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# Analyzing the Effect of Magnetic Field on the Performance of Heat Exchanger

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**Abstract***: In contemporary engineering practices, optimizing heat transfer efficiency in heat exchangers stands as a pivotal pursuit across numerous industrial sectors. This pursuit is underscored by the need to bolster performance metrics while maintaining or even reducing energy consumption. The study herein delves into a comprehensive analysis of the influence of magnetic fields on heat exchanger performance, a topic of growing interest due to its potential to revolutionize heat transfer methodologies.*

*In the realm of heat exchanger optimization, active techniques play a crucial role in enhancing heat transfer efficiency. Unlike passive methods, which rely solely on flow obstructions, active techniques harness external power sources to induce surface vibrations or generate electrical fields within the heat exchanger system. This study focuses exclusively on the analysis of active techniques, particularly the utilization of magnetic fields, to augment heat transfer performance. A number of researches are being carried out to improve the heat transfer rate of the heat exchanger. The investigation involves the integration of an electro-magnet and nano-particles into the heat exchanger setup, allowing for the precise modulation of magnetic fields within the fluid medium. Through systematic experimentation across varying Reynolds numbers, the impact of magnetic fields on heat transfer rates is meticulously examined and quantified.*

*Key findings from this study elucidate the efficacy of employing magnetic fields as an active technique to enhance heat transfer efficiency. Over here the readings are recorded for a predefined Reynolds number for the ease of comparison and study. Thus, the effect of nanofluid at varied concentrations at different Reynolds numbers was being recorded and analyzed.*

**Keywords:** Active techniques, magnetic field, Nanoparticles, heat exchanger, electro-magnet, Reynolds Number

## I. INTRODUCTION

In recent years, there has been a surge in interest surrounding innovative techniques aimed at enhancing heat transfer efficiency in various engineering applications. Among these methods, the utilization of magnetic fields to manipulate heat transfer processes within heat exchangers has garnered considerable attention. Magnetic fields possess the capability to alter fluid flow patterns, augment thermal conductivity, and modify convective heat transfer coefficients, presenting promising avenues for improving the performance of heat exchangers.

A heat exchanger is basically being made use of to transfer heat between a source and a working fluid. In conventional heat exchangers, The tubular heat exchanger is the simplest form of heat exchanger; pipes are being placed serially beside another pipe of a larger diameter. Where in fluid flows through the pipe.

When it comes to fluid flow in heat exchangers, they operate with turbulent flow stream. When fluid flow is turbulent in nature, it gives higher energy transfer rates as compared to Laminar or Transient flow types. When a fluid flow is turbulent, its high intensity turbulence provides faster and more efficient mixing of fluid properties, which enhances the heat transfer rate making, the heat exchanger more effective & efficient in terms of energy.

In this project an experimental system of laminar flow heat exchanger is designed for the use of ‘nanofluid’ as one of the working fluid. With the help of nanofluid and electromagnetic field the laminar flow gets converted into turbulent flow. Results are compared with pure fluid (without any additives). The experiment is to be characterized by use of nanoparticles, which are ferrous oxide nanoparticles (Fe2O3), particles are to be mixed with water (base fluid) with the aim to enhance the heat transfer rate with the aid of an electromagnet. The heat transfer coefficient of the heat exchanger is examined when nanofluid is utilized instead of the normal process fluids.

## II. LITERATURE REVIEW

While researching and finding useful information for this project, we came across several research papers, which helped us gather the valuable resources and knowledge required for the fulfillment of the project. They helped us to analyze and imagine the scope of the project and focus on the important aspects of the project. These papers did lay a solid foundation for us in the terms of selection of nano-particles, base fluid, quantity of the nano -particles, calculations, etc. Some researchers have carried out experiments while some have carried out numerical analysis. A very few portion is being explored in this field compared to its optimum potential. These papers have played a role of a guiding light for us in terms of how much of the work in terms of research is being completed and where there could be more scope. Thus, all the literature being referred to proved to be fruitful for the study being carried out by us.

Farzad Fadaei, Mohammad Shahrokhi, Asghar Molaei Dehkordi and Zeinab Abbasi [1] explored how magnetic fields influence heat transfer properties, focusing on Fe3O4 ferrofluids. The research aims to understand the mechanisms behind heat transfer improvement in the presence of magnetic fields.

Qiang Li,Yimin Xuan [3] experimentally drew conclusions regarding the effect of external magnetic field and its orientation on the thermal behaviour on the magnetic fluid. It was being observed that upon the application of a magnetic field, the fluid displays characteristics such as magneto-viscous effect, magneto-thermal effect and magneto-optimal effect.

Maryamalsadat Lajvardi n,Jafar Moghimi-Rad, Iraj Hadi, Anwar Gavili, Taghi Dallali Isfahani, Fatemeh Zabihi, Jamshid Sabbaghzadeh [4] carried out the experimental analysis regarding the effect of magnetic nano-particle concentrations and the various magnet positions. A conclusion was even drawn that such ferrofluids do posses the ability to enhance the heat transfer by controlling the magnetic filed strength, ferrofluid properties and even temperature distribution.

Chidanand K. Mangrulkara, Ashwinkumar S. Dhoblea , Sunil Chamolib , Ashutosh Guptab , Vipin B. Gawande [7] through this paper deeply discuss about the constructional challenges being faced while building cross-flow heat exchangers and the ways to improve their thermal performance. The latest state-of-the-art developments are deeply discussed with its evaluating parameters and some recommendations to improve further ahead.

M. Bahiraei, M. Hangi [8] carried out research on various aspects, including the behaviour of these fluids under different magnetic field strengths, particle concentrations, and temperatures. They discuss mechanisms like Brownian motion and thermophoresis influencing heat transfer enhancement.

Reza Aghayari, Heydar Maddah, Fatemeh Ashori, Afshi Hakiminejad , Mehdi Aghili [9] carried out experimentation on a double pipe heat exchanger and did conclude that there is a reduction of thermal boundary layer thickness due to the presence of nano-particles and the random motion within the base fluid results in the enhancement of the convective heat transfer coefficient.

According to the literature review, we conclude that the introduction of Nano-particles in the fluid increases the rate of heat transfer of the system for both types of flows i.e. laminar and turbulent flows. The heat transfer properties do not only depend upon the concentration of nanoparticles but also on their shape and surface area. The heat transfer of the system also increases due to the collision of Nano-particles with the fluid molecules and the walls of the heat exchanger. Among the variety of comparing heat Exchangers turned out to be the fine design of cross-flow heat Exchangers as the most effective and efficient heat Exchanger. It is also being prominently discussed and observed by the researchers that along with the concentration of nano-particles, factors like the intensity of magnetic field, position of magnets, temperature difference, etc do have an effect on the heat exchanger.

## III. EXPERIMENTATION

### 3.1 Methodology

First and foremost beginning with identifying the need and even the problems being faced in enhancing the heat transfer rate of heat exchanger. Initializing the research on available information, a deep search for a number of literatures and research papers was being done. Followed by extraction of useful data, graphs, images, etc. was carried out. Even a number of professors were contacted regarding the project and their useful insights were taken into consideration.

The basic objectives were finalized, which are expected to be accomplished by the completion of this project. The basic conceptualization was done regarding the experimental set-up to be fabricated in coming future. Resources that were going to be required were enlisted and their availability was kept in check consistently from a number of sources.

Project budget and the approximate material cost from quotations were being compared in order to check the feasibility. Material required to build the foundation of the project were being procured. As the prime requirement of the project is nanoparticles, contacted a number of dealers in order to have them at an affordable price.

The experimental set-up was being fabricated. Firstly, the frame was fabricated as per the design. Post the completion of frame fabrication, the copper pipe and G.I were being threaded and were connected with the help of flange couplings. Between the G.I and the copper pipe, there was orifice plate installed, this resulted in increase in velocity of fluid flow. Once the full setup was ready along with pump and other attachments, we moved working on heating coil that was going to wound on the copper pipe. And to control the voltage of heating coil, dimmerstat was installed. The coil was covered with the insulation of Asbestos and Glass fibre.

To build the electro-magnet, we used the 22 gauge copper wire and wounded it around the test section and built a circuit for varying the current flow over the wire. It consist of voltmeter and Rheostat for controlling the magnet. Additionally flow control valve, Temperature indicator and all other measuring instruments were installed. Moving further, first we took the trial of heat exchanger setup, just to verify any leakage don't exists and checking the temperature sensors working properly or not. After that we kept the flow control valve fully opened, we took the reading of manometric deflection for highest. After getting the highest deflection we calculated Reynolds number for the highest value. By assuming the set of Reynolds numbers we calculated deflection for each no. for whom the remaining experiments would be carried out and based on these calculation flow control valve was adjusted as per deflection. Then for each calculations Nusselt numbers were calculated. The final yet the most important part was the recording and calculation of the number of things we had observed throughout the experimental runs. Then did plot the calculations and recorded data on the graphs in order to represent the results gained for various conditions through the number of experimental runs.

### 3.2 Factors Considered for Analysis

### Heat transfer Enhancement Technique

The heat transfer techniques are being broadly classified in two types which are : a. active and b. passive. The passive ones are being done with the help of some structural changes or addition of fins, extensions, etc. And on the other hand in active techniques the aid of power supply in being opted and turbulence is being created in the flow of fluids in order to have greater heat transfer. The crucial elements in this project resulting into this turbulence will be with the help of 'nanoparticles' and 'electromagnet'.

Rheostat: Employed to maintain a constant voltage supply to the setup, the rheostat regulates the speed of the induction motor. By controlling the voltage, researchers can ensure consistent operating conditions throughout experimental procedures.

### Nanoparticles

The selection of nanoparticles for enhancing heat transfer in a fluid system involves careful consideration of factors such as size, magnetic properties, stability, and saturation in the base fluid. In this case, Fe3O4 nanoparticles are chosen for their magnetic properties, cost effectiveness, and availability. It's crucial for the nanoparticles to be paramagnetic to avoid issues like magnetic memory. When subjected to an electromagnetic field, these nanoparticles migrate towards the inner surface of the pipes, carrying hot fluid with them. This facilitates improved heat transfer between the hot fluid, the copper pipe, and the surrounding cold fluid, ultimately enhancing overall heat transfer efficiency.

### Electromagnet

To be precise, an electromagnet is a device consisting of a core of magnetic material surrounded by a coil through which an electric current is passed to magnetize the core. Here, the M.S. pipe will be acting as the core metal and its selection is being made on the basis of its availability, cost and machineability. The coil surrounding the metal core will be that of copperas it comes with better insulation. Single turn of this wire will be wound around the outer surface of the M.S. pipe. throughout the length for which the effect is required. The effect of the magnetic effect on the magnetic nanofluid and thus on its heat transfer rate is going to be recorded and analysed.

### Reynolds Number (Re)

Reynolds number is a dimensionless quantity used to determine the type of flow pattern whether the flow of fluid is laminar, transient or turbulent. The heat transfer rate is more significant in case of turbulent flow as compared to that of laminar. Thus, in this experiment the heat transfer rate at various Reynolds number in turbulent flow pattern were recorded and analysed for water and nanofluids at various concentration of nano-particles in the base fluid. A series of Reynolds number were fixed for the ease of experimentation and calculation purpose. The Reynolds number for which the number of experiments carried out were2000,3000,4000,5000,6000.

### Nusselt Number (Nu)

The Nusselt number (Nu) is a dimensionless parameter used in heat transfer analysis to characterize the convective heat transfer efficiency of a fluid flow over a surface. It represents the ratio of convective to conductive heat transfer across the fluid boundary layer. The Nusselt number is defined differently depending on the type of flow regime (e.g., laminar or turbulent)and the geometry of the surface.

### Experimental Set-up

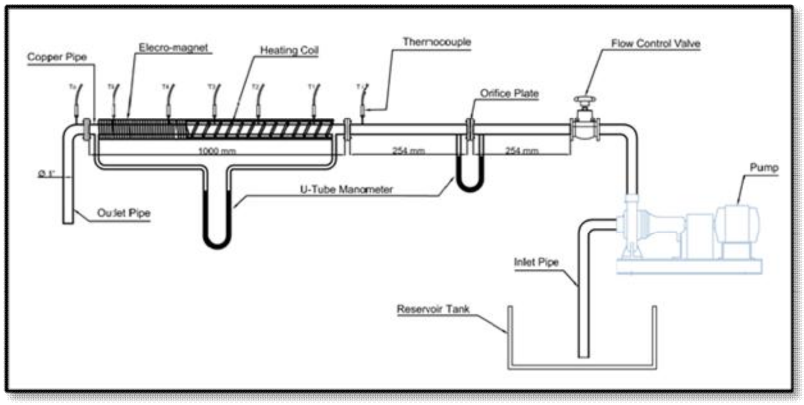

Figure No 1 : Proposed Model

Figure No 2 : Actual Experimental Set-up

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**Materials and Dimensions**

Frame Dimensions:

- Length of Frame = 1180mm
- Frame Table Height = 770mm
- Thickness of rod = 32mm
- Total Height = 770mm

Pipe Dimensions:

- Copper Pipe Diameter = 1”
- Copper Pipe Length = 1000mm
- G.I. pipe Diameter = 1/2 ”
- G.I. Pipe Length = 254mm
- Flange Diameter = 75mm
- Total Length of Pipes = 1508mm

Heating Coil Specifications:

- Heating Coil Capacity = 2000W
- Dimmerstat Specifications:
- Dimmerstat Range = 0-270volts

Temperature Indicator Specifications:

- Temperature Indicator Range = 12 channels
- Temperature Measuring Devices (Thermocouples):

Range = 0 to 130℃
Manometer Specification:
Manometer Type = U-Tube Manometer
Manometer Range = 250-0-250mm Hg

Electro-Magnet:
Copper winding – 22 gauge Ø.

Nano-Particles:
Type: Magnetite Iron oxide (Fe3O4)
Purity: 99.9%
Bulk Density = 0.69 gm/cm3

**Procedure of Experimentation**

**Part 1:** Baseline with Pure Water

1. System Setup:
Fill the reservoir tank with pure water.
Connect the reservoir pump to circulate water through the heat exchanger loop.
Ensure the electromagnet is off for this part of the experiment.
2. Flow Rate Variation:
Set the pump to achieve a desired flow rate within the laminar flow regime.
Allow the system to reach steady-state operating temperature, where inlet and outlettemperatures remain constant.
Measure the manometric deflection corresponding to different flow rates
Record the inlet and outlet temperatures of fluids using the thermocouples.

Repeat steps 2.2 - 2.5 for several different flow rates to obtain a range of Reynoldsnumbers.
3. Data Analysis:
For each flow rate data set, calculate the Reynolds number (Re) using the measuredflow rate, pipe diameter, and water properties.
Calculate the average heat transfer rate (Q) based on the mass flow rate, specificheat capacity of water, and temperature difference between hot and cold fluids.
Compute the Nusselt number (Nu) using the thermal conductivity of water, pipediameter, and average heat transfer rate.
Compare the obtained Nusselt number with established correlations for laminar flowin tubular heat exchangers.

**Part 2:** Effect of Magnetic Field with Nanofluid
1. Nanofluid Circulation:
Add nanoparticles (e.g., Fe3O4 nanoparticles) to the water to create a magneticnanofluid. Thoroughly stir in the nanofluid to ensure uniform dispersion ofnanoparticles.
Replace the pure water in the reservoir tank with the prepared nanofluid.
steps 2.1 - 2.5 from Part 1, but keep the electromagnet off for this initialnanofluid test.
This establishes a baseline for heat transfer with the nanofluid under no magneticfield influence.
2. Magnetic Field Application:
Activate the electromagnet and adjust the power supply to achieve a desiredmagnetic field strength.
Repeat steps 2.2 - 2.5 from Part 1 for the same range of flow rates as before, butwith the magnetic field applied.
3. Data Analysis:
Perform the same calculations for Reynolds number (Re), heat transfer rate (Q), andNusselt number (Nu) as in Part 1, for each flow rate data set with the magnetic field.
Compare the Nusselt numbers obtained with and without the magnetic field for thenanofluid. Analyze the impact of the magnetic field on heat transfer performance.

**Concentration of Nano-particles**

While carrying out literature survey, it was being repeatedly observed that the factors affecting the heat transfer rate are area, thermal conductivity of the material, intensity of the magnetic field, flow pattern of the fluid, the amount of nano-particles present in the nanofluid, etc. In order to observe this effect, were carried out a experimental run on 5% of volumetricconcentration of nanoparticles in water. The experimental trial for nanofluid concentration were carried out at every Reynolds number in order to maintain a constant parameter for comparison. And as expected after a thorough study of the research papers, gradual growth in the overall heat transfer coefficient was being observed after a number of iterations for every pre-defined Reynolds number. For the experimentation purpose, the quantity of base fluid to be converted into a nanofluid was 10 litres. With the addition of nano-particles to the base fluid, increase in the heat transfer coefficient was observed which symbolised the increase in heat transfer rate. Along with that it is equally important to know about the maximum saturation of nano-particles possible in the fluid.
During our experimentation we had maintained a hot water reservoir of capacity 10 litres and wherein the vol. 5% and 500gms

**Data Reduction**

Formula to Calculate Reynolds Number (Re)
$Re=\rho vD/\mu$
Where,
Re – Reynolds Number
ρ – Density of water ‘$kg/m^3$’
v – Velocity of water ‘m/s’
D – Diameter of Copper pipe ‘m’
First and fore most we have to calculate the highest Reynolds Number (Re) using this formula and then we need to calculate the velocity by using the formula

Formula to Calculate Heat Transfer (q)

After calculating velocity we need to calculate the Heat transfer Rate (q) by using the following formula

$$q=A\times v$$

Where,

q – Heat transfer ‘W’

A – Area of Copper pipe ‘m$^2$’

v – Velocity of water ‘m/s’

Here, we get ‘q’ in “W”

After calculating ‘q’ we then calculate the Manometric which is denoted by ‘$x$’ in mm of Hg by using the following formula

$$q=Cd\times((A1\times A2))/\sqrt{(A1^2-A2^2)}\times\sqrt{(2g\times x)}$$

$$x=q^2/(2g\times Cd\times((A1^2\times A2^2)/(A1^2-A2^2)))$$

Where,

q – Heat transfer ‘W’

Cd – Distance coefficient

A1 – Area of GI pipe ‘m$^2$’

A1 – Area of Orifice plate ‘m$^2$’

v – Velocity of water ‘m/s’

h – Manometric deviation ‘m’

g – Gravitational constant ‘m/s$^2$

$x$– Manometric Deflection

Formula to Calculate Nusselt Number (Nu)

For calculation of Nusselt Number (Nu) we need to find out the ‘q’ in “W” for the we need Voltage produced by Heater and Current, then calculating further by the following formula

$$Q=V\times I$$

Where,

Q – Volume flow rate ‘m3/s’

V – Temperature at Surface of Pipe at Point ‘m3/ ‘℃’

I – Current ‘℃’

After the calculation of ‘q’ we need to calculate ‘h’ in ‘W/m2K’ for the we would require average temperatures of point on the surface of pipe and average of temperatures of inlet and outlet of the pipe respectively which are ‘Tavg’ and ‘Tavg1’ respectively for that we calculate using the following formulas

$$Tavg=((T1+T2+T3+T4+T5)/5)$$

Where,

Tavg – Average Temperature at Surface of Pipe ‘℃’

T1 – Temperature at Surface of Pipe at Point no 1 ‘℃’

T2 – Temperature at Surface of Pipe at Point no 2 ‘℃’

T3 – Temperature at Surface of Pipe at Point no 3 ‘℃’ ’

T4 – Temperature at Surface of Pipe at Point no 4 ‘℃’ ’

T5 – Temperature at Surface of Pipe at Point no 4 ‘℃’

And for Average temperature at Inlet and Outlet of the pipe

$$Tavg1=(Tin+Tout)/2$$

Where,

Tavg1 – Average Temperature at Inlet and Outlet of pipe ‘℃’

T1 – Temperature at Surface of Pipe at Point no 1 ‘℃’

T2 – Temperature at Surface of Pipe at Point no 2 ‘℃’

T3 – Temperature at Surface of Pipe at Point no 3 ‘℃’

After the calculation of the average temperatures we need to find out the Heat Transfer Coefficient ‘h’ in ‘W/m2K’ by using the following formula

$$Q=h\times\pi\times0.0254\times(Tavg-Tavg1)$$

Where,
Q – Volume flow rate ‘m3/s’
h – Heat Transfer Coefficient ‘’
Tavg1 – Average Temperature at Inlet and Outlet of pipe ‘℃’

Here we get the Heat Transfer Coefficient ‘h’ in ‘W/m2K’ here after we need to finf the NusseltNumber (Nu) by using the following formula

$$Nu=(h\times D)/k$$

Where,
Nu – Nusselt Number
h – Heat Transfer Coefficient
D – Diameter of Copper pipe ‘m’
k – Thermal Conductivity ‘’ W/m-K

## IV. RESULT AND DISCUSSION

**Introduction**

In this chapter the results being observed after thorough calculations will be represented graphically in order to have a systematic outlook at the outcomes of the number of experimental runs being carried out. A sample calculation regarding the calculation is being given based on which the graphs are being plotted.

Sample Calculations
To find Nu for Re=4000,
To find velocity (v) -
We have-
Diameter of Copper pipe, D = 0.025 m,
Density, $\rho = 12.6$ kg/m3
Dynamic viscosity of water, $\mu = 0.001002$ kg/m-s
$Re=\rho vD/\mu$
$4000=(1000\times v\times0.025)/0.001002$
$v=0.157795276$ m/s
To find Heat Transfer (q) -
Area of copper pipe -
$A=〖\pi/4\ D〗^2$
$A=〖\pi/4(0.025)〗^2$
$A= 0.000506451\ m^2$
Heat Transfer -
$q=A\times v$
$q=0.000506451\times0.157795276$
$q=7.99155E-05$
To find (x) –
Area of GI pipe -
We have-
Diameter of Copper pipe, d1 = 0.015 m
$A1=〖\pi/4(d1)〗^2$
$A1=〖\pi/4(0.015)〗^2$
$A1=0.000176625\ m^2$

Area of Orifice plate -
We have-
Diameter of Copper pipe, d2 = 0.008 m
$A2= 〖\pi/4(d2)〗^2$
$A2= 〖\pi/4(0.008)〗^2$
$A2= 0.00005024\ m^2$
For Manometric deviation ( x) -
$q=Cd\times((A1\times A2))/\sqrt{(A1^2-A2^2)}\times\sqrt{(2g\times x)}$
$x=q^2/(2g\times Cd^2\times((A1^2\times A2^2)/(A1^2-A2^2)))$
$x=((7.99155E-05)^2)/((2\times 9.81)\times(0.6)^2\times((0.000176625^2\times 0.00005024^2)/(0.000176625^2-0.00005024^2)))$
$x=0.329245683$ m of $H_2O$
To find Heat Transfer Coefficient (h) –
We have-
Heater Voltage, V = 150v
Current, I = 1.2 amp
Volume flow rate (Q) –
$Q=V\times I$
$Q=150\times 1.2$
Q=180 m3/s
Average Temperature at Surface of Pipe (Tavg) –
$Tavg=((T1+T2+T3+T4+T5)/5)$
$Tavg=((40+43+39+40+42)/5)$
Tavg=40.8 ℃
Average Temperature at Inlet and Outlet of pipe (Tavg1) –
$Tavg1=(Tin+Tout)/2$
$Tavg1=(37+39)/2$
Tavg1=38 ℃
Heat Transfer Coefficient (h) –
$Q=h\times\pi\times 0.0254\times(Tavg-Tavg1)$
$180=h\times\pi\times 0.0254\times(40.8-38)$
h=806.0298195 W/m2-K
Nusselt Number (Nu) –
We know that,
Thermal Conductivity of Water, k = 0.555 W/m-K
$Nu=(h\times D)/k$
$Nu=(806.0298195\times 0.0125)/(0.555)$
Nu=36.88857192
Nu by using Corelation -
We know that,
Prandtl Number, Pr = 6.9
$Nu=0.023\times(Re)^{0.8}\times(Pr)^{0.4}$
$Nu=0.023\times(4000)^{0.8}\times(6.9)^{0.4}$
Nu=37.92411592

Thus, in a similar way calculations were carried out for each and every experimental run and then further represented on the graphs for the further discussions and chalking down of conclusions.

**Results**

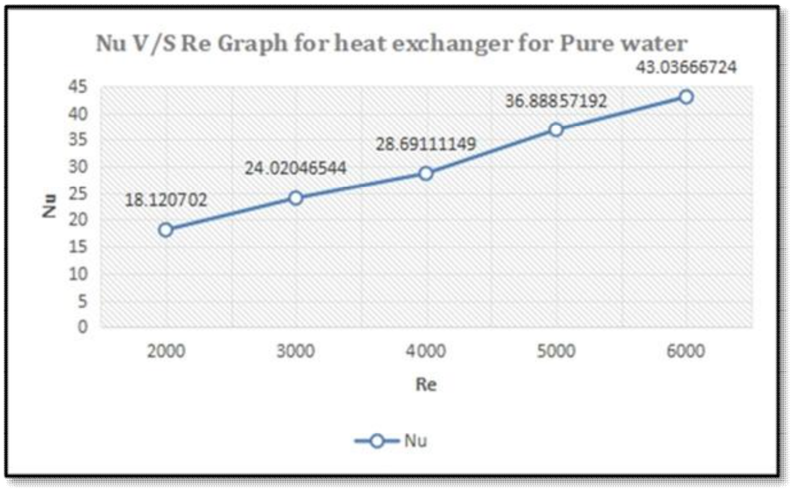

Figure No 3Variation in Reynolds Number (Re) for pure water

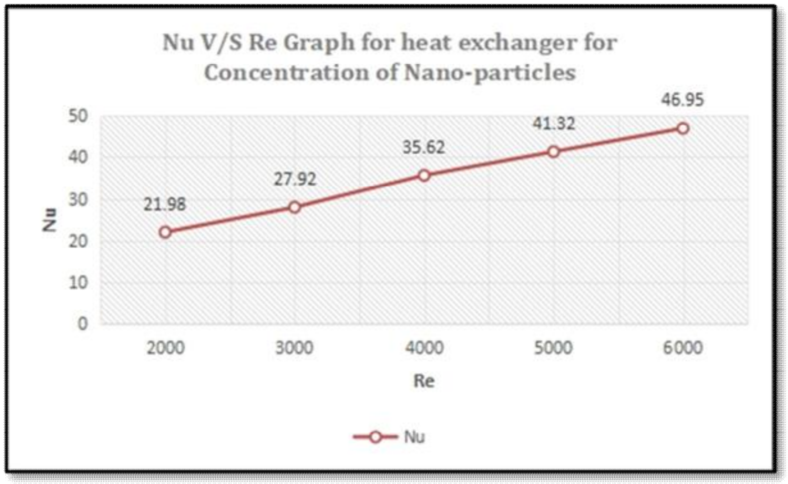

Figure No 4Variation in Reynolds Number (Re) for Nanofluid

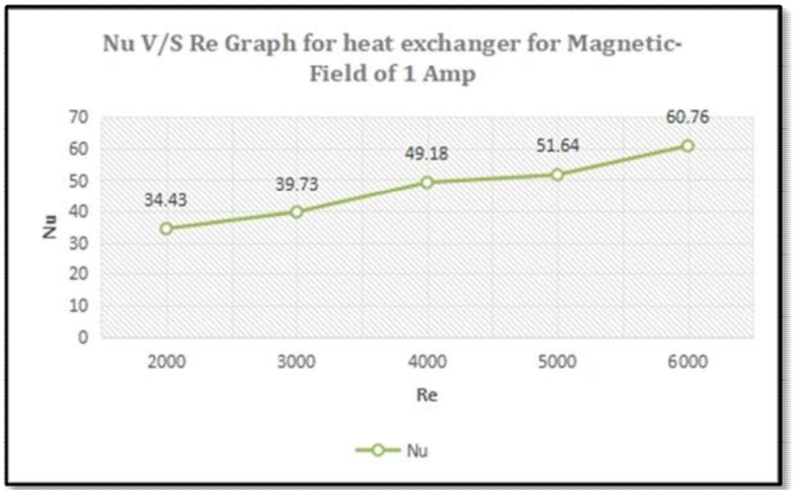

Figure No 5Variation in Reynolds Number (Re) with Nanofluid and

**Electro-Magnet with 1amp of current**

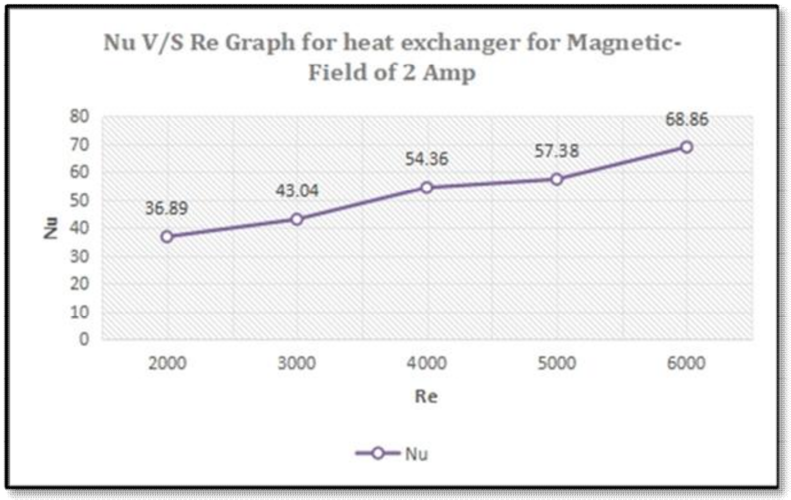

**Figure No 6 Variation in Reynolds Number (Re) with Nanofluid and**

**Electro-Magnet with 2amp of current**

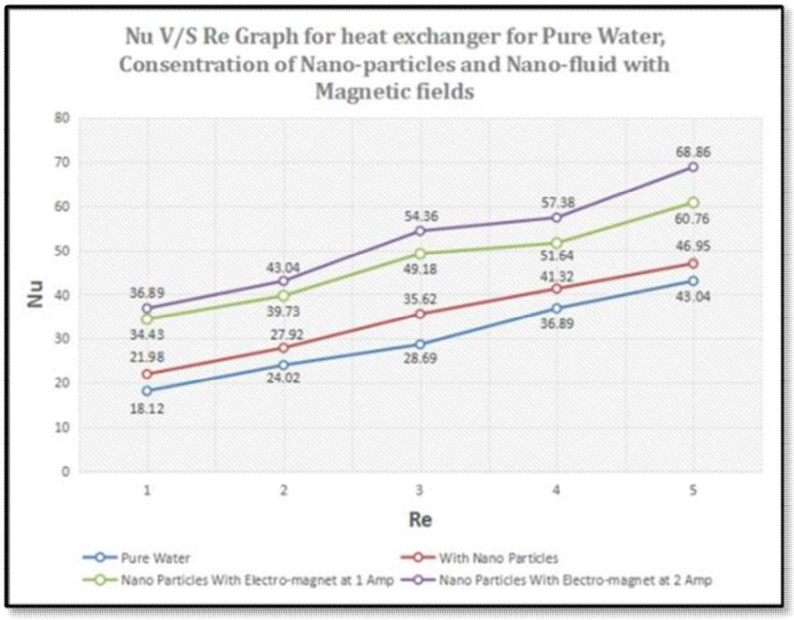

**Figure No 7 Variation in Reynolds Number (Re) with and without Nanofluid and Nanofluid with**

**Electro-Magnet with 1amp and 2amp of current**

Maintaining the base fluid at the same quantity of nano-particle concentration and recording the readings when the temperature measuring devices till it reach a steady state and thorough calculations were the measures been keenly followed throughout in order to generate the results in form of graphs From the above graphs (i.e. Fig 4.1, Fig 4.2, Fig 4.3) it could be observed that there is an increase in heat transfer coefficient (h) and therefore Nusselt Number (Nu) increases meaning an increase in heat transfer rate as we move from water to nanofluids. This is thus a cumulative effect of property enhancement of base fluid with the addition of nano-particles to it as well as the effect of the electromagnet on the nanofluid.

## V. CONCLUSION

Experimentation runs on a tubular heat exchanger, experimentation was conducted and heat transfer coefficient for various water and nano-fluid was calculated as a measure for further analysis. The heat transfer coefficient was compared in a pair of pure water and nanofluid with electromagnet.

The experimental readings followed by calculations and analysis led to the following conclusions:

- There was considerable increase in heat transfer coefficient when the fluid is changed from pure water to nano-fluid
- There was 7.08 % increase in Nusselt number when compared to pure water
- When electromagnetic field was generated at 1 Ampere of current there was 21.98 % in Nu number and at 2Ampere of current 26.76% increase was recorded.
- It was observed that for the decreasing value of Reynolds number the heat transfer coefficient goes on decreasing. So it can be concluded that Reynolds number is directly proportional to heat transfer coefficient. To get better heat transfer coefficient it is advised to use a magnetic field around the heat exchanger with nano fluids.
- The best reading were observed when the temperature of fluid was relatively low.

## VI. ACKNOWLEDGMENT

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