Enhancement of Heat Transfer of Heat Exchanger by Using Nanofluid and Coiled Insert

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Abstract- Heat exchanger using nanofluid is a device in which the heat transfer takes place by using nanofluid. In this the working fluid is nanofluid. Nanofluid is made by the suspending nanoparticles 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 nanofluid and distills 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 1.27 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.

Keywords: Nanofluids, coiled inserts, Reynold's Number, Heat Exchanger, Thermal Performance Factor, Heat Transfer, and Friction Factor.

I. INTRODUCTION

The heat exchangers have an important role in the energy storage and recovery. Due to the development of modern technology, the heat exchangers required in various industries for high heat-flux cooling to the level of megawatt per meter square. At this level, cooling with conventional fluids such as water and ethylene glycol and so forth, are challenging. Hence, it is necessary to increase the heat transfer performance of working fluids in the heat transfer devices. Heat transfer augmentation techniques (passive, active and compound) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. The rate of heat transfer can be increased passively by increasing the surface area, roughness, and by changing the boundary conditions. The active method involves addition of nano-sized, high thermal conductivity, and metallic powder to the base fluid, to increase the heat transfer rate. Such a fluid is termed as nanofluid. Passive techniques, where inserts are used in the flow passage to augment the heat transfer rate, are best suited compared to active techniques. Because the insert manufacturing process is simple and these techniques can be easily applied in an existing application.

In many literature gap shows the experimentation on perforated twisted insert like in experimental analysis of heat transfer characteristics using inserts in tubes. Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Heat transfer augmentation techniques refer to different methods used to increase these techniques and broadly divided in two groups, passive and active. Active techniques involve some external power input for the enhancement of heat transfer. Passive heat transfer augmentation method does not use any external power input. One of the ways to enhance heat transfer performance in passive method is to increase the effective surface area and residence time of the heat transfer fluid. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase surface area, given time and similarly heat transfer coefficient in existing system. Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer rate.

II. DIFFERENT METHODS OF HEAT TRANSFER ENHANCEMENT

Heat transfer enhancement, augmentation deals with the improvement of thermo hydraulic performance of heat exchangers. Different enhancements techniques have been broadly classified as passive and active techniques.

A. Active method

The active method involves external power input for the enhancement in heat transfer; for examples it includes mechanical aids and the use of a magnetic field to disturb the light seeded particles in a flowing stream, etc**.**

B. Passive method

The Passive heat transfer augmentation methods does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. By Using this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layers which increase effective surface area, residence time and simultaneously heat transfer coefficient increases in an existing system. Methods generally used are, extended surface, displaced enhancements devices, rough surfaces surface tension devices, Inserts Inserts requires additional arrangements to make to fluid flow which enhance and augment the heat transfer. The types of inserts are: twisted tape, wire coils, ribs, baffles, plates, helical screw insert, mesh inserts, convergent – divergent conical rings, conical rings etc. Twisted tapes are the metallic strips twisted using some of the suitable techniques as per the required shape and dimension, which are inserted in the flow to enhance the heat transfer. The twisted tape inserts are most suitable and widely used in heat exchangers to enhance the heat transfer. Twisted tape inserts increase heat transfer rates with less friction factor. The use of twisted tapes in a tube gives simple passive technique for enhancing the convective heat transfer by making swirl into the heavy flow which disrupting the boundary layer at the tube surface due to rapidly changes in the surface geometry. Which means to say that such type of tapes induce turbulence and swirl flow which induces inside the boundary layer and which gives better results of heat transfer coefficient and Nusselt number due to the changes in geometry of twisted tape inserts. Simultaneously, the pressure drop inside the tube will be increases when using twisted-tape as an insert. For this a many researchers have been done by experimentally and numerically to investigate the desired design to achieve the better thermal performance with less frictional losses. The heat transfer enhancement of twisted tapes inserts depends on the Pitch and Twist ratio.

C. Compound Enhancement

When any two or more techniques i.e. passive and active may be employed simultaneously to enhance the heat transfer of any device, which is greater than that of produced by any of those techniques separately, the term known as Compound enhancement technique.

III. REVIEW WORK

S. Eiamsaard and team [2001] in their paper, have made the comparison of the heat transfer rate, pressure drop behavior and thermal performance between wire coil inserts of varying pitch ratios, twisted tape and their combination inserted in a test tube and also developed correlations of the nusselt number and friction factor for all parameters studied. They end up with the conclusion that at low Reynolds number, the compound devices of the Twisted Tape with twist ratio=3 provide the highest thermal performance.

Wand and Suden [2003] also have discussed the comparison of wire coil inserts and twisted tape in their work. It was observed and noted that to disturb the central core flow the twisted tapes are the solution but if peripheral annular flow is to be mixed with core flow the wire coil inserts perform better. In context with heat transfer rate they have concluded that twisted tape perform better than the wire coil inserts. In process industries the fluids used have high density because of high viscosity and dirt and thus they need high pumping power. In such cases the pumping power is the important element and is drive to put constraints on selection of passive device. When pumping power is an issue pressure drop adds limitation on type of insert, as twisted tape cause more pressure drop than wire coil inserts. To analyze such involvement of pressure drop in the heat transfer enhancement many of researchers have introduced a term 'Overall enhancement efficiency' to predict the performance of an insert. It counts positive effect of heat transfer improvement and negative effect of pressure drop rise.

Sibel Gunes, Veysel Ozceyhan, Orhan Buyukalaca,[2007] in their first paper investigated experimentally, the heat transfer and pressure drop in a tube with wire coil insert in turbulent flow regime. The coiled wire they used had equilateral triangular cross section and was inserted separately from the tube wall. The experiments were carried out with three different pitch ratios (P/D = 1, 2 and 3) and two different ratio of equilateral triangle length side to tube diameter (a/D = 0.0714 and 0.0892) at a distance (s) of 1 mm from the tube wall in the range of Reynolds number from 3500 to 27,000. The use of coiled wire inserts leads to a considerable increase in heat transfer and pressure drop over the smooth tube. The nusselt number rises with the increase of Reynolds number and wire thickness and the decrease of pitch ratio. The highest overall enhancement efficiency of 36.5% is achieved for the wire with a/D = 0.0892 and P/D = 1 at Reynolds number of 3858. Consequently, the experimental results reveal that the best operating regime of all coiled wire inserts is detected at low Reynolds number, leading to more compact heat exchanger.

Sibel Gunes, Veysel Ozceyhan, Orhan Buyukalaca,[2010] in their second paper performed experimental study with same setup as in [1]. But in this paper they focused on coil separation from tube wall. The experiments were performed with a constant wire thickness of a = 6 mm, three different pitch ratios (P/D= 1, P/D= 2 and P/D=3) and two different distances (s = 1 mm, s=2 mm) at which the coiled wire inserts were placed separately from the tube wall. They varied

Reynolds numbers from 4105 to 26400 in these experiments. They found that nusselt number and friction factor increase with decreasing pitch ratio (P/D) and distance(s) for coiled wire inserts. The highest overall enhancement efficiency of 50%was achieved for the coiled wire with P/D = 1 and s = 1 mm at Reynolds number of 4220. As a result, it was found to them that using these coiled wire inserts are thermodynamically advantageous at all Reynolds numbers.

Mr. Kumbhar D.G., Dr. Sane N.K. [2012] both investigated Heat transfer, friction factor and enhancement efficiency characteristics in a horizontal circular tube fitted with conical wire coil tabulators experimentally. In this work two enhancement heat transfer devices were applied. They used conical coil inserts and full length wire coil inserts, placed in test tube, through which air was working fluid. The coiled wire inserts of 6mm, 9mm and 12mm spring pitches were introduced in each run. In addition, the conical wire inserts of pitch ratio 2.5mm and 3.5mm were also tested. The Reynolds number was varied from 2000 to 10000. Their experimental results revel that the tube fitted with the conical coil inserts and full length wire coil inserts provides nusselt number values of around 5% to 12% and enhancement efficiency varies between 0.78 to O. 98 compared with the plain tube.

Er. Pardeep Kumar, ManojSain, Shweta Tripathi [2013] performed experimental work on five wire coils of different pitch, inserted in a smooth tube in laminar and transition regimes. They also carried Isothermal pressure drop tests and heat transfer experiments under uniform heat flux conditions. They studied the air flow friction and heat transfer characteristics in a round tube fitted with coiled wire turbulators. They worked in turbulent regime with Re = 2000 – 10,000 and Pr = 0.7. It was found that use of coiled circular wire causes a high pressure drop increase, which depends mainly on spring pitches and wire thickness. The heat transfer in case of the conical coil was highest as compare to the plain pipe and the pipe containing the coil of different pitches. The outcome of their study says that the enhancement efficiency increases with the decreasing pitches and found highest in the conical sets and at a Reynolds number 2200- 3000, the friction factor was highest.

Prof. Mathew V Karvinkoppa [2014] in his paper worked over horizontal concentric tube in tube heat exchanger for its heat transfer enhancement using wire coil inserts. Till his study investigation was carried out for only one coil, which usually placed in the inner tube of the exchanger and its outer surface mates to inner surface of the tube. He says that the case that

contains more than one spring and location of the spring in the tube had not been focused. In an experimental investigation into effects of numbers (n= 4, 5, 6), incline angles (θ =0 deg, 7 deg, 10 deg etc.), and outer diameters of the springs (Ds=7.2mm, 9.5mm, 12mm, etc) for heat transfer and pressure drop by using spring coils as turbulators in a heat exchanger whose inner tube is heated by constant temperature water vapor on all surfaces.

B.Silapakijwongkul[2015] In this work, effect of the tapes twisted in clockwise and counterclockwise arrangement (C-CC arrangement) on heat transfer and friction factor characteristics in a double pipe heat exchanger was investigated experimentally. The mean heat transfer rates obtained from using C-CC twisted-tape arrangement and original twisted-tape arrangement are found to be 219% and 204%, respectively over the plain tube.

C. Thianpong[2015] This paper describes heat transfer enhancement attributed to helically twisted tapes (HTTs). Each helically twisted tape was fabricated by twisting a straight tape to form a typical twisted tape then bending the twisted tape into a helical shape. The experiments were performed using HTTs with three twist ratios (y/W) of 2, 2.5 and 3, three helical pitch ratios (p/D) of 1, 1.5 and 2 for Reynolds number between 6000 and 20,000. The conventional helical tape (CHT) was also tested for comparison. The obtained results reveal that at similar conditions (y/W and p/D), HTTs give lower nusselt number and friction but higher thermal performance factor than CHTs. Heat transfer rate and friction factor increase as the tape twist ratio and helical pitch ratio decrease, while the thermal performance shows opposite trend.

Paisarn Naphon & Parkpoom Sriromruln[2016] presented papers for micro fin tubes with coiled wire inserts. The heat transfer characteristics and the pressure drop of the horizontal double pipes with and without coiled wire insert were investigated. The inner and outer diameters of the micro-fin tube were 8.92 and 9.52 mm, respectively. The coiled wire was fabricated by bending a 1-mm-diameter iron wire into the coil wire with coil diameter of 7.80 mm. Cold and hot water were used as working fluids in shell side and tube side, respectively. The test runs were performed at the cold and hot water mass flow rates ranging between 0.01 and 0.07 kg/s and between 0.04 and 0.08 kg/s, respectively. The inlet cold and hot water temperatures were between 15 and 20 °C and between 40 and 45 °C, respectively. The results obtained from the micro-fin tube with coiled wire insert were compared with those obtained from the smooth and micro fin tubes. They found that the coiled wire insert had a significant effect on the enhancement of heat transfer. However, the friction factor of the tube with the coiled wire insert also increases. And the very important, they stated that wire coil effectiveness is in inverse proportion with Reynolds Number.

V. M. Kriplani [2016] Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. These techniques are used in heat exchangers. Some of the applications of heat exchangers are-in process industries, thermal Power plants, air-conditioning equipments, refrigerators, radiators for space vehicles, automobiles etc. These techniques broadly are of three types viz. passive, active and compound techniques. The present paper is a review of the passive augmentation techniques used in the recent past.

C. Thianpong [2017] This article reports an experimental investigation on heat transfer and pressure drop characteristics of turbulent flow in a heating tube equipped with perforated twisted tapes with parallel wings (PTT) for Reynolds number between 5500 and 20500. The design of PTT involves the following concepts: (1) wings induce an extra turbulence near tube wall and thus efficiently disrupt a thermal boundary layer (2) holes existing along a core tube, diminish pressure loss within the tube. The parameters investigated were the hole diameter ratio (d/W= 0.11, 0.33 and 0.55) and wing depth ratio (w/W = 0.11, 0.22 and 0.33). A typical twisted tape was also tested for an assessment. Compared to the plain tube, the tubes with PTT and TT yielded heat transfer enhancement up to 208% and 190%, respectively. The evaluation of overall performance under the same pumping power reveal that the PTT with d/W= 0.11 and w/W = 0.33, gave the maximum thermal performance factor of 1.32, at Reynolds number of 5500. Empirical correlations of the heat transfer, friction factor and thermal performance for tubes with PTTs were also developed.

Smith Eiamsa-ard [2017] Influence of helical tapes inserted in a tube on heat transfer enhancement is studied experimentally. The maximum Nusselt number may be increased by 160% for the full-length helical tape with centered-rod, 150% for the full length helical tape without rod and 145% for the regularly-spaced helical tape, s = 0.5, in comparison with the plain tube.

Alberto Garcı a, Pedro G. Vicente, Antonio Viedma [2017] all together studied helical-wire-coils fitted inside a round tube in order to characterize their thermo-hydraulic behavior in laminar, transition and turbulent flow. In laminar flow, results show that wire coils behave mainly as a smooth tube. Transition to turbulent flow takes place at low Reynolds numbers (Re = 700) and in a gradual way. Wire coils have a predictable behavior within the transition region since they show continuous curves of friction factor and Nusselt number, which involves a considerable advantage over other enhancement techniques. In turbulent flow, wire coils cause a high pressure drop increase which depends mainly on pitch to wire-diameter ratio p/e. These show considerable heat transfer augmentations: at Re = 10,000, depending mainly on dimensionless pitch p/d.

IV PROBLEM IDENTIFICATIONS

From the study of various research papers we have obtained the following problems:

1. Single method is not much more potential to increase the heat transfer.
2. To increase the friction factor, turbulence device used which is costly and complex to use.

V RESEARCH OBJECTIVES

Heat transfer can also be enhanced by using nanofluid (CuO + pure water) equipped with coiled inserts (p/d ratios are 0, 2 and 4) in a 2 meter copper tube. nanofluid increase the thermal conductivity of base fluid (pure water). These coiled inserts acts as a turbulence generator. The use of this generated turbulence is expected to create the tangential velocity 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. The objectives of this work are to:

1. Compare the heat transfer rate (Nu) with respect to plane tube (without nanofluid and inserts).

2. Compare the friction losses or pressure drop with respect to plane tube (without nanofluid and insert).

VI. 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 nanofluid/water hrough control valve we should make the U-tube manometer leveled.
- The flow control valve is then opened to adjust predetermined rate of flow of nanofluid/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 nanofluid/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 nanofluid/water have been taken only after the steady state condition is reached which is assumed to be reached when the pipe surface temperature and nanofluid/water outlet temperature did not deviate over 15 minute time period.
- After reaching the Quasi-steady state condition the inlet, outlet nanofluid/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.

VII RESULTS AND ANALYSIS

Thermal performance of heat exchanger depends upon – Area which is in contact with the system fluid, the heat convective coefficient, flow pattern i.e. counter or parallel flow, Inlet temperature of the fluids exchanging heat, The Number of transfer Units. The thermal performance factor is defined as:

$$TPF=\frac{\left(\frac{Nu}{Nu_0}\right)}{\left(\frac{f}{f_0}\right)^{\frac{1}{3}}}$$

Here Nu, f, Nu_0 and f_0 are the Nusselt numbers and friction factors for a tube configuration with and without inserts and nanofluid respectively.

The Nusselt number obtained from plane tube will be validated by DittusBoelter correlations. 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

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

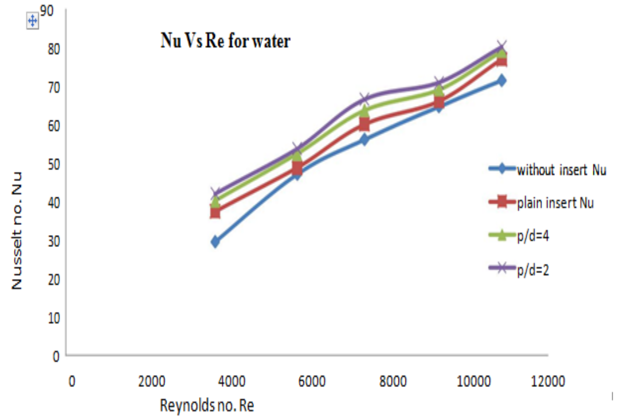

Fig 1: Variation of nusselt number and Reynolds number for different inserts with water only

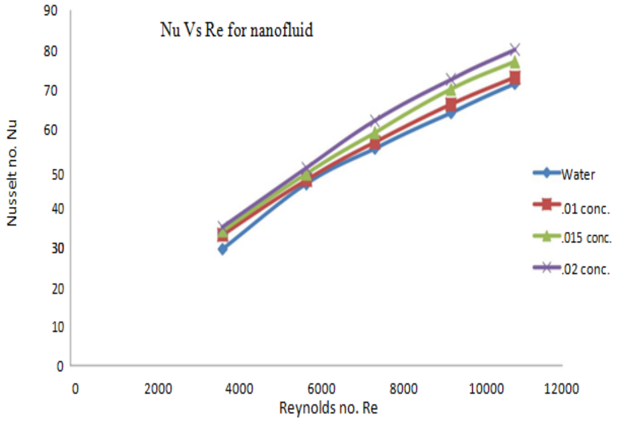

Fig 2: Variation of nusselt number and Reynolds number for different Vol% of CuO /water nanofluid

Nanofluids with higher concentration of CuO particles yield higher thermal performance factors. Therefore, it can be stated that the increment in nusselt number or heat transfer improvement as a positive effect over that from the increase of friction loss as a negative effect. This outcome becomes obvious at low reynolds number where pressure losses are insignificant. The effects of the presence of helical coiled inserts and their pitch ratio on thermal performance factor are also principally governed by the influence of heat transfer improvement.

VIII CONCLUSIONS AND FUTURE WORK

The experimental results of the heat transfer enhancement by using CuO/water nanofluid 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 nanofluid 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 nanofluid 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 nanofluid and inserts) parallel arrangement (PA).
4. For the range considered, the maximum thermal performance factor of 1.27 is found with the use of nanofluid 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.

In Future, the next steps in the nanofluids research are to concentrate on the heat transfer enhancement and its physical mechanisms, taking into consideration such items as the optimum particle size and shape, particle volume concentration, fluid additives, particle coating and base fluid. Better characterization of nanofluids is also important for developing engineering designs based on the work of multiple research groups, and fundamental theory to guide this effort should be improved. Important features for commercialization must be addressed, including particle settling, particle agglomeration, surface erosion, and large scale nanofluid production at acceptable cost. nanofluids offer challenges related to production, properties, heat transfer, and applications. In this section we highlight some future directions in each of these challenging areas.

1. Development of theoretical equations for thermo physical properties of CuO nanofluids is the grey area to be explored.
2. The effect of nano particles size on heat transfer and friction characteristics of nanofluids can be taken up for investigation.
3. Study on heat transfer investigation by changing the relative proportion in the base fluid constituents can be taken up as future work.
4. The research work can be extended by considering the effect of thickness of the twisted tape inserts

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