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# INVESTIGATION OF HEAT TRANSFER IN CONCENTRIC TUBE HEAT EXCHANGER EQUIPPED WITH HELICAL COILED INSERT USING CuO-$H_2O$ BASED NANOFLUID

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## ABSTRACT

*Heat exchanger using nano fluid is a device in which the heat transfer takes place by using nano fluid. In this the working fluid is nano fluid. Nano fluid is made by the suspending nano particles in the fluid like water, ethylene glycol and oil, hydrocarbons, fluorocarbons etc. An investigation of forced convection heat transfer has been carried out in a concentric tube heat exchanger equipped with helical coiled inserts using $CuO/water$ as a nano fluid and distill water as base fluid. Tests has been conducted for plain tube and for tube with inserts for the determination of heat transfer, friction factor and thermal performance factor in the Reynolds number range 3000 to 11000 and volume concentration from 0.01%, 0.015% and 0.02% of nano fluid at room temperature. The results achieved from the use of the CuO/water nano fluid and helical coiled inserts, are compared with plain tube with and without inserts. The experimental results reveal that at similar operating conditions, heat transfer, friction factor as well as thermal performance factor associated with the simultaneous application of CuO/water nano fluid and helical coiled insert are higher than those associated with the individual techniques. Evidently, heat transfer rate increases with increasing CuO/water nano fluid volume concentration and decreasing pitch ratio. In addition, the copper oxide based nano fluid coupled with helical coiled insert in a copper tube in parallel arrangement offer higher heat transfer performances than plain tube. In this experimental study, the maximum thermal performance factor 1.23 is found with the use of CuO/water nano fluid at volume concentration of 0.02% in copper tube coupled with helical coiled inserts at pitch ratio (p/d=2) in parallel arrangement, for Reynolds number of 3713.93.*

***Keyword: Nano Fluids, Reynolds's Number, Heat Exchanger, Thermal Performance Factor.***

## I. INTRODUCTION

Enhancement of heat transfer using various techniques has received strong attention over the years in order to reduce the size and cost of heat exchanger. Many techniques have been developed for enhancing heat transfer rate in heat exchanger as the effective ones: (1) Nanofluids (2) Inserting fluid turbulators and (3) Roughening heat exchanger surfaces. Although for better heat transfer, combination of all the three or any two techniques can be used.

Heat exchanger using nano fluid is a device in which the heat transfer takes place by using nano fluid. In this the working fluid is nano fluid. Nano fluid is made by the suspending nano particles in the fluid like water, ethylene glycol and oil, hydrocarbons, fluorocarbons etc.

### 1.1 Nano Fluids

India is blessed with an abundance of sunlight, water and biomass. Vigorous efforts during the past two decades are now bearing fruit as people in all works of life are more aware of the benefits of renewable energy, especially decentralized energy where required in villages and in urban or semi-urban centres. India has the world's largest programmed for renewable energy. Government created the Department of Non-conventional Energy Sources (DNES) in 1982.

Energy is defined as the ability or the capacity to do work. Energy is the basic ingredient to sustain life and development. Work means moving or lifting something, warming or lighting something. There are many sources of energy that help to run the various machines invented by man. There has been an enormous increase in the demand for energy since the middle of the last century as a result of industrial development and population growth. World population grew 3.2 times between 1850 and 1970, per capita use of industrial energy increased about twenty fold, and total world use of industrial and traditional energy forms combined increased more than twelve fold. Nano fluid, a suspension of nano particles in a continuous and saturated liquid, has been found capable to get considerably higher thermal conductivities than their respective base fluids resulting in better convective heat transfer coefficients. Fluids have higher specific heat compare to metals, and metals have higher thermal conductivity compare to solids. So when we added a small amount of nano particle to base fluid it will increase the thermal conductivity of base fluid.

The thermal conductivity of nano fluids has drawn increasing attention since Cho[3] first postulated that heat transfer could be improved through the addition of metallic nano particles to the heat transfer fluid. He addressed the limitation in thermal conductivity of typical heat transfer fluids and suggested the addition of more conductive solid particles would enhance the fluid thermal conductivity beyond that suggested by conventional models. The advantages of using nano particles are that they are more easily suspended in the fluid, they may be used in micro channels, and the small size causes less wear to machinery. However, aggregation of particles must be minimized in order to benefit from these effects of small particle size.

### 1.2 Fluid Turbulators

Heat transfer can also be enhanced by using rotating inserts in a round tube. These rotating insert acts as a swirl generator. The use of the swirl generator is expected to create the tangential velocity or swirling flow to prolong residence time of the flow and to enhance the tangential and radial fluctuation, therefore leading to increase in heat transfer inside the test tube .These techniques are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications. In comparison to the passive techniques, these techniques have not shown much potential as it is difficult to provide external power input in many cases. In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer. Augmentation of heat transfer by this method can be achieved by:

- MECHANICAL AIDS
- FLUIDS VIBRATORS
- ELECTROSTATICS FIELDS
- INJECTION
- SUCTION
- SURFACE VIBRATION
- JET IMPEGEMENT
- ELECTROSTATIC FIELDS

## II. EXPERIMENTAL SETUP

The schematic representation of the experimental setup is depicted in Fig.1, along with its photograph in Fig.2, it consists of a test section, data logger, personal computer, flow meter, receiving tank, chiller, hot fluid tank, pump, bypass valve arrangement and u-tube manometer. The test section consists of a double pipe heat exchanger; the test nano fluid was flowing on the inner tube-side (A straight copper tube with 2000mm length, 17 ± 0.02mm inner diameter, and 20 ± 0.05mm outer diameter was used as the test section) and the annulus tube is made of cast iron and its diameter is 0.05 m. The hot fluid is pumped through the annular region and the water/nano fluid flows through the inner tube by using a pump. The mass flow rates for both the hot fluid and the water/nano fluid are controlled with by-pass valve arrangements. Two flow meters (MAS Technologies Ltd., India) were used to measure the mass flow rate of cold fluid and hot fluid. Throughout the experiments the mass flow rate of hot fluid is kept constant and the mass flow rate of nano fluid is varied from 2 LPM to 6 LPM. The outside surface of the annulus tube is wounded with cotton rope and POP insulation to minimize the heat loss from the test section to atmosphere. In order to measure the temperatures of the fluids, a total of eight T-type thermocouples were used, Four T-type thermocouples were mounted on the test section at axial positions in mm of 40 (T1), 80 (T2), 120 (T3), and 160 (T4) from the inlet of the test section to measure the wall temperature distribution, and other two T type thermocouples were inserted into the flow at the inlet and exit of the test section to measure the bulk temperatures of nano fluids and hot water. Thermocouple ends are connected to the temperature indicator system and the thermocouple readings are recorded in the DTC for further processing. The thermocouples are calibrated (±0.1 $^{o}$C) before placement in the test section. The receiving tank and hot fluid tanks both have the capacity of 20 liters and they are made of stainless steel. The nano fluid, which runs in a closed loop, before entering the test section passes through a chiller to maintain the inlet temperature constant. The pressure drop across the inner tube of the test section was measured by placing a U-tube manometer between both ends of the tube. To achieve this purpose, 4-mm holes drilled at both ends of the inner tube are connected using flexible tubing to the U-tube manometer; its fluid is mercury and the equivalent height is recorded as a function of the mass flow rate. Once the system reached to steady state, the readings of four T thermocouples were recorded and used for heat transfer calculations.

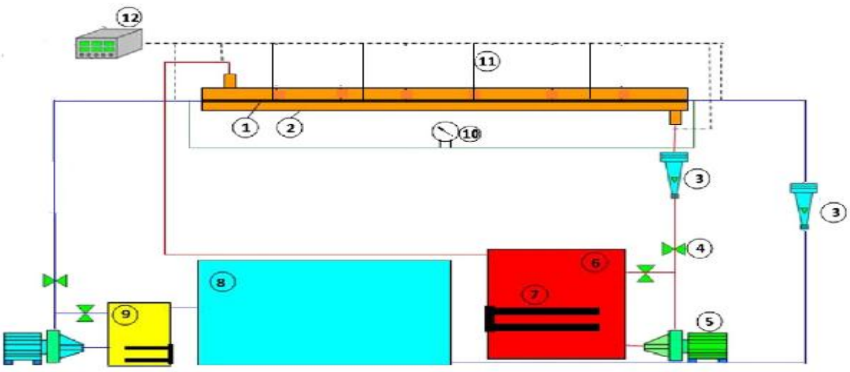


**Figure 1: Schematic Diagram of Experimental Setup**

1—inner tube (copper tube), 2—outer tube(GI pipe), 3—rotameter, 4—control valve, 5—water pump, 6—hot tank, 7—electrical heater, 8—cooling unit, 9—cold tank, 10—U tube manometer, 11—thermocouples, and 12—temp, indicator.

**Figure 2: Photograph of Experimental Setup**

## III. PROBLEM FORMULATION ANALYSIS

Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nano particles, nano fibers, nano tubes, nano wires, nano rods, nano sheet, or droplets) in base fluids. In other words, nano fluids are nano scale colloidal suspensions containing condensed nano materials. They are two-phase systems with one phase (solid phase) in another (liquid phase). Nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields.

### 3.1 Two Step Methos

Nano fluid for the experiment was prepared in nano technology lab in physics department at MANIT Bhopal. Two-step method is the most widely used method for preparing nano fluids. Nano particles, nano fibers, nano tubes, or other nano materials used in this method are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. Two-step method is the most economic method to produce nano fluids in large scale, because nano powder synthesis techniques have already been scaled up to industrial production levels. Due to the high surface area and surface activity, nano particles have the tendency to aggregate. The important technique to enhance the stability of nano particles in fluids is the use of surfactants. However, the functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications.

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

**Figure 3: Ultrasonic Cleaner apparatus for sonication process of CuO Nanofluids**

## IV. METHODOLOGY

- Make sure the components and instruments are connected properly with the experimental set up for proper operation.
- Both the motors is then switched on. Before adjusting the flow of nano fluid/water through control valve we should make the U-tube manometer leveled.
- The flow control valve is then opened to adjust predetermined rate of flow of nano fluid/water for the testing section.
- Experiment is conducted to collect the data regarding heat transfer coefficient and frictional flow under Quasi-steady state condition.
- Each change in rate of flow of nano fluid/water the system should attained a steady state before the data were recorded.

- At least 1.5 hrs is required for the system to attain a steady state.
- The temperature reading of copper pipe at different flowing rates of nano fluid/water have been taken only after the steady state condition is reached which is assumed to be reached when the pipe surface temperature and nano fluid/water outlet temperature did not deviate over 15 minute time period.
- After reaching the Quasi-steady state condition the inlet, outlet nano fluid/water temperature and pipe surface temperature was recorded by using temperature indicator through thermo-couple wires and pressure drop across the copper pipe by using U tube manometer.
- For each iteration five different values of Reynolds No. has been taken and observations for five different values of Nusselt No. and friction factor.
- The parameters measured during the experiments are Inlet temperature, outlet temperature and copper pipe surface temperature by using universal temperature indicator and thermocouple wires, Pressure drop across the copper was calculated by using U-tube manometer.

## V. RESULT AND DISCUSSION

The Nusselt number obtained from plane tube will be validated by Dittus Boelter correlations. This correlation is valid for Reynolds number more than 10000 and in our experiment Reynolds number is also more than 10000. This correlation can be expressed as

$$Nu = 0.023\ Re^{0.8}\ Pr^{n}$$

For Heating n =0.4

For cooling n = 0.3

Our experiment is carried out in heating mode so we will take n = 0.4 and finally correlation for our experiment will be

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$$

The friction factor obtained from plane tube will be validated by Blasius correlations. This correlation can be expressed as

$$f = 0.316\ Re^{-0.25}$$

**Table 1 Observation for flow without insert with water**

| **Without Insert with water** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reynolds No. (Nu)** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** | **$T_6$** | **$T_7$** | **$T_8$** | **$T_B$** | **$T_W$** | **Nu (Nusselt No.)** | **Friction factor (f)** |
| | **Temperature in ($^0$C)** | | | | | | | | | | | |
| 3713.93 | 62.5 | 35.5 | 58.1 | 54.4 | 53 | 52.2 | 47.9 | 60 | 40.95 | 54.625 | 29.45 | 0.06525 |
| 5755.89 | 66.0 | 37 | 57.4 | 55.5 | 52.3 | 48.8 | 46.4 | 62 | 41.7 | 53.5 | 47.17 | .06419 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7427.7182 | 66.2 | 37.4 | 55.1 | 52.2 | 48.1 | 44.8 | 43.7 | 61.5 | 40.55 | 51.125 | 55.94 | .06331 |
| 9284.6477 | 63.9 | 36.5 | 55 | 48.8 | 46.1 | 44 | 42.7 | 60 | 39.6 | 48.475 | 64.54 | .06223 |
| 10842.95 | 64 | 37.3 | 52.8 | 49.5 | 45 | 43 | 42.7 | 59.4 | 39.8 | 47.57 | 71.42 | .06183 |

**Table 5.2 Observation for Flow with Plain Insert with Water**

| With plain Insert with water | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reynolds No. (Nu)** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** | **$T_6$** | **$T_7$** | **$T_8$** | **$T_B$** | **$T_W$** | **Nu (Nusselt No.)** | **Friction factor (f)** |
| | **Temperature in ($^0$C)** | | | | | | | | | | | |
| 3713.93 | 64 | 36.2 | 55.4 | 53.6 | 50.8 | 48.8 | 46.9 | 59.5 | 41.55 | 52.15 | 37.35 | 0.1126 |
| 5755.89 | 65.8 | 37.4 | 55 | 53 | 50.1 | 47.3 | 45.9 | 60 | 41.65 | 51.35 | 48.66 | .1026 |
| 7427.7182 | 65.8 | 37.3 | 55.7 | 53.8 | 50.4 | 45.6 | 44 | 59.1 | 40.7 | 50.625 | 60 | .0926 |
| 9284.6477 | 66.2 | 37.6 | 54 | 52.3 | 49.6 | 46.8 | 43.8 | 59.5 | 40.7 | 50.675 | 66 | .0800 |
| 10842.95 | 65.8 | 37.4 | 52.8 | 49.6 | 46.3 | 44.5 | 42.3 | 60.2 | 39.85 | 48.3 | 76.87 | .0877 |

**Table 3 Observation for flow with insert (p/d=4) with water**

| With Insert (p/d=4) with water | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reynolds No. (Nu)** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** | **$T_6$** | **$T_7$** | **$T_8$** | **$T_B$** | **$T_W$** | **Nu (Nusselt No.)** | **Friction factor (f)** |
| | **Temperature in ($^0$C)** | | | | | | | | | | | |
| 3713.93 | 64 | 35.4 | 53 | 51.2 | 49 | 47.1 | 46.4 | 58 | 40.9 | 50.07 | 40.13 | .1532 |
| 5755.89 | 65.1 | 36.2 | 54.2 | 52 | 51.7 | 49.3 | 46.1 | 60.3 | 41.15 | 51.8 | 52.32 | .1432 |
| 7427.7182 | 64.3 | 36.7 | 54 | 52.2 | 50 | 48.7 | 44.9 | 59 | 40.8 | 51.22 | 63.59 | .1300 |
| 9284.6477 | 65 | 35.8 | 55 | 52.1 | 50.3 | 49 | 43.1 | 60.2 | 39.45 | 51.6 | 69 | .1155 |
| 10842.95 | 65.2 | 36.1 | 54.7 | 52.8 | 51 | 48.8 | 42 | 60.1 | 39.05 | 51.82 | 79.11 | .1000 |

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**Table 5.4 Observation for flow insert (p/d=2) with water**

| With Insert (p/d=2) with water | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reynolds No. (Nu)** | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_B$ | $T_W$ | **Nu (Nusselt No.)** | **Friction factor (f)** |
| | **Temperature in ($^0$C)** | | | | | | | | | | | |
| 3713.93 | 65 | 36.5 | 56 | 53.3 | 50.1 | 48.6 | 48.5 | 59.1 | 42.5 | 52 | 41.99 | .1600 |
| 5755.89 | 65.7 | 36 | 56.4 | 53.7 | 51.1 | 49.1 | 46.9 | 60 | 41.45 | 52.75 | 53.67 | .1500 |
| 7427.7182 | 64.3 | 38 | 55 | 52.3 | 50 | 48.9 | 47.4 | 59.6 | 42.7 | 51.55 | 66.45 | .1355 |
| 9284.6477 | 66 | 37.5 | 56.1 | 54.2 | 52.1 | 50 | 45.6 | 60.1 | 42.45 | 53.1 | 70.85 | .1255 |
| 10842.95 | 65.3 | 37.8 | 55.7 | 53.4 | 51.2 | 49.3 | 44.8 | 59.8 | 41.3 | 52.4 | 80.11 | .1200 |

**Table 5 Observation for flow without Insert with CuO/water(0.01 concentration)**

| without Insert with CuO/water(0.01 concentration) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reynolds No. (Nu)** | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_B$ | $T_W$ | **Nu (Nusselt No.)** | **Friction factor (f)** |
| | **Temperature in ($^0$C)** | | | | | | | | | | | |
| 3713.93 | 63.2 | 43.1 | 55 | 53.7 | 50.6 | 47.3 | 47.9 | 56.2 | 45.5 | 51.65 | 33 | .06825 |
| 5755.89 | 62 | 45 | 56 | 54.1 | 53.4 | 50.1 | 48.6 | 57.7 | 46.8 | 53.4 | 47 | .06725 |
| 7427.7182 | 65.1 | 36 | 55.6 | 53 | 50.6 | 46.6 | 42.2 | 58.2 | 39.1 | 51.45 | 56.55 | .06625 |
| 9284.6477 | 65.7 | 43.6 | 55.6 | 53.8 | 51 | 48.9 | 46.1 | 59.1 | 44.85 | 52.325 | 66.15 | .06525 |
| 10842.95 | 61.6 | 43.2 | 55.1 | 52.4 | 50 | 48.1 | 46.6 | 56.3 | 44.9 | 51.4 | 73 | .06425 |

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**Table 6 Observation for flow Plain insert with CuO/Water (0.01 concentration)**

| Plain Insert with CuO/ water(0.01 conc.) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reynolds No. (Nu)** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** | **$T_6$** | **$T_7$** | **$T_8$** | **$T_B$** | **$T_W$** | **Nu (Nusselt No.)** | **Friction factor (f)** |
| | **Temperature in ($^0$C)** | | | | | | | | | | | |
| 3713.93 | 64.3 | 36.3 | 55.1 | 53.3 | 50.7 | 48.6 | 46.9 | 59.4 | 41.55 | 52.15 | 35 | .1226 |
| 5755.89 | 65.5 | 37.6 | 55 | 53 | 50.1 | 47.3 | 45.9 | 60 | 41.65 | 51.35 | 49.55 | .1129 |
| 7427.7182 | 65.1 | 37.2 | 55.7 | 53.8 | 50.4 | 45.6 | 44 | 59.1 | 40.7 | 50.625 | 59 | .1030 |
| 9284.6477 | 66 | 37.4 | 54 | 52.3 | 49.6 | 46.8 | 43.8 | 59.5 | 40.7 | 50.675 | 69 | .0929 |
| 10842.95 | 65.4 | 37.4 | 52.8 | 49.6 | 46.3 | 44.5 | 42.3 | 60.2 | 39.85 | 48.3 | 76 | .0823 |

## V. CONCLUSION

The experimental results of the heat transfer enhancement by using CuO/water nano fluid in a copper tube fitted with coiled insert lead to the following conclusions.

1. Convective heat transfer, friction factor as well as thermal performance factor associated with the simultaneous application of CuO/water nano fluid and coiled insert are higher than those associated with the individual techniques.

2. Convective heat transfer, friction factor as well as thermal performance factor tend to increase with increasing CuO concentration of nano fluid and p/d ratio of inserts.

3. At similar condition, the copper tube coupled with coiled insert in parallel arrangement (PA) offer higher heat transfer performance than the ordinary(without nano fluid and inserts) parallel arrangement (PA).

4. For the range considered, the maximum thermal performance factor of 1.23 is found with the use of nano fluid of 0.02% by volume in the copper tube equipped with coiled insert (in PA arrangement) at p/d ratio of 2 and Reynolds number of 3713.93.

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