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Increasing Thermal Conductivity of a Heat Exchanger Using Copper Oxide Nano Fluids & Ethylene Glycol

B. Meganathan M.E, (Assistant Professor), Guru Prasanth.G, Manikandan.S, Pakeer Irfan Ahamed.A, Vishal.P.V.
Department of Mechanical Engineering, Velammal Institute of Technology, Chennai, India.

ABSTRACT
A Nano fluid is the evolving concept which is very rarely used in the many core industries. Nano fluids have found a great application in heat exchangers by increasing the thermal conductivity. We have aimed to increasing the heat transfer co-efficient by using copper oxide Nano fluid. The Nano particles are formed by using precipitation method and their fluids are formed by adding surfactants to the base fluid. The comparative study on the Heat exchanger is made by using the CuO Nano Fluid and Hot water. The analysis and the results shows that the overall heat transfer rate increases when subjected to Nano Fluids. The ethylene glycol fluid used along with copper oxide Nano fluid will offer resistance to fouling.
Key Words: Heat exchanger, Precipitation process, Copper oxide Nano particle, Surfactants, Copper oxide Nano fluid Overall heat transfer increased.

I. INTRODUCTION

Nano particles research is gaining increasing interest due to their unique properties, such as increased electrical conductivity, toughness and ductility, increased hardness and strength of metals and alloys, luminescent efficiency of semiconductors, formability of ceramics.

Heat exchanger is a device in which heat is transferred from one medium to another across a solid surface. Efficiency of heat exchanger depends on the type of flow. If the flow is laminar, heat transfer in the boundary of liquid flow will be maximum and heat in the center of flow will not be transmitted efficiently. But due to the surface roughness factor of the pipes used for flow, the flow of all liquids will be a transitional flow. This factor increases the heat transfer coefficient to some extent. If the flow is fully turbulent the heat concentrated in the center of liquid flow will spread equally and the temperature of fluid will be even throughout the flow. This will ensure constant heat transfer throughout the length of flow.

The idea behind development of Nano fluids 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 equipment. Nano fluids help in conserving heat energy and heat exchanger material. The important parameters which influence the heat transfer characteristics of Nano fluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of Nano fluids also depend on operating temperature of Nano fluids. Hence, the accurate measurement of temperature dependent properties of Nano fluids is essential. Thermo physical properties of Nano fluids are pre requisites for estimation of heat transfer coefficient and the Nusselt number.

Fouling is one the major factor which will reduce the heat transfer coefficient of a heat exchanger. Fouling is a dirt layer that gradually builds up on heat transfer surfaces, increases thermal resistance. If the flow is laminar or transitional, fouling on the inner surface of heat exchanger will be high. This factor requires the heat exchanger to be cleaned periodically. But when the fluid is enter into the exchanger along with ethylene glycol, it will vanish the dirt layer and cause resistance to fouling.

II. LITERATURE SURVEY

[3]Nano fluids have opened a new dimension in heat transfer process and heat transfer technology stands at the cross roads of miniaturization on one hand and astronomical increases in heat flux on the other. The recent investigations confirm the potential of Nano Fluids in enhancing heat transfer required for present age technology. The present investigation goes detailed into investigating the increase of thermal conductivity with temperature for Nano Fluids with water as base fluids and particles of Al2O3 or CuO as suspension materials.

[6] In the paper published by Kiyuel Kwak et.al. They have considered the rheological properties of Nano fluids made of CuO particles of 10-30 nm in length and ethylene glycol in conjunction with the thermal conductivity enhancement. When they examined using TEM,

individual CuO particles have the shape of prolate spheroid of the aspect ratio of 3 and most of the particles are under aggregated states even after sonication for a prolonged period. From the rheological property it has been found that the volume fraction at the dilute limit is 0.002, which is much smaller than the value based on the shape and size of individual particles due to aggregation of particles. In traditional heat transfer fluid such as water or ethylene glycol to increase thermal conductivity and therefore heat transfer performance. For example, when 0.3 volume percent of copper Nano particles are dispersed in ethylene glycol, one can observe about 40% of increase in thermal conductivity (Eastman and Choi, 1995). Metal oxides such as aluminum oxide or titanium oxide are also feasible Even though the amount of heat transfer increase is not as large as metal particles.

[9].In the journal "Experimental determination of thermal conductivity of three Nano fluids and development of new correlations" Published by Debendra K. Das Experimental investigations have been carried out for determining the thermal conductivity of three Nano Fluids containing aluminum oxide, copper oxide and zinc oxide nanoparticles dispersed in a base fluids of 60:40 (by mass) ethylene glycol and water mixture. Particle volumetric concentration tested was up to 10% and the temperature range of the experiments was from 298 to 363 K. The results show an increase in the thermal conductivity of Nano Fluids compared to the base fluids with an increasing volumetric concentration of nanoparticles. The thermal conductivity also increases substantially with an increase in temperature. Several existing models for thermal conductivity were compared with the experimental data obtained from these Nano Fluids, and they do not exhibit good agreement.

Praveen k.Namburu et.al. Published a journal about the behavior of Nano fluids when subjected from-35OC to 50OC to demonstrate their application in cold region. Due to the severe winter conditions, ethylene glycol or propylene glycol mixed with water in different volume percent ages are typically used to lower the aqueous freezing point of the heat transfer medium. Such heat transfer fluids are used in baseboard heaters in homes, heat exchangers, automobiles and in industrial plants in cold regions. At low temperatures, ethylene glycol mixtures have better heat transfer characteristics than propylene glycol mixtures. A 60% ethylene glycol and 40% water by weight fluids mixture is most commonly used in the sub-arctic and arctic regions of Alaska.

III. COPPER OXIDE NANO PARTICLE.

3.1 COPPER OXIDE

Copper oxide which appears as brownish – black powder with the formula CuO has a thermal conductivity higher than Aluminium (which is available in excess), gold and silver. The method of preparation of the Copper oxide Nano particle is also affordable and less complicated preparation. They can be reduced to metallic copper when exposed to hydrogen or carbon monoxide under high temperature.

Fig 3.1 Photographic view of Copper oxide Nano particle.

Chemical Properties:
Chemical symbol : CuO
Electronic Configuration : Cu [Ar] 3d104s1
Physical Properties:
Density : 6.31 g/cm3
Molar Mass : 79.55 g/mol
Thermal Properties:
Melting Point : 12010 C
Boiling Point : 20000 C

3.2 METHOD OF PREPARATION.

The various methods for preparing the Nano particles are

1.Sol gel method:

The method is used for the fabrication of metal oxides, especially the oxides of silicon and titanium. The process involves conversion of monomers into a colloidal solution (sol) that acts as the precursor for an integrated network (or gel) of either discrete particles or network polymers.

2.Hydrothermal method:

Hydrothermal processing can be defined as any heterogeneous reaction in the presence of aqueous solvents or mineralizes under high pressure and temperature conditions to dissolve and recrystallize (recover) materials that are relatively insoluble under ordinary conditions

3.Pyrolysis Method:

In the process of CO2 laser pyrolysis, the condensable products result from laser induced chemical reactions at the crossing point of the laser beam with the molecular flow of gas or vapor phase precursors

4.Laser ablation:

Laser ablation means the removal of material from a surface by means of laser irradiation. The term "laser ablation" is used to emphasize the non-equilibrium vapor/plasma conditions created at the surface by intense laser pulse, to distinguish from "laser evaporation," which is heating and evaporation of material in condition of thermodynamic equilibrium.

5.Precipitation method:

In this process the Nano particles are prepared by precipitation caused by sodium hydroxide in Copper nitrate which is formed by dissolving pure Copper material in Nitric acid. The whole Process is explained below.

3.3 Requirements.

The following are the materials that are required for the production of 5gms of Copper oxide Nano particle.

Copper wire : 3.33 Gms
Nitric acid : 20 ml
Distilled Water : 500 ml
NaOH pellets : 10% in distilled water
Filter paper
Magnetic stirrer
Ethylene glycol
Crucible
Heat exchanger setup

3.4 Procedure.

The method of preparation which is used for the preparation of Nano fluid is by Precipitation method. In this method the pure copper wire of 3.33gm were taken and was added to 20 ml of nitric acid. Constant stirring is done for about 10 minutes till the copper wire gets dissolved in the nitric acid forming Copper Nitrate

$$Cu + 2\,HNO_3 = Cu\,(NO_3)_2 + 2\,H^+$$

Fig 3.4.1 Dissolution of Copper in Nitric acid.

A greenish brown color solution is obtained after stirring of the dissolved copper wire in the nitric acid. A 200 ml of distilled water is added to the greenish brown color solution. The solution will turn into blue color after the addition of 200 ml of distilled water.

10 grams of Sodium Hydroxide pellets is added to 100 ml of distilled water i.e. 10% of sodium hydroxide in distilled water. Continuous stirring is carried out till the pellets get dissolved in the distilled water. The dissolved sodium hydroxide is mixed with the copper nitrate solution in drops

$$Cu\,(NO_3)_2 + 2\,NaOH = Cu\,(OH)_2 + 2\,NaNO_3$$

Fig 3.4.2. Addition of NaOH in Cu $(NO_3)_2$ using Magnetic Stirrer.

A continuous stirring is made with the help of magnetic stirrer. The solution turns into light blue color along with the precipitation formed by 10% sodium hydroxide. After the 100 ml NaOH solution is mixed with the copper light blue solution the solution is filtered using the filter paper and the particles is collected in the filter paper.

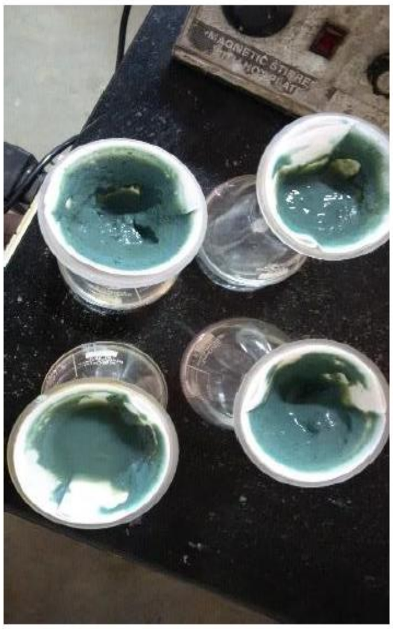

Fig 3.4.3. The Precipitate got after the stirring.

The filter paper is made to dry and then the copper oxide Nano particles is removed from the filter paper and got in the semi-solid and power form. The Whole particles are taken in the crucible and crushed.

Crushed Nano particle is sintered to 6000C in the furnace for about an hour and then left to cool inside the furnace till the temperature reaches 30OC. The specimen is tested for the presence of Copper oxide using X-Ray diffraction method and the test for the Nano particle is found using the Scanning Electron Microscope. The thermal analysis is found using the TG/DTA method.

$$Cu\ (OH)_2 = CuO + H_2O$$

(A) (B)

`Fig 3.4.4. The Nano particles got before Sintering process (A) and after sintering process (B)**

IV. COPPER OXIDE NANO FLUID

4.1 INTRODUCTION

The idea behind development of Nano fluids 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 equipment. Nano fluids help in conserving heat energy and heat exchanger material. The important parameters which influence the heat transfer characteristics of Nano fluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of Nano fluids also depend on operating temperature of Nano fluids. Hence, the accurate measurement of temperature dependent properties of Nano fluids is essential. Thermo physical properties of Nano fluids are pre requisites for estimation of heat transfer coefficient and the Nusselt number.

The amount of CuO nanoparticles required for preparation of Nano fluids is calculated using the law of mixture formula. A sensitive balance with a 0.1 mg resolution is used to weigh the CuO Nanoparticles very accurately.A stable Nano fluids
with uniform particle dispersion is required and the same is used for measuring the thermo physical properties of Nano fluids

4.2 METHODS OF PREPARATION.

There are three methods of preparation of Nano fluids. They are

4.2.1 By mixing of Nano material to the base liquid.

In this method, the nanoparticles are directly mixed in the base liquid and thoroughly stirred. Nano fluids prepared in this method give poor suspension stability, because the nanoparticles settle down due to gravity, after a few minutes of Nano fluids reparation. The time of particle settlement depends on the type of nanoparticles used, density and viscosity properties of the host fluids.

4.2.2. By acid treatment of base fluids.

The PH value of the base fluid can be lowered by adding a suitable acid to it. A stable Nano fluid with uniform particle dispersion can be prepared by mixing nanoparticles in an acid treated base fluid. But acid treated Nano fluids may cause corrosion on the pipe wall material with prolonged usage of Nano fluids. Hence acid treated base fluids are not preferred for preparation of Nano fluids even though formation of stable Nano fluids is possible with such base fluids.

4.2.3. By adding surfactants to the base fluids.

In this method a small amount of suitable surfactant, generally one-tenth of mass of nanoparticles, is added to the base fluid and stirred continuously for few hours. Nano fluids prepared using surfactants will give a stable suspension with uniform particle dispersion in the host liquid. The nanoparticles remain in suspension state for a long time without settling down at the bottom of the container. After estimating the amount of nanoparticles required for preparation of CuO Nano fluids for a given volume concentration, nanoparticles are mixed in the base fluid of water-Propylene glycol mixture. In the present investigation, neither surfactants nor acid are added in the CuO Nano fluids, because with the addition of surfactants the thermo physical properties of Nano fluids are affected. Addition of acid may damage the tube material because corrosion takes place after a few days with the prolonged usage of such Nano fluids in practical applications.

Copper oxide Nano fluids of five different volume concentrations in range of 0.025, 0.1, 0.4, 0.8, and 1.25% are prepared for measuring the temperature dependent thermal conductivity and viscosity of all the Nano fluids concentration considered in the present work. Normally agglomeration of nanoparticles takes place when nanoparticles are suspended in the base fluid. All the test samples of CuO Nano fluids used subsequently for estimation of their properties were subjected to magnetic stirring process followed by ultrasonic vibration for about 5 hours. The CuO Nano fluids samples thus prepared are kept for observation and no particle settlement was observed at the bottom of the flask containing CuO Nano fluids even after four hours. In the present experiments with CuO Nano fluids, the time taken to complete the experiment for property estimation is less than the time required for first sedimentation to take place and hence surfactants are not mixed in the CuO Nano fluids. The CuO Nano fluids prepared are assumed to be an isentropic, Newtonian in behavior and their thermo physical properties are uniform and constant with time all through the fluid sample. This prepared fluid is sent into the heat exchanger and then the heat transfer co efficient is calculated.

4.3 FORMULA USED FOR CALCULATION

Overall heat transfer coefficient, U

Performance of heat exchanger is evaluated normally by the overall heat transfer coefficient "U" that is defined by the equation:

$$Q = U \times A \times LMTD$$

Where,
Q = Heat exchanged, KW
A= Heat transfer surface area, m^2
LMTD= Log mean temperature difference in °C
U = Overall heat transfer coefficient, W/m^2K

1. Heat transferred in hot fluid, $Q_h = W x C_{ph} \times (T_i - T_o)$
2. Heat trans. in cold fluid $Q_c = W \times C_{pc} \times (t_o - t_i)$
3. Heat transfer coefficient, $h_i = q/\Delta T (KW/(m^2K))$
4. Heat flux $(q) = Q/A$ (KW/m^2)
5. Temperature range of hot fluid $\Delta T = T_i - T_o$ (K)
6. Temperature range of cold fluid $\Delta t = t_i - t_o$ (K)
7. Effectiveness, $\epsilon = (t_o - t_i) / (T_i - T_o)$
8. $LMTD = ((T_i - t_o) / (T_o - t_i)) / \ln((T_i - t_o) / (T_o - t_i))$
9. Reynolds number $(Re) = \rho VD / \mu$

Where,
ρ= Density of the fluid (kg/m^3)
μ= Dynamic viscosity (kg/(m-s))
V = Mean velocity of fluid (m/s)
D = Diameter of pipe (m)

10. Nusselt number $(Nu) = 0.023 \Pr^n Re^{(4/5)}$
Where, Pr = Prandtl number

11. Entrance length $L_e = 1.359D(Re)^{1/4} \approx 10D = 0.3m$

V. V. RESULTS AND CONCLUSION.

5.1 Scanning Electron Microscope Test.

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample

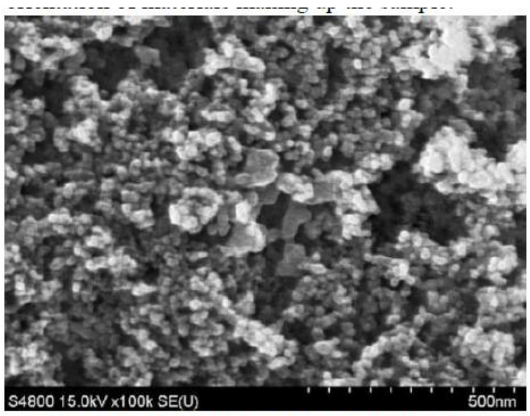

Fig 5.1. SEM analysis of CuO Nano Particles.

5.2 X-Ray diffractometer.

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. The analyzed material is finely ground, homogenized, and average bulk composition is determined

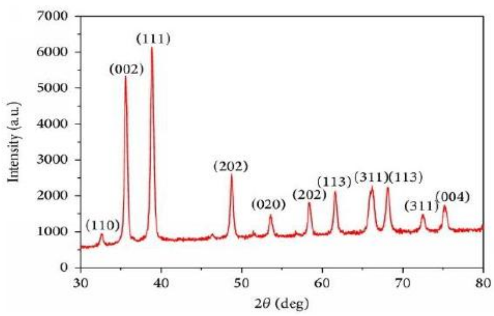

Fig 5.2. XRD analysis of CuO Nano Particles.

5.3 Thermal Analysis.

The prepared nano fluid is passed into the heat exchanger as a replacement of the cold water and their thermal analysis is shown below:

5.3.1.Reynolds Number Vs Heat transfer coefficient

In this study, first we took the performance test of counterflow heat exchanger without twisted tape(TAT) and then with twisted tape(TAT). Both the results are compared and shown in the graph (fig5.0). The graph clearly shows that, when the flow is subjected to the twisted tape, the heat transfer coefficient (hi) increases. This is because, the twisted tape will increase the reynolds number(Re) of flow, when the reynolds number(Re) increases, heat transfer coefficient also increases simultaneously

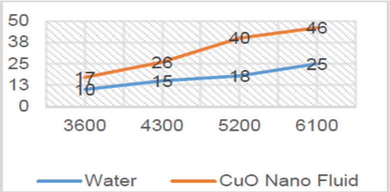

Fig 5.3.1. Reynolds Number(Re) Vs hi (KW/m^{2}K)

5.3.2. Heat transfer (Q) Vs Temperature of fluids

The temperature of fluid at inlet and outlet of both the pipes are compared with the heat transfer rate taking nano fluid in the outlet pipe and hot water in the inlet pipe and the results are shown.

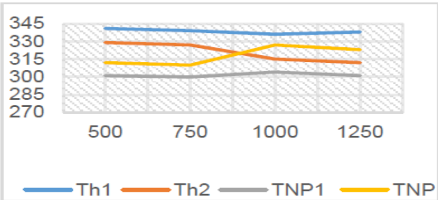

Fig 5.3.2. Heat transfer (Q), vs Temperature of fluids in (k)

5.3.3. Length of pipe (L) Vs Heat transfer rate (Q)

As said before, If the heat transfer length increases it will simultaneously increase the performance of heat exchanger. As we know, the length of pipe is directly proportional to heat transfer (Q), when the length of fluid flow increases, heat transfer rate also increases. The fig 7.0. clearly shows the heat transfer rate for different length of pipes we calculated.

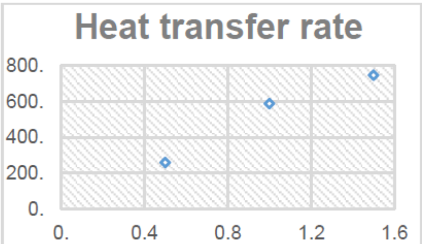

Fig 5.3.3. Length of pipe in (m) vs Heat transfer rate (Q)

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