Fabrication and performance improvement of heat exchanger using wire coil inserts with hybrid nano particles*

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ABSTRACT

Keywords:
Temperature,
Heat Exchanger,
Fluid Flow,
Nanoparticles,
Inserts.

In the last decade, a number of investigations have been conducted to identify the possible mechanisms that contribute to the enhanced effective thermal conductivity of nano particle suspensions [Nano fluids]. The thermal performance of heat exchangers depends on a variety of factors including geometric, kinetic and spatial aspects related to the net heat transfer rate encountered between the heat transfer sections and flow of fluids.

A laminar flow convective heat transfer of Al_2O_3 - Cu + Water nanofluids flowing through a horizontal tube heat exchanger pipes with and without coil inserts were experimented. For this purpose, Al_2O_3 - Cu nano particles were synthesized, characterized and dispersed in distilled water to form stable suspension containing 0.1% volume concentration of nanoparticles. Two wire coil inserts were made of Cu was introduced in the heat exchanger tubes to increase the heat transfer performance of nano fluid flowing in it. The performance of nano fluid in heat exchanger with and without wire coil inserts were calculated and reported.

1. Introduction

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. There are three primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium due to the fact that the average temperature difference along any unit length is greater.

In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing Resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. The driving temperature across the heat transfer surface varies with position, but an appropriate

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mean temperature can be defined. In most simple systems this is the "log mean temperature difference" (LMTD). Sometimes direct knowledge of the LMTD is not available and the NTU method is used. A device used to transfer heat from a fluid flowing on one side of a barrier to another fluid (or fluids) flowing on the other side of the barrier. When used to accomplish simultaneous heat transfer and mass transfer, heat exchangers become special equipment types, often known by other names. When fired directly by a combustion process, they become furnaces, boilers, heaters, tube-still heaters, and engines. If there is a change in phase, in any one of the flowing fluids — the condensation of steam to water. Heat exchangers may be so designed that chemical reactions or energy-generation processes can be carried out within them. The exchanger then becomes an integral part of the reaction system and may be known, for example, as a nuclear reactor, catalytic reactor, or polymerizer.

Heat exchangers are normally used only for the transfer and useful elimination or recovery of heat without an accompanying phase change. The fluids on either side of the barrier are usually liquids, but they may also be gases such as steam, air, or hydrocarbon vapours or they may be liquid metals such as sodium or mercury. Fused salts are also used as heat-exchanger fluids in some applications. Most often the barrier between the fluids is a metal wall such as that of a tube or pipe. However, it can be fabricated from flat metal plate or from graphite, plastic, or other corrosion-resistant materials of construction. Heat exchangers find wide application in the chemical process industries, including petroleum refining and petrochemical processing; in the food industry, for example; in aircraft and space vehicles; and in the field of cryogenics for the low-temperature Separation of gases. Heat exchangers are the workhorses of the entire field of heating, ventilating, air-conditioning, and refrigeration.

Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1-100nm) suspended within them. These particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant (1). Serrano et al. (2) provided excellent examples of nanometer in comparison with millimeter and micrometer to understand clearly as can be seen in Fig. In the past few decades, rapid advances in nanotechnology have led to emerging of new generation of heat transfer fluids called “nanofluids”. Nanofluids are defined as suspension of nanoparticles in a basefluid. Some typical nanofluids are ethylene glycol based copper nanofluids; water based copper oxide nanofluids, etc. Nanofluids are dilute suspensions of functionalized nanoparticles composite materials developed about a decade ago with the specific aim of increasing the thermal conductivity of heat transfer fluids, which have now evolved into a promising nanotechnological area. Such thermal nanofluids for heat transfer applications represent a class of its own difference from conventional colloids for other applications. Compared to conventional solid-liquid suspensions for heat transfer intensifications, nanofluids possess the flow.

2. Nanoparticles Introduction

In nanotechnology, a particle is defined as a small object that behaves as a whole unit in terms of its transport and properties. It is further classified according to size: in terms of diameter, fine particles cover a range between 100 and 2500 nanometers, while ultrafine particles, on the other hand, are sized between 1 and 100 nanometers. Similar to ultrafine particles, nanoparticles are sized between 1 and 100 nanometers. Nanoparticles may or may not exhibit size-related properties that differ significantly from those observed in fine particles or bulk materials. Although the size of most molecules would fit into the above outline, individual molecules are usually not referred to as nanoparticles.

Nano clusters have at least one dimension between 1 and 10 nanometers and a narrow size distribution. Nano powers are agglomerates of ultrafine particles, nanoparticles, or Nano clusters. Nanometer-sized single crystals, or single-domain ultrafine particles, are often referred to as nanocrystals. Nanoparticle research is currently an area of intense scientific interest due to a wide variety of potential applications in biomedical, optical and electronic fields.

3. Definition

There is no accepted international definition of a nanoparticle, but one given in the new PAS71 document developed in the UK is: "A particle having one or more dimensions of the order of 100nm or less".

- There is a note associated with this definition: "Novel properties that differentiate nanoparticles from the bulk material typically develop at a critical length scale of under 100nm".

- The physics of nanoparticles mean that their properties are different from the properties of the bulk material.

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4. Why We Use Nanoparticles

- The basic concept of dispersing solid particles in fluids to enhance thermal conductivity can be traced back to Maxwell in the 19th Century.
- Studies of thermal conductivity of suspensions have been confined to mm- or mm size particles.
- The major challenge is the rapid settling of these particles in fluids.
- Nanoparticles stay suspended much longer than micro-particles and, if below a threshold level and/or enhanced with surfactants/ stabilizers, remain in suspension almost indefinitely. Furthermore, the surface area per unit volume of nanoparticles is much larger (million times) than that of micro particles (the number of surface atoms per unit of interior atoms of nanoparticles, is very large).
- These properties can be utilized to develop stable suspensions with enhanced flow, heat-transfer, and other characteristics.

5. Applications of Nanoparticles

- Application of nanoparticles in electrochemical sensors and biosensors.
- Cyclodextrins in targeting.
- Application of nanoparticles for the delivery of drugs to the brain
- Application of nanoparticles in the photocatalytic degradation of water pollutants
- Application of nanoparticles for the enhancement of latent fingerprints
- Application of nanoparticles in domestic refrigerators
- Recent developments in the application of nanoparticles prepared from w/o micro emulsions in heterogeneous catalysis.
- Medical application of functionalized magnetic nanoparticles. Fig. -1.

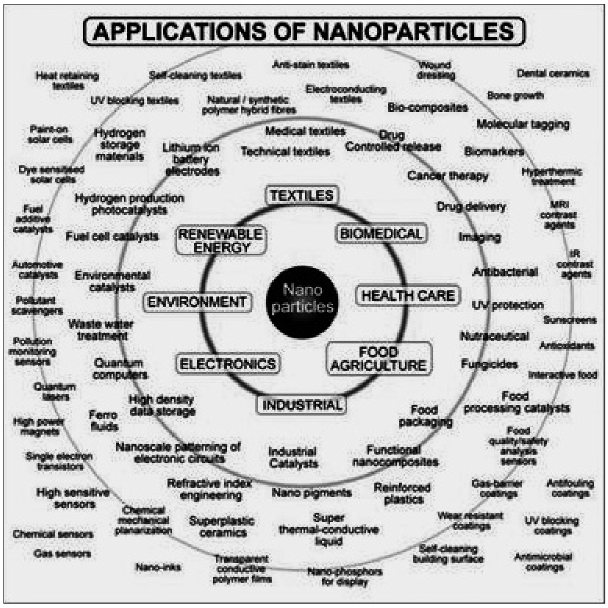

Fig. 1. Applications nano particles.

6. Literature Survey

- **A. E. Kabeel, T. Abou El Maaty and Y. El Samadony," The effect of using nano-particles on corrugated plate heat exchanger performance", Applied Thermal Engineering, Volume 52, Issue 1, 5 April 2013, Pages 221–229.**

The application of nano-fluids is thought to have a strong potential for enhancing the heat transfer characteristics of the corrugated plate heat exchanger-PHE. The corrugated PHE is one of the most versatile and wide using types of heat exchangers. In this study, an experimental test loop has been constructed to study the PHE thermal characteristics; heat transfer coefficient, effectiveness, transmitted power and pressure drop at different concentrated volume fractions of AL_2O_3 nano-material (1–4%) in pure liquid water as a base fluid. The measured heat transfer coefficient results were compared and verified against a theoretical model, a reasonable consistence was noticed. A pronounced increase in both the heat transfer coefficient and the transmitted power was observed by increasing the nano-material concentration. A further research work for the same field is required to remove the inauspicious between different researchers.

- **IndranilGhosh, Sunil Kumar Sarangi & Prasanta Kumar Das"Synthesis of multistream heat exchangers by thermally linked two-stream modules" International Journal of Heat and Mass Transfer, Volume 53, Issues 5–6, February 2010, Pages 1070–1078.**

A simple yet very efficient algorithm has been devised for the analysis of multistream heat exchangers. In this approach, an n-stream heat exchanger is considered as a stack of (n − 1) two-stream exchangers separated by diabatic partitions. Starting from the analysis of the basic two-stream units the entire heat exchanger has been designed non-iteratively.

- **Ewa Piotrowska and AndrzejChochowski" Application of parametric identification methods for the analysis of the heat exchanger dynamics" International Journal of Heat and Mass Transfer, Volume 55, Issues 23–24,November 2012, Pages 7109–7118.**

The investigation of heat exchanger dynamics has been carried out. The three kinds of exchangers have been taken into consideration: the low power plate heat exchanger, the high power industrial heat exchanger and the model of heat exchanger. The dynamics of the examined exchangers has been analyzed using the parametric identification methods and their implementation in MATLAB.

- **Srbislav B. Genic, Branislav M. Jacimovic, Marko S. Jaric and Nikola J. Budimir," Analysis of fouling factor in district heating heat exchangers with parallel helical tube coils", International Journal of Heat and Mass Transfer, Volume 57, Issue 1, 15 January 2013, Pages 9–15.**

This paper presents the results of measurements of thermal performance of 8 heat exchangers with parallel helical coils. Measurements were conducted in substations in 2 district heating systems The values of fouling resistances were found to be slightly lesser than usual values for typical shell-and-tube heat exchangers with straight tubes. Analysis of thermal performance of heat exchangers showed that the shell-side heat transfer coefficient had been calculated using the correlation based on hydraulic diameter.

- **Salam K. Al-Dawery, Ayham M. Alrahawi and Khalid M. Al-Zobai, "Dynamic modeling and control of plate heat exchanger", International Journal of Heat and Mass Transfer, Vol. 55, Issues 23–24, November 2012, Pages 6873–6880.**

A general model has been developed to suggest the transient responses of a plate heat exchanger. The predicted and experimental step responses of the system have been analyzed using the frequency response analysis. The results indicate that the system is represented by a first order lag and dead time. A closed fit between the simulated and experimental data has been discussed.

- **Yonghua You, AiwuFan, Suyi Huang and Wei Liu," Numerical modeling and experimental validation of heat transfer and flow resistance on the shell side of a shell-and-tube heat exchanger with flower baffles", International Journal of Heat and Mass Transfer, Volume 55, Issues 25–26, December 2012, Pages 7561–7569.**

In the present study, a numerical model based on the concepts of porosity and permeability is developed to obtain the shell-side thermal hydraulic performances. In this model, the distributed resistances and heat sources, as well as the distributed turbulence kinetic energy and its dissipation rate are introduced to account for the impacts of tubes on the fluid. With this model, the velocity and temperature fields, together with the distribution of convective heat transfer coefficient, are obtained and presented to help analyzing the underlying mechanism of shell-side thermal augmentation. The present work shows that this model is economic and effective in the thermal hydraulic design and analysis of a whole device.

- **Sofia G. Mavridou and Demetri G. Bouris, "Numerical evaluation of a heat exchanger with inline tubes of different size for reduced fouling rates", International Journal of Heat and Mass Transfer, Volume 55, Issues 19–20, September 2012, Pages 5185–5195.**

This paper describes the numerical evaluation of a novel cross flow tube bundle heat exchanger that combines tubes of different diameter in an inline arrangement for the purpose of reducing gas side particulate fouling rates while preserving acceptable levels of heat transfer and pressure drop performance. Three arrangements are compared: a common inline tube bundle heat exchanger with cylinders of equal diameter and two other arrangements that consist of alternately placed cylinders with a diameter ratio of d/D = 0.5, at two different transverse spacings. Numerical calculations are performed in order to study heat transfer, pressure drop and fouling rates from flue gases with suspended ash particles.

- **HumaadIjaz, Uma M. K. Ati and Vladimir Mahalec," Heat exchanger network simulation, data reconciliation & optimization", Applied Thermal Engineering, Volume 52, Issue 2, 15 April 2013, Pages 328–335.**

This work introduces new heat exchanger network (HEN) model for networks containing single phase and two phase exchangers. Rigorous simulation of HEN performance requires sequential solutions of two sets of linear equations: mass balances and energy balances which are linear in temperatures. This enables data reconciliation via QR factorization as sequential solution of linear mass and energy balances.

- **Z. Ismail and R. Karim,"Laminar flow heat transfer of dilute viscoelastic solutions in flattened tube heat exchangers", Applied Thermal Engineering, Volume 39, June 2012, Pages 171–178.**

Heat transfer studies of non-Newtonian liquids in non-circular exchangers are not many, and much less on viscoelastic liquids in flattened tubes. Heat transfer studies of dilute viscoelastic liquids in flattened tubes with 0.635 cm and 1.27cm original diameters and 50cm–76cm lengths and aspect ratios ranging from 1.4 to 5.7 were carried out. Five flattened tube heat exchangers with four thermocouples soldered at regular intervals on the outside wall were placed in turn in the experimental circuit to determine the heat transfer coefficients. Hot water was used as the heating medium; and dilute solutions of polyacrylamide in water and in water/glycerol mixtures were used as the viscoelastic solutions. Heat transfer increase as a result of flattening the tubes could be 101% higher while the effect due to secondary flow had a maximum additional increase compared to that for water of 40% for the 250ppm solution at an aspect ratio of 1.6. Corresponding values for the 500ppm solutions in water and in water/glycerol mixture were about 53% and 55% respectively at an aspect ratio of 1.8. Increased polymer concentration had only a marginal effect on heat transfer performance.

7. Overview of Nanofluid

- Nanofluid is a suspension containing nano-scaled metallic or non-metallic totally suspended particles which are stabled within a solvent fluid (the heating medium).
- The nano-fluids are suspensions of solid nano-particles with sizes typically of 1-100 nm in traditional liquids such as water, glycol and oils.
- These solid-liquid composites are very stable and show higher thermal conductivity and higher convective heat transfer performance than traditional liquids.
- A nanofluid is a new type of heat transfer fluid that operates via nanoparticles suspended in a conventional host liquid (Choi 1995), nanorefrigerant is one kind of nanofluid, and the host fluid of nanorefrigerant is refrigerant.

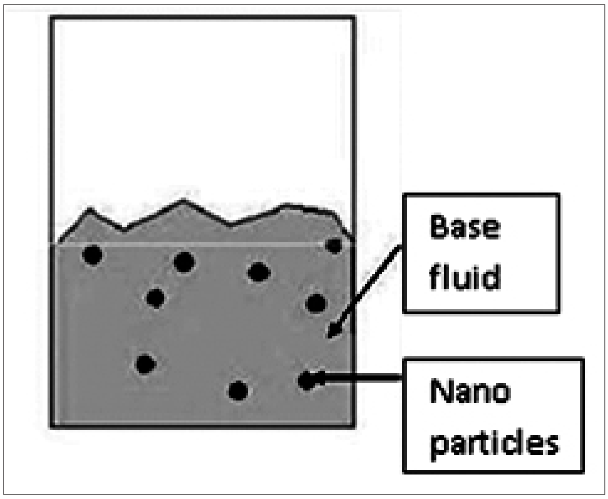

Fig. 2. Nano fluid.

Nanoparticle materials include:

- Oxide ceramics – Al_2O_3, CuO
- Metal carbides – SiC
- Nitrides – AlN, SiN
- Metals – Al, Cu
- Nonmetals – Graphite, carbon nanotubes
- Layered – Al + Al_2O_3, Cu + C
- Functionalized nanoparticles

Base fluids include:

- Water
- Ethylene- or tri-ethylene-glycols and other coolants
- Mineral Oil and other lubricants
- Polymer solutions.

8. Synthesis of Nanolubricant

Nanofluids are defined as a liquid in which particles of nanometer dimensions are suspended. Here we have used Al_2O_3 + Cu as nanoparticles while distilled water is used as a base fluid. The reason for choosing Al_2O_3 + Cu as nanoparticles is that they have excellent chemical and physical stability and are also commercially cheap. The advantage of distilled water is cheaper and easily available. Nanofluids with different concentrations were prepared for the experiments such as Al_2O_3 + Cu (85:15), (90:10) and (95:05). Nanoparticles of the required amount and base fluid were mixed together. Dispersants were not used to stabilize the suspension as the addition of dispersants may have influenced the heat transfer characteristics of the nanofluid.

The mixing of Al_2O_3 + Cu nanoparticle and distilled water was done by ultrasonic bathing method. This method works on the principle of sound wave propagation. This system consists of one container, two 500ml conical flask, one temperature and time indicator, water, separate stands for holding the flasks. First of all we have taken very low volume concentration of nanoparticle as 0.01% and on the basis of this we got the mass fraction of Al_2O_3 + Cu.

Fig. 3. Setup of ultrasonic bath system.

9. Working Steps

- Both flask is cleaned neatly and make it dry.
- Both the flask is filled with 500 ml of base liquid.
- 0.5gm of Al_2O_3 + Cu is added in each flask.
- Now ultrasonic bath system container is filled with water up to indicated level (approx 6lits).
- Flasks in the container (on the steel net covering the inside surface of container) is put and hold the flask neck with the help of stands for its rigidity.
- Now switch on the system and set the time as 30 min and temp at 30°c.
- After 30 min. flask are taken out and make it stirrer with the help of magnetic stirrer.
- This stirrer helps in proper mixing of particle and distilled water
- Now without taking out the stirrer again do the ultrasonic bathing of solution for next 30 min at 30°c temp. This process is repeated until the particle is mixed properly.

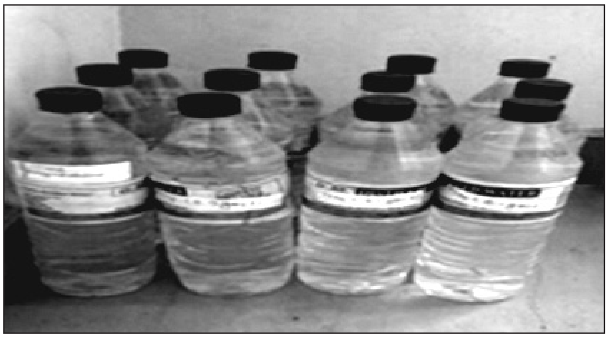

Fig. 4. Distilled water for synthesis.

In this, the mixture takes place due to the propagation of sound wave from water to flask and flask to water. Thus we got the proper mixture of Al_2O_3 + Cu nanoparticle with distilled water by ultrasonic bath process in 1 hour 30 min. The same procedure was for different ratios.

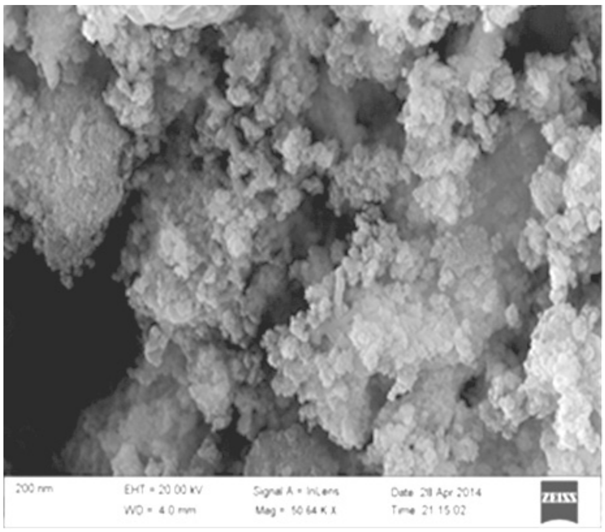

Fig. 5. SEM test report 1.

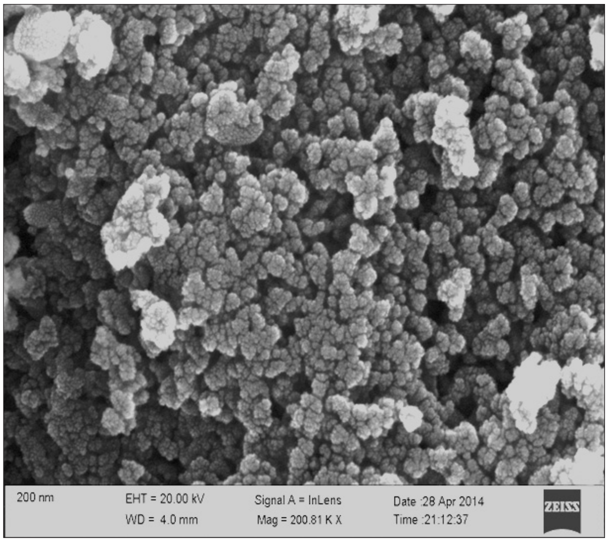

Fig. 6. SEM test report 2.

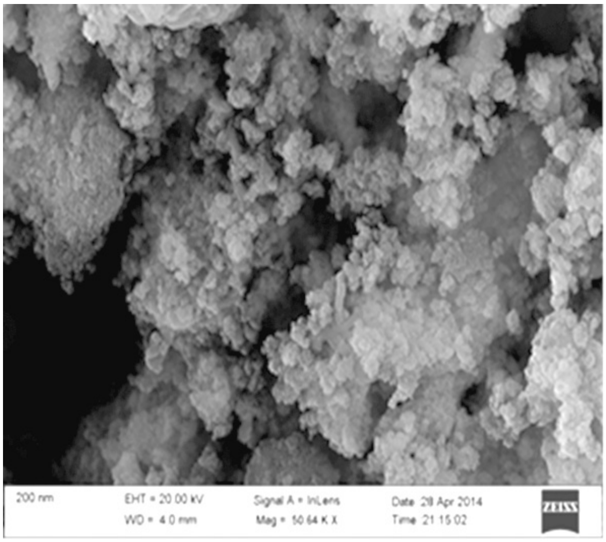

Fig. 7. SEM test report 3.

10. Heat Exchangers

Types of Heat Exchangers: Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required.

Tube Heat Exchangers: Tube diameter: Using a small tube diameter makes the heat exchanger both economical and compact. However, it is more likely for the heat exchanger to foul up faster and the small size makes mechanical cleaning of the fouling difficult. To prevail over the fouling and cleaning problems, larger tube diameters can be used. Thus to determine the tube diameter, the available space, cost and the fouling nature of the fluids must be considered

Plate Heat Exchanger: Another type of heat exchanger is the plate heat exchanger. One is composed of multiple, thin, slightly separated plates that have very large surface areas and fluid flow passages for heat transfer. This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical.

Plate and Shell Heat Exchanger: A third type of heat exchanger is a plate and shell heat exchanger, which combines plate heat exchanger with shell and tube heat exchanger technologies. The heart of the heat exchanger contains a fully welded circular plate pack made by pressing and cutting round plates and welding them together. Nozzles carry flow in and out of the platepack (the 'Plate side' flowpath).The fully welded platepack is assembled into an outer shell that creates a second flowpath(the 'Shell side'). Plate and shell technology offers high heat transfer, high pressure, high operating temperature, compact size, low fouling and close approach temperature.

Adiabatic Wheel Heat Exchanger: A fourth type of heat exchanger uses an intermediate fluid or solid store to hold heat, which is then moved to the other side of the heat exchanger to be released. Two examples of this are adiabatic wheels, which consist of a large wheel with fine threads rotating through the hot and cold fluids, and fluid heat exchangers.

Plate Fin Heat Exchanger: This type of heat exchanger uses "sandwiched" passages containing fins to increase the affectivity of the unit. The designs include cross flow and counter flow coupled with various fin configurations such as straight fins, offset fins and wavy fins.

Pillow Plate Heat Exchanger: The pillow plate is constructed using a thin sheet of metal spot-welded to the surface of another thicker sheet of metal. The thin plate is welded in a regular pattern of dots or with a serpentine pattern of weld lines. After welding the enclosed space is pressurized with sufficient force to cause the thin metal to bulge out around the welds, providing a space for heat exchanger liquids to flow, and creating a characteristic appearance of a swelled pillow formed out of metal.

Fluid Heat Exchangers: This is a heat exchanger with a gas passing upwards through a shower of fluid (often water), and the fluid is then taken elsewhere before being cooled. This is commonly used for cooling gases whilst also removing certain impurities, thus solving two problems at once. It is widely used in espresso machines as an energy-saving method of cooling super-heated water to use in the extraction of espresso.

Concentric Tube Heat Exchangers: The concentric tube heat exchanger consists of two tubes that are concentrically arranged. One of the fluid (either hot or cold fluid) flows through the tube and the other through the annulus. For a CTHX, two types of flow arrangements are possible - co-current and counter-current flow. In the parallel or co-current arrangement, the flow direction of the hot fluid will be the same as that of the cold fluid. In the counter-current arrangement, the flow directions of the hot and the cold fluids are opposite to each other.

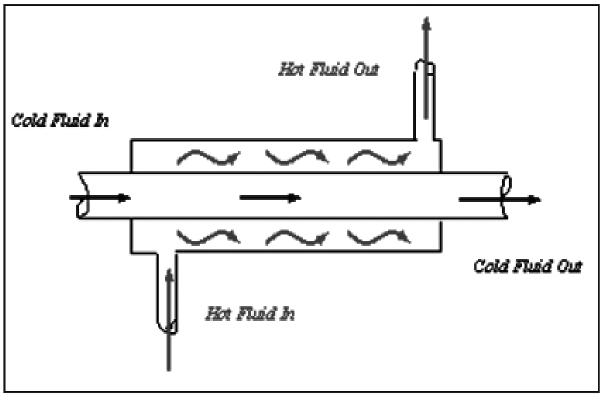

Fig. 8. Parallel flow heat exchanger

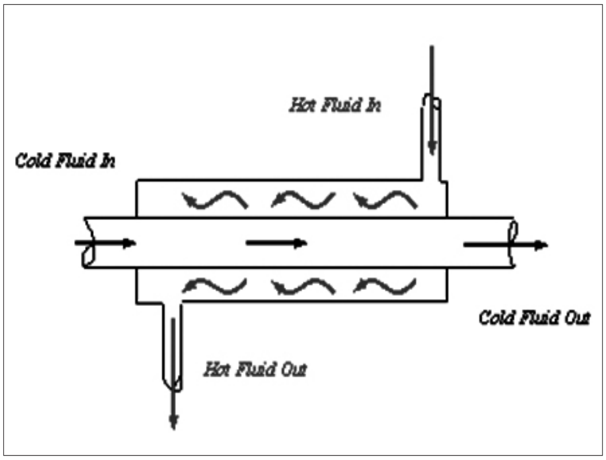

Fig. 9. Counter flow heat exchanger

11. General Heat Transfer Concepts

Heat is a form of energy that flows due to difference in temperature between two points that are located within a medium or in two different media. The transfer of heat occurs via one or any combination of the three modes of heat transfer - conduction, convection and radiation. Generally, the radiation heat transfer is of little importance for heat exchangers operating at low temperatures and will not be considered here. Thus, the discussion here will be limited to convective and conductive heat transfers.

Transfer rate or Flow rate = Driving Force/ Resistance

The transfer rate can also be expressed in terms of products of a transfer coefficient, transfer area and the driving force as follows:

Transfer Rate = Transfer Co - Efficient x Transfer Area x Driving Force

We can see that the resistance can be expressed in terms of a product of transfer coefficient and transfer area, or

1/Resistance = Transfer Co-efficient x Transfer Rate

Some examples of applicability of equation (1) to describe physical situations include flow of charges or electric current ($i = \Delta V/R_{elec}$), where the driving force is the electric potential difference (ΔV) and flow of incompressible fluid in a horizontal pipe ($v = \Delta P/R_f$), where the driving force is the pressure difference (ΔP).

Similarly, the rate of heat transfer can be described by the following equation:

$$Q = \frac{\Delta T}{R_{thermal}}$$

In the equation above, the driving force or ΔT is the difference in temperature between two points and $R_{thermal}$ is the thermal resistance or the resistance to heat transfer. The thermal resistance is a function of the geometry, the properties (e.g., thermal conductivity, viscosity, heat capacity etc.) of the medium or media between the two points, and, in case of convective heat transfer, the flow conditions.

Conventionally, heat transfer rates are expressed in terms of a heat transfer coefficient, usually denoted by h or U, in a form similar to equation below.

$$Q = hA(\Delta T)$$

One of the key challenges in heat exchanger design and heat transfer calculations is the determination of the thermal resistance or the heat transfer coefficient (*h*).

The current project focuses on experimental determination of the heat transfer coefficients. However, prior to discussing the methods for determination of heat transfer coefficients, it is important that we understand the mode(s) of heat transfer occurring so that appropriate equations are applied.

12. Overall Heat Transfer in a CTHX

In a heat exchanger, the temperature difference between the hot fluid and cold fluid may vary along the length of the heat exchanger as shown in the Figure 3 below. This is due to the fact that the hot fluid temperature decreases as it transfers heat to the cold fluid, while the cold fluid temperature increases. As shown in the Figure below, for parallel or co-current flow arrangement, the temperature difference is maximum at the inlet and decreases slowly towards the outlet. Accordingly, the heat transfer rate is maximum at the inlet and minimum at the outlet.

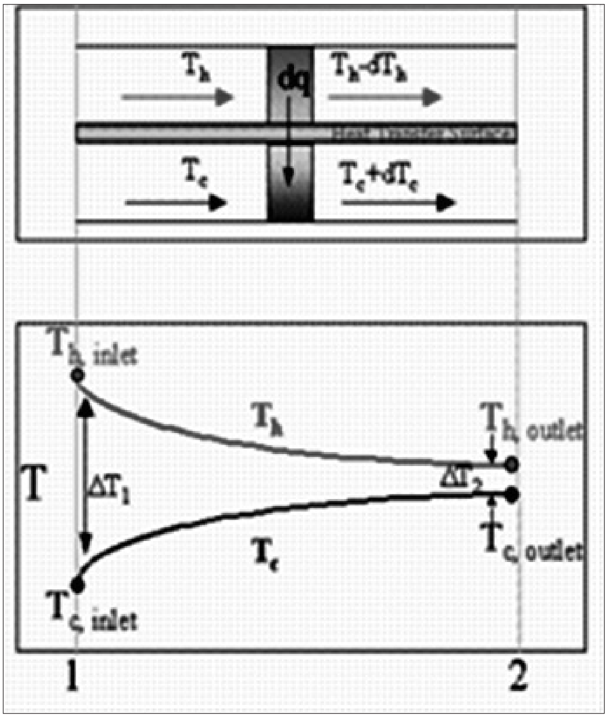

Fig. 10. Parallel flow

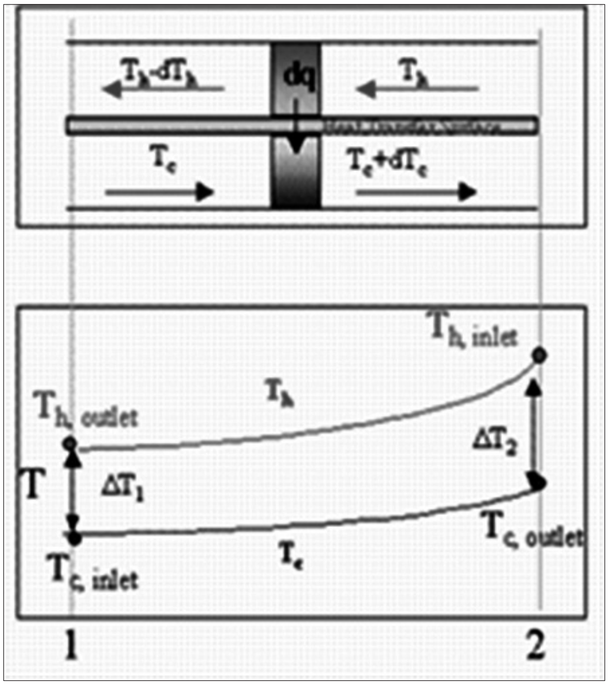

Fig. 11. Counter flow

13. Calculation of Mean Temperature

The appropriate form of mean temperature difference is the log mean temperature difference and has been derived from considerations of varying temperatures along the heat exchanger length. The log mean temperature difference is defined as follows:

$$\Delta T_m = LMTD = \frac{\Delta T_1 - \Delta T_2}{ln\,(\Delta T_1/\Delta T_2)}$$

Parallel flow configuration

$\Delta T1 = T_{h,inlet} - T_{c,inlet}$

$\Delta T2 = T_{h,outlet} - T_{C,outlet}$

Counter flow configuration

$\Delta T1 = T_{h,outlet} - T_{c,inlet}$

$\Delta T2 = T_{h,inlet} - T_{c,outlet}$

14. Determination of Overall Heat Transfer Coefficient Experimentally

If the inlet and outlet temperatures of hot and fluid streams and the flow rates are known, the overall heat transfer rates (Q) can be calculated, provided the heat capacity of the fluid is known. Further, if the overall heat transfer area is known, the "actual" or experimental overall heat transfer coefficient can be calculated using:

The overall heat transfer rate can be measured from enthalpy changes of the hot and the cold fluids. The overall heat gain rate by cold fluid (Qc) is equal to the difference in enthalpy of the fluid at the inlet and outlet as shown below:

$$Q_c = \dot{m}_c \,\bar{c}_{p,c}(T_{c,outlet} - T_{c,inlet})$$

Where the first term on the RHS of equation (10) is mass flow rate of the cold fluid, the second term is an average specific heat capacity. The above equation is valid for a temperature range over which the specific heat capacity does not vary significantly and no "phase" change occurs (e.g. boiling of water).

Similarly, the overall heat loss rate by hot fluid can be calculated by enthalpy loss of the hold fluid and is equal to the difference in enthalpy of the fluid at the inlet and oulet.

$$Q_h = \dot{m}_h \,\bar{c}_{p,h}(T_{h,inlet} - T_{h,outlet})$$

If there are no other form of heat loss or gain occurs then, $Q_c = Q_h = Q$ and is equal to the overall heat transfer rate through the walls of the exchanger.

The overall inlet/outlet stream temperatures differences (^{0}C) may be calculated using above two equations.

The heat transmission area, A, is obtained using equation

$$A = \pi \, d_m \, L$$

$$d_m = (d_0 + d_i)/2$$

15. Efficiency Determinations

To calculate the overall percent efficiency

$$\eta = \frac{Q_a}{Q_e} x100$$

The overall mean temperature efficiency is defined as follows:

$$\eta_m = \frac{\eta_h + \eta_c}{2}$$

16. Fabrication of Heat Exchanger

16.1. Components description

16.2. Heater

We are using a instant water heater to heat the water, to heat the water and to use it as the heating fluid. Tank less water heaters also known as instant water heaters. Flow, inline, flash, on-demand, or instant-on water heaters—are gaining in popularity. These high-power water heaters instantly heat water as it flows through the device, and do not retain any water internally except for what is in the heat exchanger coil. Copper heat exchangers are preferred in these units because of their high thermal conductivity and ease of fabrication. Tank less heaters may be installed throughout a household at more than one point-of-use (PoU), far from a central water heater, or larger centralized models may still be used to provide all the hot water requirements for an entire house. The main advantages of tank less water heaters are a plentiful continuous flow of hot water (as compared to a limited flow of continuously heated hot water from conventional tank water heaters), and potential energy savings under some conditions.

17. Low Pressure Pump

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps. Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or windpower. A centrifugal pump is a rotodynamic pump that uses a rotating impeller to increase the pressure and flow rate of a fluid. Centrifugal pumps are the most common type of pump used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward or axially into a diffuser or volute chamber, from where it exits into the downstream piping system. Centrifugal pumps are typically used for large discharge through smaller heads. Centrifugal pumps are most often associated with the radial-flow type. However, the term “centrifugal pump" can be used to describe all impeller type rotodynamic pumps including the radial, axial and mixed-flow variations. Pumps are used throughout society for a variety of purposes. Early applications include the use of the windmill or watermill to pump water. Today, the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, refrigeration (usually called a compressor), chemical movement, sewage movement, flood control, marine services, etc.

18. Temperature Sensors

A sensor is a device which receives and responds to a signal when touched. A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C (it is basically the slope Dy/Dx assuming a linear characteristic). Sensors that measure very small changes must have very high sensitivities. Sensors also have an impact on what they measure; for instance, a room temperature thermometer inserted into a hot cup of liquid cools the liquid while the liquid heats the thermometer. Sensors need to be designed to have a small effect on what is measured; making the sensor smaller often improves this and may introduce other advantages. Technological progress allows more and more sensors to be manufactured on a microscopic scale as microsensors using MEMS technology. In most cases, a microsensor reaches a significantly higher speed and sensitivity compared with macroscopic approaches

19. Tanks

We have provided two Tanks made of Stainless Steel. The First Tank carries the water to the Heater and receives the water from the Heater. Second one contains the Cold Fluid which is to be warmed or to which the heat has to be transferred. The third one is the receiver tank.

20. Types of Valve

20.1. Ball valve

A ball valve is a valve with a spherical disc, the part of the valve which controls the flow through it. The sphere has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked. The handle or lever will be in line with the port position letting you "see" the valve's position. The ball valve, along with the butterfly valve and plug valve, are part of the family of quarter turn valves. Ball valves are durable and usually work to achieve perfect shutoff even after years of disuse. They are therefore an excellent choice for shutoff applications (and are often preferred to globe valves and gate valves for this purpose). They do not offer the fine control that may be necessary in throttling applications but are sometimes used for this purpose. Ball valves are used extensively in industrial applications because they are very versatile, supporting pressures up to 1000 bar and temperatures up to 482°F (250°C). Sizes typically range from 0.2 to 11.81 inches (0.5 cm to 30 cm). They are easy to repair and operate.

20.2. Control valves

Control valves are valves used to control conditions such as flow, pressure, temperature, and liquid level by fully or partially opening or closing in response to signals received from controllers that compare a "setpoint" to a "process variable" whose value is provided by sensors that monitor changes in such conditions. The opening or closing of control valves is usually done automatically by electrical, hydraulic or pneumatic actuators. Positioners are used to control the opening or closing of the actuator based on electric or pneumatic signals. These control signals, traditionally based on 3-15psi (0.2-1.0bar), more common now are 4-20mA signals for industry.

20.3. Insulation

Glass wool is a thermal insulation that consists of intertwined and flexible glass fibers, which causes it to "package" air, resulting in a low density that can be varied through compression and binder content. It can be a loose fill material, blown into attics, or, together with an active binder sprayed on the underside of structures, sheets and panels that can be used to insulate flat surfaces such as cavity wall insulation, ceiling tiles, curtain walls as well as ducting. It is also used to insulate piping and for soundproofing.

20.4. Copper tube or pipe material

Copper tube or Pipe material should have high thermal conductivity, low cost, easy working and inertness with the refrigerant. Till date most commonly used pipe material is soft copper with all refrigerants except ammonia. The pipe material used with ammonia is mild steel as ammonia is highly corrosive to copper. (ref fig . 12)

20.5. Wire Coil Inserts

Copper Insert material should have high thermal conductivity, low cost, easy working and inertness with the distilled water. Till date most commonly used material is soft copper. The pitch of the coil

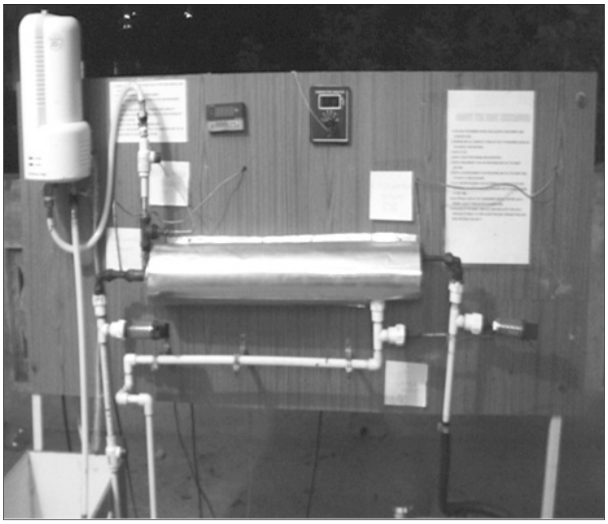

Fig 12. Fabrication setup of heat exchanger.

Fig. 13. Copper coil inserts.

was varied depends upon the inner diameter of the copper pipe. Usually about 8-10 numbers of turn were made in the inserts.

This wire coil insertswere easily available, also reduces the fluid flow rate. So that, the heat carrying time was increased in a huge manner. The variation and differences in heat transfer, thermal conductivity, LMTD and temperature differences were shown in tabulation and graph.

21. Calculation and Tabulation

Al_2O_2: Cu (85:15) Ratio Nano mixture with inserts:

Calculations

1. Q_h = 0.0248 X 4187[52 – 40.6]
   Q_h = 1183.748 W

2. Q_c = 0.0248 X 4187 [38.4 – 28.6]
   Q_c = 947.875 W

3. Q = (1183.748+947.875)/2
   Q = 1065.79 W

4. LMTD = [(52 – 28.6) – (40.6 – 38.4) / [(52 – 28.6) / (40.6 – 38.4)]
   LMTD = 8.964 K

5. U = 1065.79 / (0.05890 X 8.964)
   U = 2018.63W/m^2 K

Tabulation.

	Hot water			Cold water		
S. No.	T_1IN^{0}C	T_2IN^{0}C	Mass Flow Rate lit/sec	T_3IN^{0}C	T_4IN^{0}C	Mass Flow Rate lit/sec
1	48	38	41	28	37	44
2	50	39	41	28	37	44
3	52	40	40	29	38	43
4	54	42	40	29	39	43
5	56	44	39	29	41	42
Mean	52	40.6	40.2	28.6	38.4	43.2

Result and Discussion

From the literature it is found that the nano particles are doing vital role in the field of heat transfer. Extensive research is going on using nano fluids in a heat exchanger. In this work, a remarkable improvement was found in the heat transfer characteristics using wire coil inserts. The experimental result was obtained with hybrid nano particles in a heat exchanger with and without wire coil inserts. (Fig. 14)

From the graph it was clearly found that the heat transfer enhancement was found more in wire with coil inserts. This enhancement may be due to the following reasons.

- Wire coil inserts will reduce the flow rates slightly.

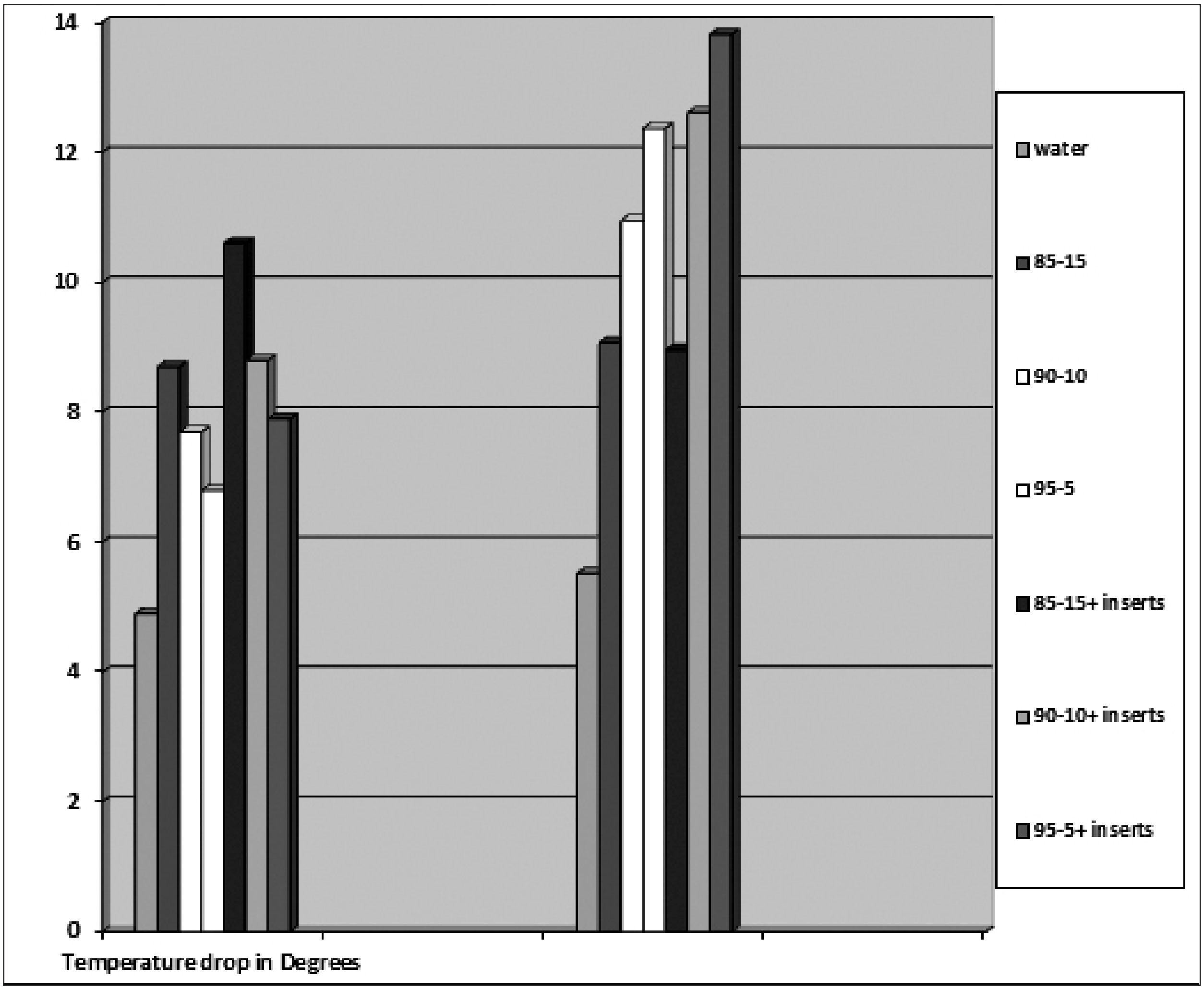

Fig. 14. Comparison statement with and without copper inserts.

- The slight reduction in flow rate within the test section, increased in the heat transfer characteristics.
- It was found that the wire coil size also an important factor which has to be considered since it influences in the heat transfer characteristics.
- The results of wire coil inserts was compared with and without wire coil inserts.
- Hence from the above it is clearly found that the wire coil inserts will play a major role in heat transfer enhancement
- It is strongly believed that the reduction of flow rate within the test section is the reason for heat transfer enhancement.

Conclusion

To find the heat transfer capabilities of hybrid nano particles with wire coil inserts, an experimental setup of a heat exchanger was fabricated and experiments were conducted with and without wire coil inserts. The results clearly indicated that the enhancement was due to the wire coil inserts which reduces the flow rate within the test section where measurements were taken.

Futurework

- The size of the wire coil can be changed for various ratios to find the optimum value of inserts.
- The flow inside the tube has to be justified, and the wire coil can be tested with various flow types.
- The experiments can be conducted by changing the shape of the pipe from circle to rectangle.

- Pressure drop and friction factor characteristics between a smooth pipe and a wire coil pipe has to be studied

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