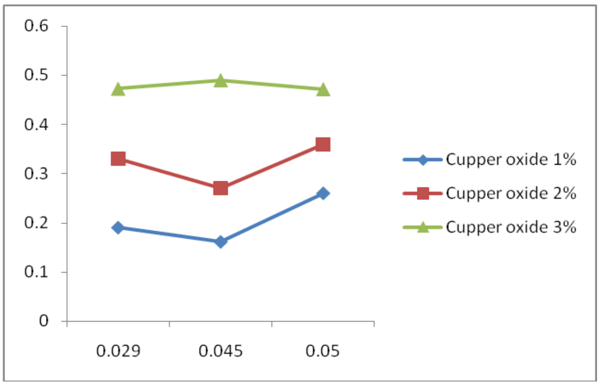




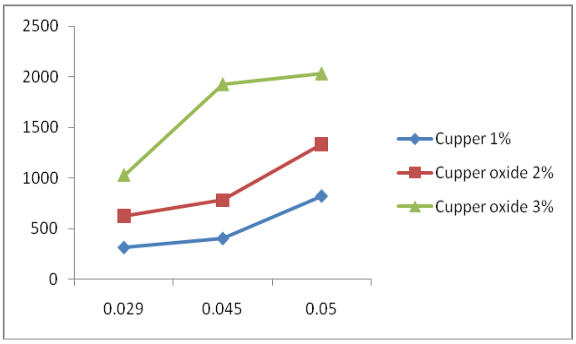
Plot 1.7. Pressure variation of cold nano fluid **Plot 1.8. Pressure variation of hot water**

Graphs of results

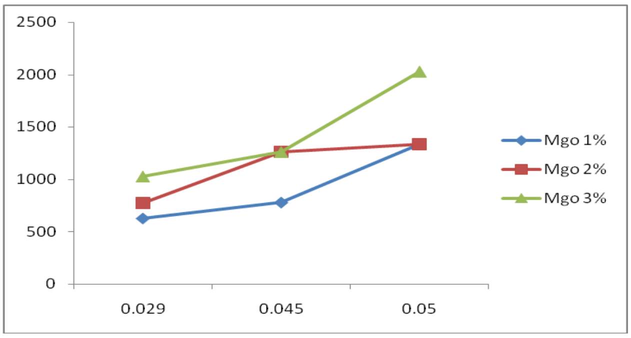




Effectiveness of heat exchanger using Cupper oxide nanofluid at different mass flow rate



Mass flow rate (kg/sec) V/S Heat transfer coefficient (W/m2K)



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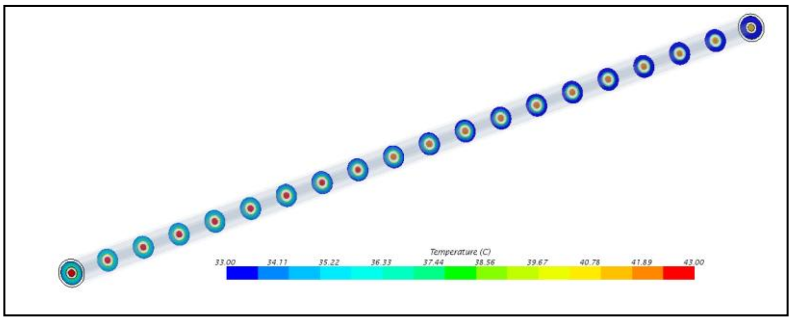
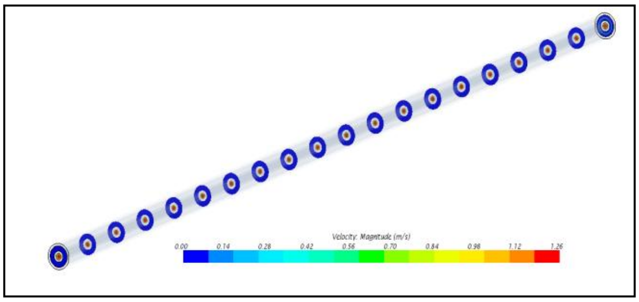
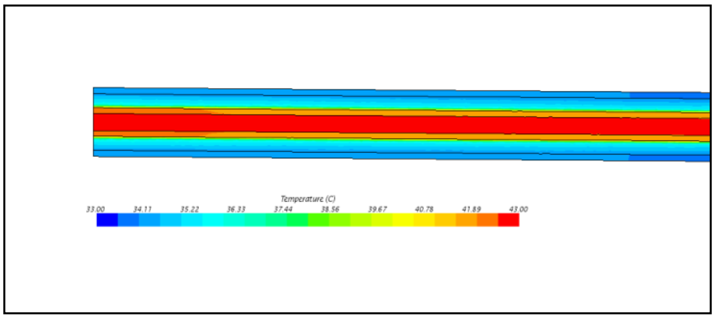
Mass flow rate(kg/sec) V/S Heat transfer coefficient(W/m2K)

3% Nano fluid



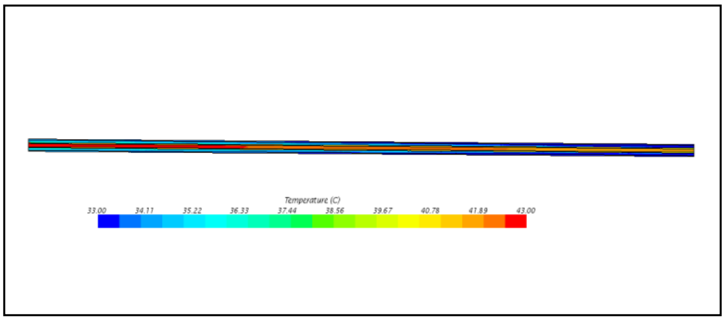
Temperature variation along the length of the heat exchanger

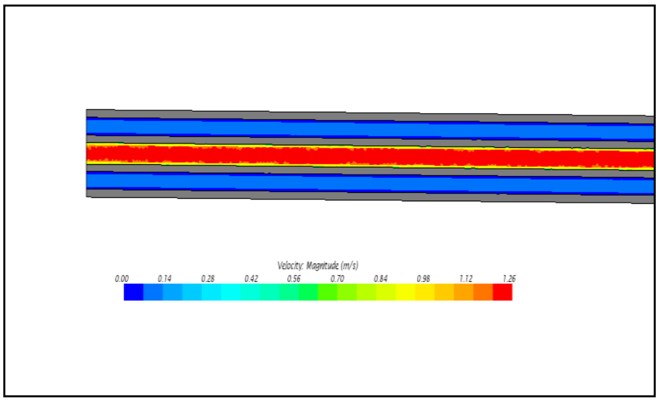




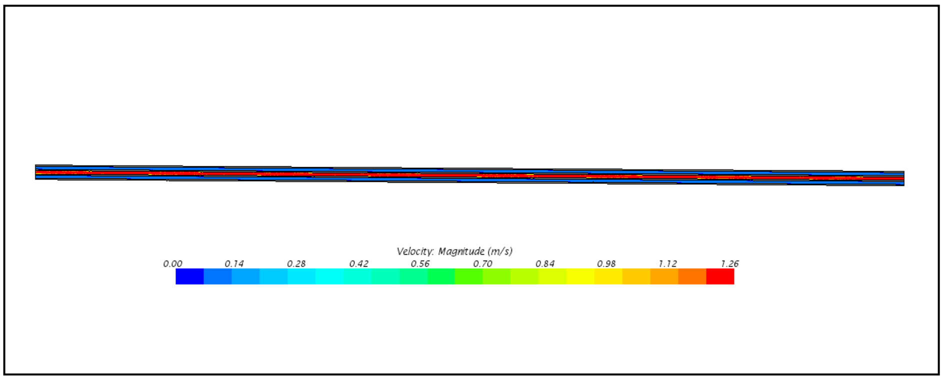
Velocity variation along the length exchanger

Temperature profile at the entrance of the heat exchanger





Velocity profile at the entrance



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Velocity profile along the heat exchanger

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