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A Study on $CaCO_3$-Water Nano Fluid Properties as a Heat Transfer Fluid

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Abstract - This paper presents An Experimental investigation on CaCO3 -Water Nano fluid properties and its performance as a heat transfer fluid. Nanofluids are colloidal suspension of nanosized solid particles in a base fluid. Generally nanoparticles are made up of metals, carbides, oxides. While base fluid may be water, ethylene glycol and oil having suspended tiny particles in the base fluids improves the thermal conductivity and thus the increase in the heat transfer performance is expected. A test study has been completed to examine the heat transfer performance of water and CaCO3 nanoparticles. This current experiment demonstrates the increases in convective heat transfer in nanofluid. The nanofluid developed by adding CaCO3-nano sized particles of 80 nm in base liquid. Demineralized water is used as base liquid. Nanofluid with different volume fraction of CaCO3 nano sized matter between 0.02-0.1 percent used in this current work. The test setup consists of a test section that includes copper pipe of 1000mm length, inner diameter 10mm and a heater. To minimize the heat loss in test section, insulation layer is covered. Thermocouples are utilized in test section to measure the temperatures. The effect of solid volume fraction, nanofluid flow rate and the inlet temperature on heat transfer performance of the nanofluid is examined in this current work. The results show an increment in heat transfer with raising volume fraction of CaCO3-nanoparticles and increase in temperature. And the experimental results also shows that for enhancing the flow rate of the nanofluid the heat transfer coefficient is also increases. The properties like thermal conductivity, viscosity, density, heat transfer rate, and overall heat transfer coefficient increases with increasing the volume fraction of the nanoparticle in the Nanofluid. And also Reynolds number and Nusselt number increases with increasing the flow rate of the nanofluid.

Index Terms: **Nano particles, Heat Transfer, Volume Fraction, Reynold's Number.**

I. INTRODUCTION

Heat transfer is most important in many industries, heat is added or removed. Heating enhancement in an industrial process May heating or cooling process to saving the energy, reduction of process time, thermal rate rise and enhancing the working life of the equipment. There are so many methods are available to enhance the heat transfer efficiency. In that using the nanofluids is an effective heat transfer enhancement method. The nanofluid which is replaces the conventional fluids like water, ethylene glycol and engine oil and increases the heat transfer performance. Using the nanofluids the properties like thermal conductivity, thermal stability, thermal diffusivity, viscosity and convective heat transfer coefficient are increases. The nanofluids are used as a heat transfer fluids for almost two decade's duo to variety of complexity no agreement has been achieved in the potential benefits of using nanofluids in a heat transfer applications. The nanoparticle possess the following advantages they are

1. Nanoparticle having a high surface area therefore more heat transfers between particles and the fluids.
2. In nanoparticle high dispersion stability can be easily achieved.
3. The Nanofluid having a reduced pumping power than compared to the pure liquid.
4. Reduced particle clogging.
5. Thermal conductivity and surface wet ability is more by varying the volume concentrations.

A. Nanofluids

Nanofluids are engineered colloidal suspensions of the solid particles in the base fluids. For preparation of the nanofluids the base fluids like water, engine oil and ethylene glycol are generally used.

The nanoparticle is first introduced by choi in 1995 and explains **Choi et al** [11].ed about the nanofluids and compared with conventional fluids in that the nanofluids which show the better thermo-physical properties than compared to conventional fluids.

The property change of nanoparticle is mainly depends on volumetric concentration of nanoparticle and shape and size of the nonmaterial. Duo to thermo physical properties the nanoparticle are widely used in various heat transfer applications. For example the thermal conductivity of the copper is 700 times more that of water and 3000 times more that of engine oil at room tempearature.therefore the fluids including suspended solid particles are having significantly enhanced thermal conductivities.

B. Features of Nanofluids

The nanofluids having some special features for various engineering applications.

Some of the special features are listed below.

1. The nano matter which shows exceptional rise in thermal conductivity than that of theoretical predictions,
2. Superfast heat transfer enhancement.
3. More stable than other colloids.
4. Less erosion and micro channels clogging.
5. Less pumping power is required.
6. Less friction coefficient.
7. Best lubrication.

C. Thermal Conductivity Enhancement Methods

The nanofluids have shown higher thermal conductivity than the conventional models having large size particle dispersion and increase in thermal conductivity was more than the predicted value. Therefore, the heat transfer in nanofluids was studies by many researchers and four possible

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reasons for increase in heat transfer were proposed by them:

1. Brownian motion of the nanoparticle
2. Liquid layering of the base fluid at the liquid solid interface
3. Nanoparticle clusters

Brownian motion of the Nanoparticle

The Brownian motion which gives to nanoparticle which is present in nanofluids in sometimes colloids with each other. in particularly when the two nanoparticle collide each other in is the case of solid-solid mode of hest transfer which could increases the overall thermal conductivity of the nanofluid. The thermal conductivity of the nanofluids is mainly related on diffusive process with a constant of diffusion D and given by the formula which is known as stokes-Einstein formula

$$D = (K_B * T)/(3*\pi*\eta*d)$$

Where, KB is the Boltzmann constant, T is the temperatures
η is the viscosity of the fluid,
d is the particle diameter

It is observed the above expressions the diffusivity is increases with increasing the temperature.

Nanoparticle Clusters

Local nanoparticle clustering is another possible mechanism offered by Keblinski, Phillpot et al They suggested that the 62 effective volume of a cluster can be much larger than the volume of the particles which will lead to higher overall thermal conductivity of nanofluids. Clusters with very low packing factor which is defined as ratio of the volume of the solid particles in the cluster to the total volume of cluster, and very larger effective volume might be one of the reasons for the unexpected thermal conductivity enhancement of nanofluids. However, the author also pointed out that the clusters existing in the dispersion may cause the settlement of particles or creating particle-free regions with high thermal resistance.

One of the most controversial heat transfer method in nanofluids is possibly the nanoparticle clustering. Nanoparticles have been experimentally observed to the nano agglomerate into clusters when suspended in the liquid. In theory. Nanoparticle clustering into porous pattern creates paths of lower thermal resistance. That would have a chief effect on the overall thermal conductivity and viscosity of nanofluid.

II. PREPARATION OF NANOFLUIDS

The synthesis of nanofluid is the main key step in experimental study of nanofluid. To synthesis nanofluid all most all solid nano particles of higher thermal conductivity can be used. The normally using solid materials like metallic and non metallic solids. Metallic solid includes Copper, Aluminum, Silver, Gold, Iron and non Metallic solid involves Silicon, Alumina, Silicon Carbide, Carbon nano tubes, Copper Oxide, Titanium Oxide. Generally two main techniques are used two synthesis nanofluid they are;

- Single step method
- Two step method

A. Single Step Method

Few methods exist for the preparation of nanofluids through a one step process. These methods include the thermal decomposition of an organo metallic precursor in the presence of a stabilizer [4], chemical reduction [1],and polyol synthesis [2, 3].The polyol method is one of the most well known a pathways to noble metal nanoparticles [4, 5, and 6]. In the polyol process, a metal precursor is dissolved in a liquid polyol (usually ethylene glycol), after which the experimental conditions are adjusted to achieve the reduction of the metallic precursor by the polyol, followed by atomic metal nucleation and metal particle growth [7]. The direct-evaporation technique was developed by **Choi et al** [11]. It consists of a cylinder containing a fluid which is rotated. In the middle of the cylinder, a source material is vaporized.

B. Two Step Process

The preparation of nanofluids begins by direct mixing of the base fluid with the nonmaterial. In the first step, nonmaterial's are synthesized and obtained as powders, which are then introduced to the base fluid in a second step Nanoparticle can be produced from several processes which can be categorized into one of five general synthetic methods. These five methods are:

i. Transition metal salt Reduction
ii. Thermal decomposition and photochemical methods
iii. Ligand reduction and displacement from organo metallic's
iv. Metal vapor synthesis, and
v. Electrochemical synthesis.

Transition-metal nanoclusters are only kinetically stable because the formation of the bulk metal is its thermodynamic minimum. Therefore, nanoclusters that are freely dissolved in solution must be stabilized in way that prevents the nanoclusters from coalescing.

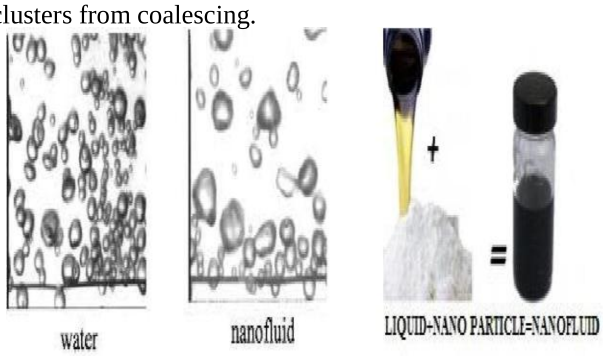

Fig.1 Nanofluid

C. Selection of Nanoparticle

In this work Calcium carbonate-water Nanofluid are used it is appear in the form of a white powder because the Calcium carbonate nanoparticle having a low cost. The thermal conductivity is expected about 2.4 w/m k and the calcium carbonate availability is more and has been widely used as fillers in polymeric materials with the main purpose of reducing costs. Calcium carbonate powder is a naturally

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pure source of calcium. It is ideal ingredient for use in dietary supplementation for food fortification, granulation, antacids and other various pharmaceutical applications. The calcium carbonate nanoparticle was produced by bubbling of CO2 gas through a suspension of calcium hydroxide.

The Calcium Carbonate nanoparticle is typically 10-80 nanometers (nm) with specific surface area (SSA) in the 30-60 m²/g range. Nano Calcium Carbonate Particles are also available in passivated and ultra high purity and high purity and coated and dispersed forms. Research into applications for Calcium carbonate nanocrystals has focused on use in drug delivery by loading them with hydrophilic protein drugs and for their potential imaging, biomedical and bioscience properties and for use in coatings, plastics, nanowire, and in alloy and catalyst applications.

Fig 2 Calcium Carbonate nanoparticle

D. Specifications of CaCO3 Nano Particles and Base fluid

Table .1 Specifications of CaCO3 nano particles

Calcium carbonate	CaCO3
Colour	White powder
Morphology	Cubic
True Density	2710 kg/m^3
Molecular mass	100.08 g/mol
Sp.Surface Area	60 m^2/g
Refractive index	1.59
Average particle Size	80 nm
Specific Heat	848.5 J/kg K
Melting point	1340˚C
pH	8-10
Odour	Odourless
Solubility in water	0.053g/L

Table 2 Specifications of Base fluid (water)

Water	H_2O
Density	1000kg/m^3
Thermal conductivity	0.6078W/m-K
Dynamic viscosity	0.00088385Pa-sec
Specific Heat	4178 J/kg K

III. EXPERIMENTAL METHODOLOGY

The figure 3 illuminates the schematic layout of the experimental setup. The experimental setup consists of double pipe heat exchanger, Rotameter, centrifugal pump, thermocouple, and Temperature display unit, overhead tank which is used for supplying cold water, hot water tank with submersion heater and a control unit.

The experimental test section which is one of the components of the experimental setup is a double pipe heat exchanger arranged in a counter current flow configuration. It consists of inner tube made up of copper with outer diameter of 12.5 mm and length of 1000 mm the outer tube is made of galvanized iron with outer diameter of 32 mm and length of 1000 mm the annulus outer diameter is chosen so that there is a small space in the annulus ensuring high velocity in the turbulent region and pipe flow. The estimated heat loss to the surrounding because of no insulation layer in the cold fluid side, based on simple one-dimensional conduction analysis is found to be approximately 0.2 W. Two calibrated flow meters: Rotameter were used in the setup, placed in the cold fluid and the hot fluid side respectively with the flow measuring range of 20-1080 LPH in cold water side and 30 cc/sec for hot water side. The flow rate is controlled manually in each side. The cold fluid is drawn from the overhead tank with the assistance of gravity and the reason we didn't use cold fluid tank in our setup was because of the readily availability of the overhead cold water tank.

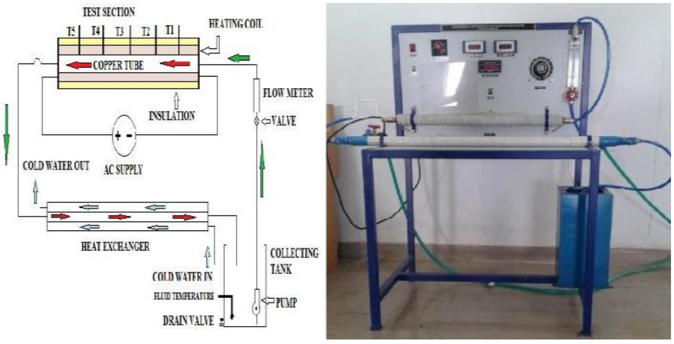

Fig. 3. Schematic View of Experimental Setup

The cold water was available with the temperature range: 28-30^{0}C and this was the local atmospheric temperature of the Mysore, India during night time of March- April. The hot water was supplied from the hot water tank at an approximated temperature of 50-52 ^{0}C with the help of the centrifugal pump. The hot water was produced with the help of the submersion Nichrome heater. Here in the heating element it consist a pipe, which is made up of copper and wounded by the nichrome wire. The ends of the nichrome wire are connected to the AC power supply. As the power is made supply to the nichrome wire, it generates the heat due to the resistance of current flow. The nichrome wire absorbs the generated heat and gets heated. With the test section experimental setup consist of a concentric tube heat exchanger to analyze the heat rejection rate of nanofluid. Here in the heat exchanger the outer pipe is made up of a galvanized iron (GI) and inner pipe made up of copper. Here the nanofluid made to flow in the inner copper tube and water to flow in the outer tube. The heat exchanger is equipped with valve it is ability to make to flow parallel and counter. Heat exchanger and the reservoir are made up of mild steel, which is coated with FCR coating to avoid corrosion.

The experimental setup with the above principle

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components also consist of measuring components such as flow meter having a maximum capacity 30 cc/sec to measure flow rate of working fluid supplied to the test section using the pump. It is fixed in between the reservoir output and entry section of the heating element. The pump is used to supply working fluid or nanofluid from reservoir to test section and heat exchanger.

IV. RESULTS AND DISCUSSIONS

The present experiment work is conducted at different flow rates of nanofluids, 10 cc, 20 cc, and 30 cc respectively.

1. The experimental result shows the density of Calcium carbonate (CaCO3) – Water nanofluid increases by raising the volume fraction of Calcium carbonate (CaCO3) nanoparticles in the base fluid.
2. The experimental results shows the specific heat of the nanofluid is decreases with increasing the volume fraction of nanoparticle.
3. The results shows that the thermal conductivity of the nanofluid is enhances with increasing the volume fraction of the nanoparticle. So thermal conductivity of CaCO3-Water nanofluid which is prepared by dispersing nanoparticle in base liquid enhance by increasing the volume fraction of CaCO3 nanoparticles in the base fluid. Thermal conductivity enhancement is depending on the metallic particle present in the nanoparticle. The Viscosity of the nanofluid is enhances with increasing the volume fraction of the nanoparticle. So Viscosity of CaCO3-Water nanofluid which is prepared by dispersing nanoparticle in base liquid enhance by increasing the volume fraction of CaCO3 nanoparticle in the base fluid.

A. Heat Absorption Rate of $CaCO_3$-Water Nanofluid for Different Volume Fraction

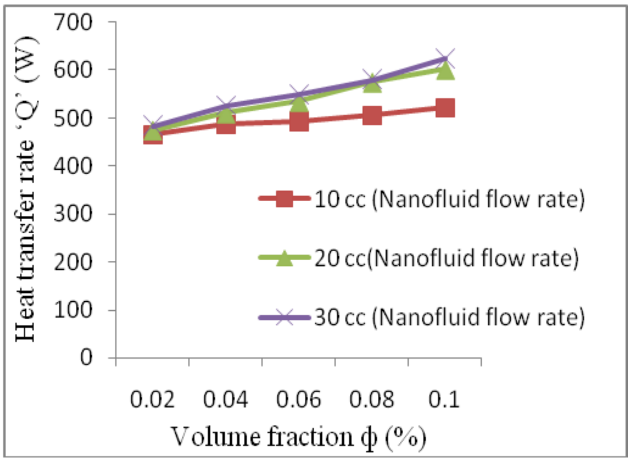

Fig 4.1 Heat Absorption Rate of $CaCO_3$ – Water Nanofluid for Different Volume Fraction

Fig 4.1 shows the variation Heat Absorption Rate of $CaCO_3$–Water nanofluid withrespect tothe volume fractio n of $CaCO_3$ nanoparticle. In the Fig. it is observed that the Heat Absorption Rate of the nanofluid is enhances with increasing the volume fraction of the nanoparticle. Since the thermal conductivity and film Coefficient of $CaCO_3$ nanofluid is increases by increasing the volume fraction results in increases of Heat absorption of nanofluid which is prepared by dispersing nanoparticle in base liquid by raising the volume fraction of $CaCO_3$ nanoparticle. And also conclude that the flow rate of nanofluid is increases the heat transfer rate is also increases.

B. Heat Transfer Coefficient of $CaCO_3$-Water Nanofluid for Different Volume Fraction

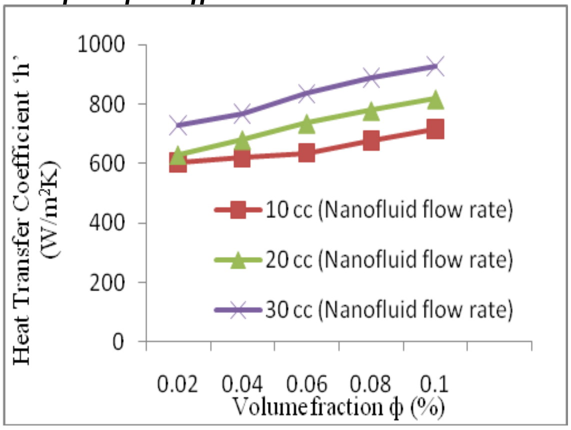

Fig 4.2 Heat Transfer Coefficient of $CaCO_3$ -Water Nanofluid for Different Volume Fraction

Fig.4.2 shows the variation Heat transfer coefficient of $CaCO_3$–Water nanofluid withrespect tothe volume fractio n of $CaCO_3$ nanoparticle. And it is observed that the Heat transfer coefficient of the nanofluid is enhances with increasing the volume fraction of the nanoparticle. Since the thermal conductivity and film Coefficient of $CaCO_3$ nanofluid is increases by increasing the volume fraction. And also conclude that the flow rate of nanofluid is increases the heat transfer coefficient is also increases.

C. Heat transfer coefficient of water and $CaCO_3$-Water Nanofluid for Different Volume Fraction at different flow rate

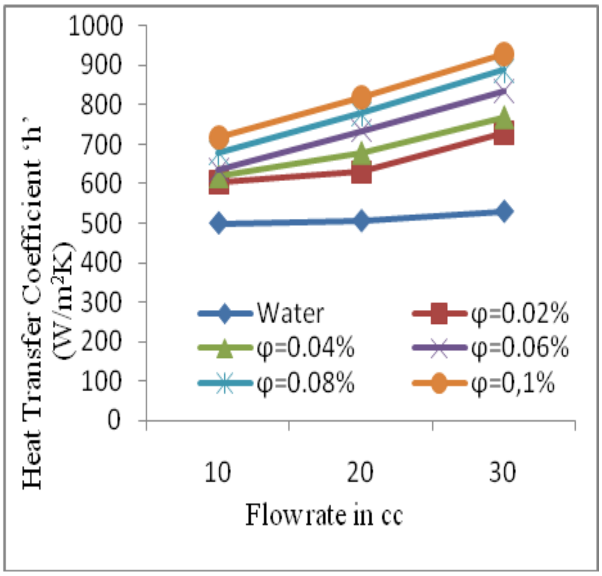

Fig 4.3 Heat transfer coefficient of water and $CaCO_3$– Water Nanofluid for Different volume fraction at different flow rate

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Fig 4.3 shows the variation heat transfer coefficient of water and $CaCO_3$-Water Nanofluid with respect to the Different Volume Fraction of $CaCO_3$ nanoparticle and different flow rate. In the above fig observe that the heat transfer coefficient is increases with increasing the volume fraction of the nanoparticle in the nanofluid. And it also shows that the heat transfer coefficient is increases with respect to the increasing flow rate of the nanofluid. Since thethermal conductivity and film Coefficient of $CaCO_3$ nanofluid is increases by increasing the volume fraction.

D.Overall heat transfer coefficient of $CaCO_3$ Water Nanofluid for Different Volume Fraction

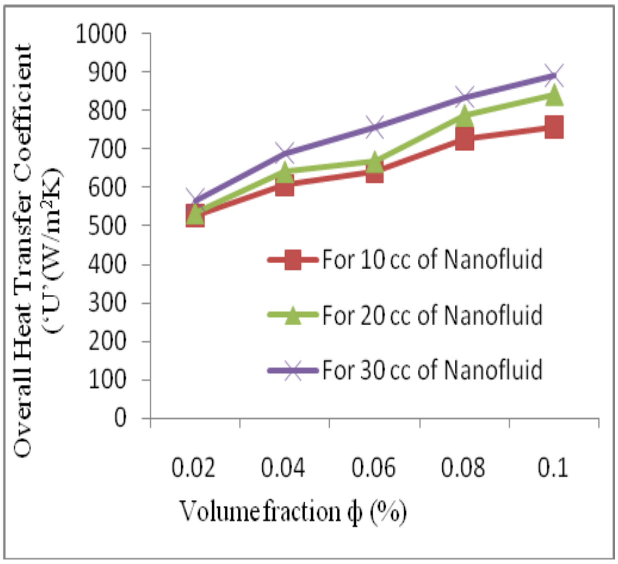

Fig 4.4 Overall heat transfer coefficient of $CaCO_3$ Water Nanofluid for Different Volume Fraction

Fig 4.4 shows the variation heat transfer rate of $CaCO_3$-Water Nanofluid with respect to the Different Volume Fraction of $CaCO_3$ nanoparticle. In the above fig observe that the Overall heat transfer coefficient is increases with increasing the volume fraction of the nanoparticles in the nanofluid. And it also shows that the overall heat transfer coefficient is increases with respect to the increasing flow rate of the nanofluid. Since the thermal conductivity a film Coefficient of $CaCO_3$ nanofluid is increases by increasing the volume fraction results in increases of Heat transfer of nanofluid which is prepared by dispersing nanoparticle in base liquid by raising the volume fraction of $CaCO_3$ nanoparticle.

E.Reynolds number (R_e) and Nusselt number (N_u) for different flow rates of nanofluid

The fig 4.5, 4.6 and 4.7 shows that the Reynolds number is directly proportional to the Nusselt number. The Reynolds number is decreases and the Nusselt number is also decreases. The flow rate of the nanofluids also shows that both Reynolds number and Nusselt number is decreases with increasing the flow rate of the nanofluid.

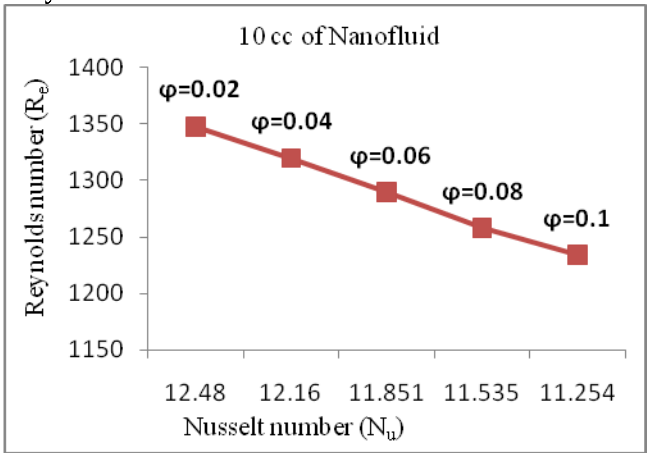

Fig 4.5 R_e Vs N_u for 10 cc of nanofluid at different volume fraction

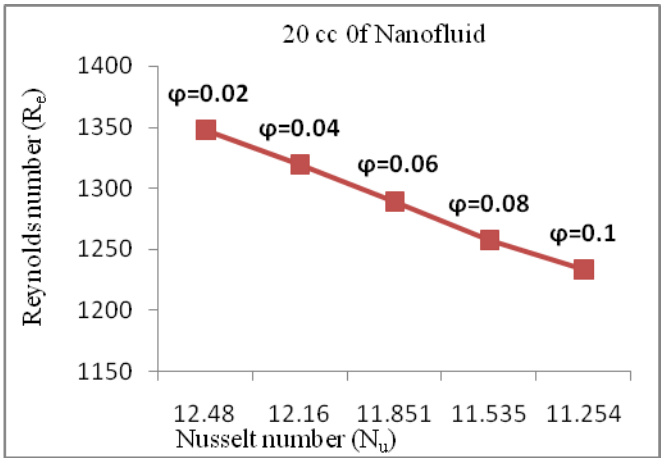

Fig 4.6 R_e Vs N_u for 20 cc of nanofluid at different Volume fraction

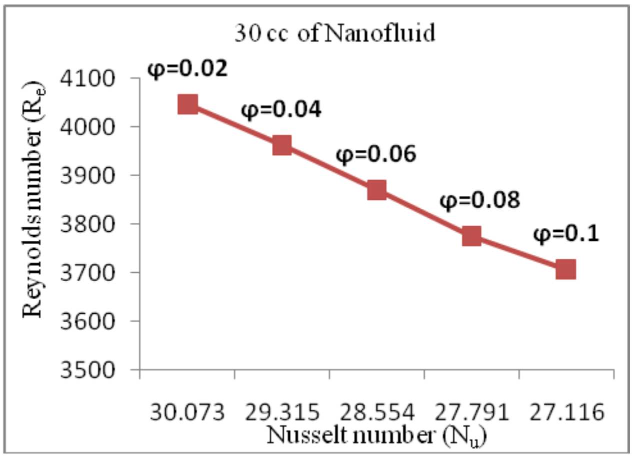

Fig 4.7 R_e Vs N_u for 30 cc of nanofluid at different volume fraction

V.CONCLUSION

In this work by observing the experimental results for Thermo physical properties of nano fluids and experimental results for test section and heat exchanger the following conclusions can be made.

- The homogeneous and stable nanofluid can be obtained by making mechanical stirring.

- Bulk density of nano particle is lesser than that of base fluid therefore there is increase in density of the nanofluid by raising the volume fraction.
- Viscosity of nanofluid increases by raising the volume fraction, because viscosity of nanofluid is depends only on the volume fraction of nano sized matters.
- Thermal conductivity of nanoparticlesis higher th an the base fluid hence as volume fraction increases in the range of 0.02–0.1% the fluid thermal conductivity of nanofluid increases minimum of 10 % to maximum of 40 % compare to the base fluid.
- In heat transfer coefficient of nanofluid increases by raising the volume fraction of nanoparticles, because the specific surface area of the dispersed $CaCO_3$ nanoparticles increases the availableheat transfer area for the fluid. And a higher thermal conductivity of CaCO3 nanoparticle makes the heat transfer coefficient of the nanofluid increases.
- Overall heat transfer coefficientof nanofluid incre ases by raising the volume fraction of nanoparticles because higher thermal conductivity of $CaCO_3$ nanoparticle make the overall heat transfer coefficient of the nanofluid and cold fluid increases by raising the volume fraction of Calcium carbonate nanoparticles in the range of 0.02-0.1 % volume fraction. The heat transfer coefficient of nanofluid is increases minimum of 12% to maximum of 57% compare to the base fluid.
- The Nusselt number is mainly depends upon Reynolds number. For increasing the flow rate of nanofluid the Reynolds number decreases and Nusselt number is also decreases.
- The flow rate increment which enhances the heat transfer rate, heat transfer coefficient and overall heat transfer coefficient and decreases the Nusselt number.

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