International Journal of New Technology and Research (IJNTR)
ISSN:2454-4116, Volume-2, Issue-2, February 2016 Pages 117-121

Analysis of Heat Transfer in Semifluid Tube Heat Exchanger Equipped with Spiral Coiled Insert Using Cuo-H_2o Based Nanofluids

Rajni Bunker, Ravi Vishwakarma

***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 analysis of forced convection heat transfer has been carried out in a semifluid tube heat exchanger equipped with spiral coiled inserts using CuO/water as a nano fluid 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 4000 to 10000 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 spiral 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 4713.93.**

***Index Terms*— Friction factor, Nusselt number, Reynolds number, Heat transfer rate.**

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 tabulators and (3) Roughening heat exchanger surfaces. Although for better heat transfer, combination of all the three or any two techniques can be used**.**

Rajni bunkar, Mechanical engg, RGPV/ SIST, CityBhopal, India.
Prof Ravi Vishwakarma, Mechanical engg, RGPV/ SIST, CityBhopal, India.

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 nanofluid. Nanofluid is made by the suspending nanoparticles in the fluid like water, ethylene glycol and oil, hydrocarbons, fluorocarbons .

Nanofluids : Nanofluids, a suspension of nanoparticles 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 nanoparticles to base fluid it will increase the thermal conductivity of base fluid. The thermal conductivity of Nanofluids has drawn increasing attention since Cho [3] first postulated that heat transfer could be improved through the addition of metallic nanoparticles to the heat transfer fluid. In order to improve heat management in existing industries, particularly data centre's and power electronics, the collaborative European project NanoHex (Enhanced Nanofluid Heat Exchange) was granted €8.3 million by the Seventh Framework Programme (FP7). The project was started in September 2009, and ended in April 2013. The NanoHex project was comprised of a consortium of twelve leading European companies and research centers. The main goal for the NanoHex project was to develop a formulation and a production pilot–line for a promising NF as a coolant, based on the partners' existing laboratory results and facilities. Detailed information about the NanoHex project and partners can be found through this link: http://www.nanohex.org. The overall strategy of the NanoHex work plan includes twelve work packages, and the role of the KTH Energy Department. The KTH Energy Department was mainly involved in suggesting an appropriate formulation for NFs based on heat transfer experiments; work also focused on predicting the heat transfer behavior of NFs.

A. Fluid tabulators

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:

i. Mechanical Aids:

Such instruments stir the fluid by mechanical means or by rotating the surface. These include rotating tube heat exchangers and scrapped surface heat and mass exchangers.

ii. Surface vibration:

They have been applied in single phase flows to obtain higher heat transfer coefficients.

iii. Fluid vibration:

These are primarily used in single phase flows and are considered to be perhaps the most practical type of vibration enhancement technique.

iv. Electrostatic fields

It can be in the form of electric or magnetic fields or a combination of the two from dc or ac sources, which can be applied in heat exchange systems involving dielectric fluids. Depending on the application, it can also produce greater bulk mixing and induce forced convection or electromagnetic pumping to enhance heat transfer

v. Injection:

Such a technique is used in single phase flow and pertains to the method of injecting the same or a different fluid into the main bulk fluid either through a porous heat transfer interface or upstream of the heat transfer section.

vi. Suction:

It involves either vapor removal through a porous heated surface in nucleate or film boiling, or fluid withdrawal through a porous heated surface in single-phase flow.

II. Objective

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).

II.. Literature Review

Understanding and improving heat transfer rate are the main concerns at different industries, including chemical processes, heating and cooling processes and micro-sized applications. Several techniques have been carried out to reduce operating cost. The most significant variables in reducing the size and cost of a heat transfer equipment's are heat transfer coefficient and pressure drop or flow resistance. The main concern for the equipment design is to minimize the flow resistance while enhancing the heat transfer coefficients. Therefore, it is vital to develop techniques to enhance the performance of heat exchangers. It has been commonly understood that the performance of heat exchangers can be improved by many augmentation techniques.

Among them, utilizing nano fluids and passive augmentation techniques like inserting turbulence promoters are considered as the effective ones.

Choi was the first who suggested the addition of solid particles in nanometric size into a base fluid and reported enhancement of thermal conductivity compared to base fluid. Many studies have conducted to evaluate the heat transfer performance and flow characteristics of various nanofluids in both the laminar and the turbulent flow regimes. Results of these studies proved that the inclusion of nanoparticles improves the thermal conductivity compared to the conventional fluid and increases heat transfer rate with the nano particle concentration. Although lots of investigations manifested the thermal conductivity contribution toward the enhancement in the convective heat transfer coefficient of nano fluids.

Although numerous investigations have been conducted on the compound heat transfer augmentations, to our best knowledge, the combination of two techniques consisting of utilizing nanofluid and inserting coiled insert has not been reported. Therefore, the purpose of the present work is to study the combined effects of these two techniques. The scope of the present work is to apply CuO nanofluids in the copper tube equipped with helical coiled insert. The ranges of interest are three different concentrations of nanofluids at 0.01, 0.015 and 0.02% by volume, three ratios of coiled insert (plane, p/d=2 and 4) and Reynolds numbers from 4000 to 14,000.

III. Experimental Validation.

Experimental setup

The schematic representation of the experimental setup is depicted in Fig.1, along with its photograph in Fig.5, 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/nanofluid flows through the inner tube by using a pump.

The mass flow rates for both the hot fluid and the water/nanofluid 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 nanofluid, 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.

Nusselt numbers determined from the experimental data on a smooth copper pipe were compared with those obtained from Dittus Boelter equation.

Dittus Boelter equation is given by
Nusselt number (Nu) =0.023 x Re0.8x Pr0.4
Where,
Re- Reynolds number
Pr- Prandtl number
Blasius equation
Friction factor (f) = 0.316 Re-0.25

IV. METHODOLOGY AND DATA REDUCTION

A. *Experimental Procedure*

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 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.

B. *Data Reduction*

i. Mean bulk nanofluid/water temperature (T_b):

$T_b = (T_i + T_o)/2o$
Where, T_i = inlet temperature of nanofluid/water in Co
T_o = outlet temperature of nanofluid/water in C

ii. Mean copper pipe surface temperature (Tw) :

$T_w = (T_{p1} + T_{p2} + T_{p3} + T_{p4})/4$

Where,

T_{p1-4} = temperature of pipe surface at different locations of plate.

iii. Pressure drop across the copper pipe (ΔP_o) :

$\Delta P_o = (\rho_m \text{ x g x } \Delta h)/5$

Where, Δh = Difference of mercury level in U-tube manometer 3
ρ_m = density of mercury i.e. 13.6 x 10

iv. Velocity of nanofluid/water:

$V = m/\rho A_1$

v. Reynold Number:

$Re = \rho VD/\mu$

Here D= Hydraulic mean Diameter.

μ = Dynamic Viscosity of nanofluid/water.

vi. The specific heat of the nanofluid was evaluated from:

$C_{p.nf} = (\varphi\rho_{np}c_{p,np} + (1-\varphi)\rho_w c_{p,w})/\rho_{nf}$

RESULTS AND DISCUSSION

A. Heat transfer

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 (14000)

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

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

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

B. Friction Factor

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

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

We had observed the variation of Nusselt number with Reynold number in fig. 6.17, 6.18, 6.20, 6.21 and 6.22 nusselt number is increasing with increase in Reynold number in all cases and in fig. 6.19, 6.23, 6.24, 6.25 and 6.26 frictions factor is decreasing with increase in Reynolds number. Nusselt number of the tube equipped with insert is considerably improved when compared with that of the tube without insert. This is responsible by the formation of turbulence generated by a insert. In addition, the heat transfer enhancement becomes more significant with decreasing p/d ratio of insert, as turbulence increases. It can also be observed that the influence of insert on heat transfer is much more significant than that of the presence of nano particles in the fluid. Moreover, heat transfer enhancement associated by the applications of nano fluid and coiled insert is found to be more effective than those offered by the individual techniques.

Nano fluids 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.

VI.CONCLUSIONS

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 1.23 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 4734.91.

FUTURE SCOPE

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 nano fluids 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

REFERENCES

[1] Khwanchit Wongcharee , Smith Eiamsa-ard, Heat transfer enhancement by using CuO/water nanofluid in corrugated tube equipped with twisted tape. International Communications in Heat and Mass Transfer 39 (2012) 251–257

[2] Heydar Maddah, Mostafa Alizadeh, Nahid Ghasemi, Sharifah Rafidah Wan Alwi , Experimental study of Al2O3/water nanofluid turbulent heat transfer enhancement in the horizontal double pipes fitted with modified twisted tapes, International Journal of Heat and Mass Transfer 78 (2014) 1042–1054

[3] N. Kannadasan, K. Ramanathan, S. Suresh, Comparison of heat transfer and pressure drop in horizontal and vertical helically coiled heat exchanger with CuO/water based nano fluids, Experimental Thermal and Fluid Science 42 (2012) 64–70

[4] A.E. Kabeel, T. Abou El Maaty , Y. El Samadony, The effect of using nano-particles on corrugated plate heat exchanger performance, Applied Thermal Engineering 52 (2013) 221e229

[5] Mohammad Hemmat Esfe, Seyfolah Saedodin, Omid Mahian, Somchai Wongwises, Heat transfer characteristics and pressure drop of COOH-functionalized DWCNTs/water nanofluid in turbulent flow at low concentrations, International Journal of Heat and Mass Transfer 73 (2014) 186–194.

[6] A.A. Rabienataj Darzi, Mousa Farhadi , Kurosh Sedighi, Rouzbeh Shafaghat, Kaveh Zabihi, Experimental investigation of turbulent heat transfer and flow characteristics of

[7] SiO2/water nanofluid within helically corrugated tubes. International Communications in Heat and Mass Transfer 39 (2012) 1425–1434

[8] M.A. Khairul, M.A. Alim, I.M. Mahbubul, R. Saidur, A. Hepbasli, A. Hossain. Heat transfer performance and exergy analyses of a corrugated plate heat exchanger using metal oxide nanofluids, International Communications in Heat and Mass Transfer 50 (2014) 8–14

[9] Alpesh Mehta,Dinesh k Tantia,Nilesh M Jha,Nimit M Patel, heat exchanger using nano fluid, International Journal of Advanced Engineering Technology, 2012/49-54

[10] S. Senthilraja1 and KCK. Vijayakumar, Analysis of Heat Transfer Coefficient of CuO/Water Nanofluid using Double Pipe Heat Exchanger**,** International Journal of Engineering Research and Technology. ISSN 0974-3154 Volume 6, Number 5 (2013), pp. 675-680.

[11] M.M.K. Bhuiya, M.S.U. Chowdhury, M. Saha& M.T. Islam, Heat transfer and friction factor characteristics in turbulent flow through a tube fitted with perforated twisted tape inserts, International Communications in Heat and Mass Transfer 46 (2013) 49–57.

[12] S. Rainieri , F. Bozzoli , L. Cattani & G. Pagliarini, Compound convective heat transfer enhancement in helically coiled wall corrugated tubes, International Journal of Heat and Mass Transfer 59 (2013) 353–362.

[13] C. Thianpong, K. Yongsiri, K. Nanan& S. Eiamsa-ard, Thermal performance evaluation of heat exchangers fitted with twisted-ring turbulators, International Communications in Heat and Mass Transfer 39 (2012) 861–868.

[14] P. Murugesan, K. Mayilsamy , S. Suresh & P.S.S. Srinivasan, Heat transfer and pressure drop characteristics in a circular tube fitted with and without V-cut twisted tape insert, International Communications in Heat and Mass Transfer 38 (2011) 329–334.

[15] S. Pethkool, S. Eiamsa-ard , S. Kwankaomeng& P. Promvonge, Turbulent heat transfer enhancement in a heat exchanger using helically corrugated tube, International Communications in Heat and Mass Transfer 38 (2011) 340–347.

[16] S.Eiamsa-ard, K.Wongcharee, P.Eiamsa-ard, C.Thianpong, Heat transfer enhancement in a tube using delta-winglet twisted tape inserts, ; Applied Thermal Engineering 30 (2010) 310-318.

[17] Smith Eiamsa-ard , PanidaSeemawute&KhwanchitWongcharee, Influences of peripherally - cut twisted tape insert on heat transfer and thermal performance characteristics in laminar and turbulent tube flows, Experimental Thermal and Fluid Science 34 (2010) 711–719.

[18] V.Kongkaitpaiboon, K.Nanan, S.Eiamsa-ard, Experimental investigation of heat