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# Analysis of Heat Transfer Rate of Heat Exchanger by Using Coiled Insert and Nano Fluid

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ABSTRACT

Heat exchangers are designed to transfer maximum heat. Use of nanofluids can increase the heat transfer rate further to a good extent. In the present work, 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 distill water as base fluid. 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 have been determined experimentally. In this 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.

## INTRODUCTION

A heat exchanger is a device, which used to transfer thermal energy between two or more fluids or between a solid object and a fluid. The fluids may be separated by solid wall to prevent mixing fluids, or they may be in direct contact. Heat exchangers are used in various applications, like refrigeration and air conditioning, power stations and space heating, chemical plants, and petrochemical plants and petroleum refineries, natural gas processing, and sewage treatment. The elegant example of a heat exchanger in an internal combustion engine is radiator. In which circulating fluid known as engine coolant flows through radiator coils and air is used to cool the coolant. Another example is the heat sink, which is transfers heat generated by an electronic or a mechanical device to a fluid medium, like air or a liquid coolant. Air heaters can be utilized for space heating or for other purposes [Hussain et al. 2016] [Nilay et al., 2017] [Kumar et al.,2017] [Sahu et al., 2016] [Gupta et al., 2021] .

Understanding and improving heat transfer rate are the main concerns. 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 nanofluids and passive augmentation techniques like inserting turbulence promoters are considered as the effective ones.

## EXPERIMENTAL SETUP

The schematic representation of the experimental setup is depicted in Fig.1

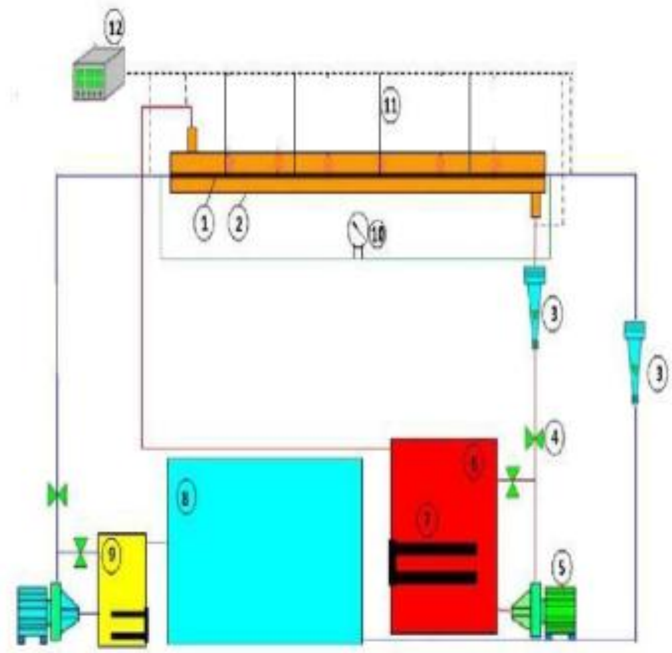


Fig.1: Experimental Setup

In the present experiment with CuO nanofluids, the time taken to complete the experiment for property estimation is less than the time required for first sedimentation to take place and hence surfactants are not mixed in the CuO nanofluids. The CuO nanofluids prepared are assumed to be an isentropic, Newtonian in behavior and their thermo physical properties are uniform and constant with time all through the fluid sample. Due to the difficulty in preparing stable nanofluids by two-step method, several advanced techniques have been employed to produce nanofluids.

## Experimental Validation

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

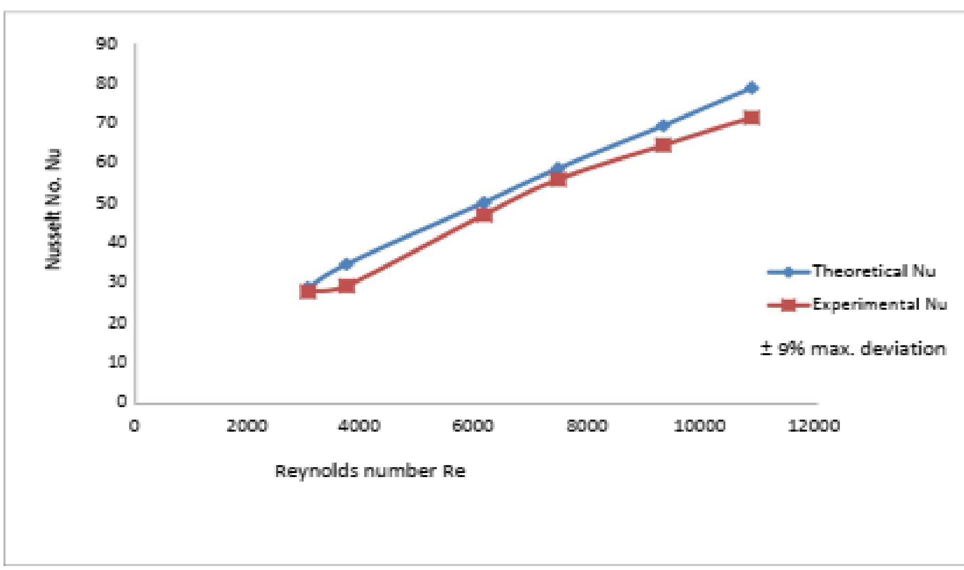


Fig. 2: Variation of experimental and calculated value of nusselt number Vs reynold no. for smooth copper pipe.

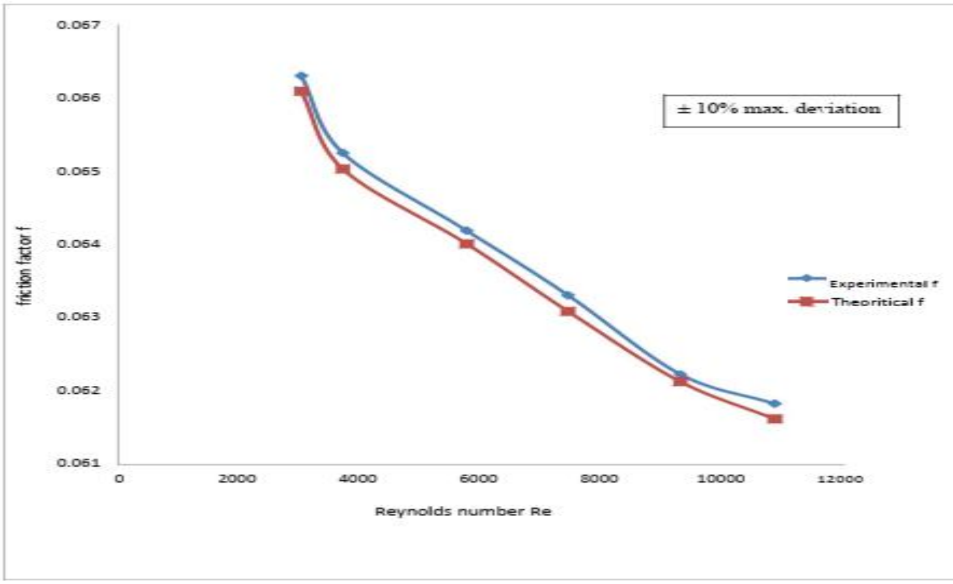


Fig. 3: Variation of experimental and calculated value of friction factor Vs reynolds no. for smooth copper pipe.

## RESULTS AND DISCUSSION

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

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 |
| 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 2: Observation for flow insert (p/d=2) with CuO/water(0.015 concentration)

| Insert(p/d=2) with CuO/water(0.015 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 | 63.1 | 43.3 | 55.1 | 53.9 | 50.5 | 47.2 | 47.9 | 56.2 | 45.5 | 51.65 | 36 | .1755 |
| 5755.89 | 62.8 | 45.1 | 56 | 54.1 | 53.4 | 50.1 | 48.6 | 57.7 | 46.8 | 53.4 | 52.55 | .1700 |
| 7427.7182 | 65.4 | 36.2 | 55.6 | 53 | 50.6 | 46.6 | 42.2 | 58.2 | 39.1 | 51.45 | 65 | .1653 |
| 9284.6477 | 65.5 | 43.5 | 55.6 | 53.8 | 51 | 48.9 | 46.1 | 59.1 | 44.85 | 52.325 | 77.5 | .1601 |
| 10842.95 | 61.7 | 43.7 | 55.1 | 52.4 | 50 | 48.1 | 46.6 | 56.3 | 44.9 | 51.4 | 84.5 | .1505 |

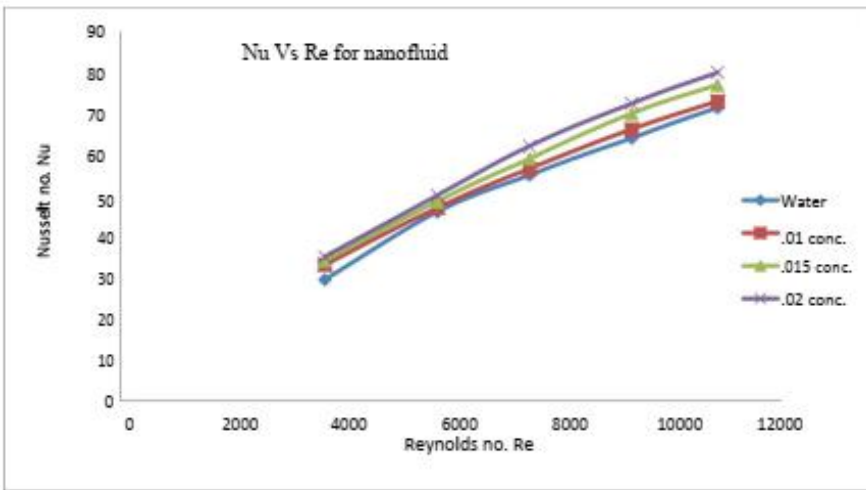


Fig. 4: Variation of nusselt number and Reynolds number for different Vol% of CuO /water nanofluid

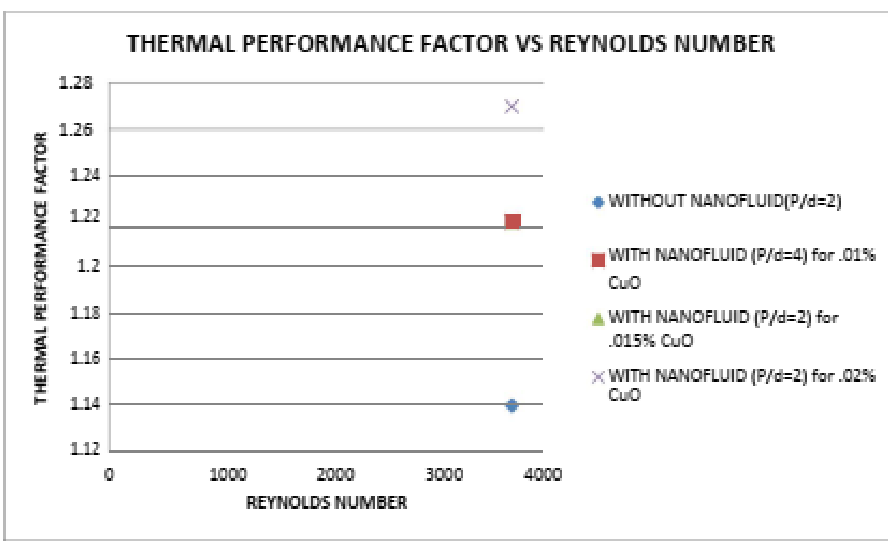


Fig. 5: Thermal performance factor for reynolds number at 3713.94

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.

## CONCLUSION

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.

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