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“Experimental Investigation On Nano Fluid Based Tubular Heat Exchanger By Using Plane Twisted Tape Inserts”

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Abstract

Heat exchangers are extensively used in various industrial applications such as power plants, refrigeration systems, chemical processing units, air-conditioning equipment, and automotive cooling systems. Improving the heat transfer performance of heat exchangers is essential for increasing energy efficiency and reducing operational costs. Among various heat transfer enhancement techniques, twisted tape inserts and nanofluids have gained considerable attention due to their simplicity, low cost, and effective thermal performance. The present work investigates the enhancement of heat transfer in a straight tube heat exchanger using a plain twisted tape insert and copper oxide (CuO) nanofluid under counter-flow operating conditions. The plain twisted tape insert produces a swirling motion inside the tube, which improves fluid mixing and reduces the thickness of the thermal boundary layer. The CuO nanofluid possesses higher thermal conductivity than conventional fluids, resulting in improved heat carrying capacity and enhanced energy transport.The experimental setup consists of a straight tube heat exchanger in which hot water flows through the inner tube while CuO nanofluid flows through the outer flow passage. Experiments were conducted at different flow rates while maintaining a constant hot fluid flow rate. The inlet and outlet temperatures of both fluids were measured to evaluate the thermal performance of the system. The experimental data were used to determine important heat transfer parameters such as heat transfer rate, Log Mean Temperature Difference (LMTD), Reynolds number, Nusselt number, convective heat transfer coefficient, overall heat transfer coefficient, friction factor, effectiveness, and Number of Transfer Units (NTU). The results indicate that the combined use of CuO nanofluid and plain twisted tape insert significantly improves the heat transfer characteristics of the heat exchanger. Although the friction factor increases because of the additional flow resistance caused by the insert, the improvement in heat

transfer performance makes this enhancement technique suitable for practical applications. The findings of the present investigation demonstrate that the combined application of CuO nanofluid and plain twisted tape insert can effectively improve the thermal performance of heat exchangers and can be utilized in various industrial thermal systems.

Keywords: CuO Nanofluid, Plain Twisted Tape Insert, Tubular Heat Exchanger, Reynolds Number, Nusselt Number, Effectiveness, NTU, LMTD.

I. INTRODUCTION

Heat exchangers are thermal devices used to transfer heat from one fluid to another without mixing the fluids. They are widely used in power plants, refrigeration systems, automobile radiators, chemical industries, air-conditioning systems, and food processing industries. Efficient heat exchangers help in reducing energy consumption and improving system performance. With increasing energy demand and fuel costs, improving heat transfer performance has become important. Better heat transfer reduces equipment size, lowers energy consumption, and increases thermal efficiency. Therefore, various heat transfer enhancement techniques are used in modern thermal systems.

HEAT TRANSFER ENHANCEMENT TECHNIQUES

Heat transfer enhancement methods are generally classified into active and passive techniques. Active methods require external energy, whereas passive methods improve heat transfer without additional power input. Passive techniques are widely used because of their simple construction and low operating cost.

- Active Techniques
- Passive Techniques
- Compound Techniques

1.1 Twisted Tape Insert

Twisted tape inserts are one of the most commonly used passive heat transfer enhancement devices. The tape is twisted along its length and inserted inside the tube. The insert creates a swirling motion in the fluid, increases turbulence, and improves fluid mixing.

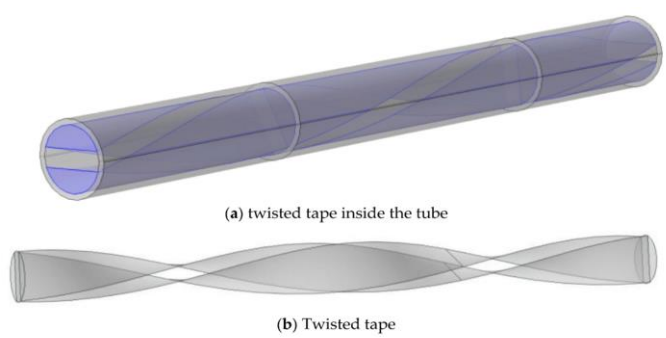

Figure 1. Plain Twisted Tape Insert

1.2 Preparation of CuO Nanofluid

Nanofluids are prepared by dispersing nanoparticles into conventional fluids. Copper oxide (CuO) nanoparticles possess higher thermal conductivity than water and improve heat transfer performance. The use of CuO nanofluid increases the heat carrying capacity of the working fluid.

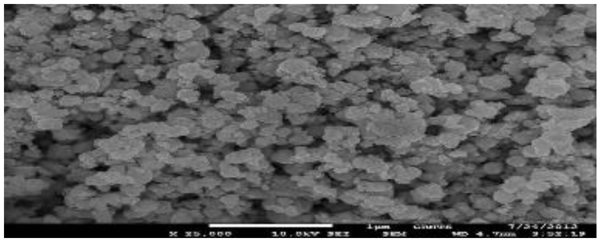

Figure 2. CUO Nanoparticle

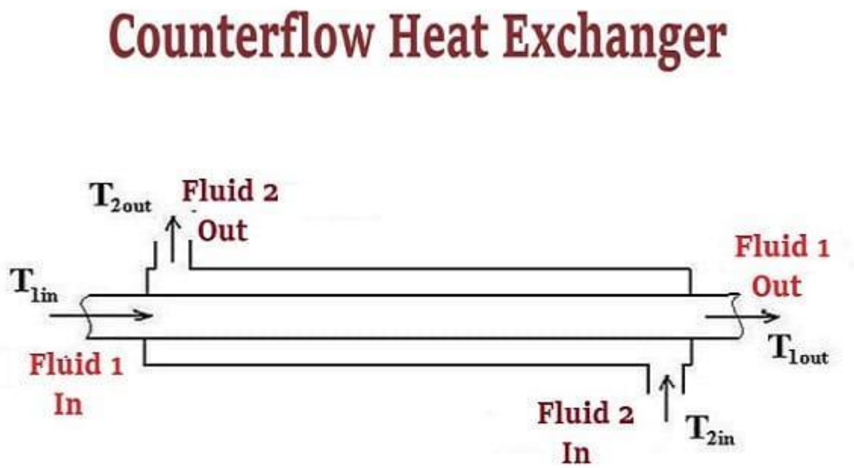

Figure 3. Counter-Flow Heat Exchanger

1.3 Performance Parameters

The performance of the heat exchanger is evaluated using various thermal and hydraulic parameters such as:

- Reynolds Number (Re)
- Nusselt Number (Nu)
- Heat Transfer Coefficient (h)
- Overall Heat Transfer Coefficient (U)
- Log Mean Temperature Difference (LMTD)
- Effectiveness (ε)
- Number of Transfer Units (NTU)
- Friction Factor (f)

These parameters help in analyzing the heat transfer and flow characteristics of the system.

1.4 Present Work

The present study investigates the enhancement of heat transfer in a straight tube heat exchanger using a plain twisted tape insert and CuO nanofluid under counter-flow conditions. Experimental investigations are carried out at different flow rates, and the thermal performance of the system is analyzed using various heat transfer parameters. The results of this study can be useful for improving the design and efficiency of industrial heat exchangers.

1.5 Experimental Set Up

Figure 4.Experimental Set Up in Lab.

II. OBSERVATION TABLE

Sr. No	Mass Flow Rate Cold Water Kg/Minute	Mass Flow Rate Hot Water Kg/Minute	Hot water inlet temperature T1 (ºC)	Hot water outlet temperature T2 (ºC)	Cold water inlet temperature T3 (ºC)	Cold water outlet temperature T4 (ºC)
1	1.87	30	55.1	53.8	28.6	39
2	2.85	30	55	53.6	28.5	36.3
3	3.15	30	55	52.8	28.5	36
4	4	30	55	53.0	28.5	35.9
5	5.21	30	55	53.8	28.5	35.1
6	6.18	30	55	53.3	28.5	34.3
7	7.69	30	55	52.6	28.6	35.1

III. CALCULATIONS

Assumptions:

- Specific Heat of Water/Nanofluid (Cp) = 4180 J/kg.K
- Copper Tube Inner Diameter = 21 mm = 0.021 m
- Flow Area = 0.000346 m^2
- Density of CuO Nanofluid = 1020 kg/m^3
- Dynamic Viscosity = 0.0012 $N.s/m^2$
- Thermal Conductivity (k) = 0.68 W/m.K

IV. Reading Observations

Parameter	Value
Average Heat Transfer Rate	2471 W
Average LMTD	21.74 °C
Average Reynolds Number	11365
Prandtl Number	7.38
Average Nusselt Number	88
Average Heat Transfer Coefficient	2850 W/m^2K
Average Overall Heat Transfer Coefficient	960 W/m^2K
Average Effectiveness	27.9 %
Average NTU	1.01
Average Friction Factor	0.031
Average Thermal Performance Factor	1.35

V. CONCLUISON & DISCUSSION

The present investigation focused on the experimental study of heat transfer enhancement in a counter-flow double pipe heat exchanger using a plain twisted tape insert and CuO nanofluid. The objective of the study was to evaluate the influence of passive heat transfer enhancement techniques on the thermal and hydraulic performance of the heat exchanger under different operating conditions. The experimental results revealed that the insertion of the plain twisted tape significantly improved the heat transfer characteristics of the heat exchanger. The twisted tape generated a swirling motion inside the tube, which enhanced fluid mixing and continuously disturbed the thermal boundary layer formed near the tube wall. This resulted in an increase in the convective heat transfer coefficient and improved thermal performance. The use of CuO nanofluid further enhanced the heat transfer process due to its higher thermal conductivity compared to conventional water. The nanoparticles improved the heat carrying capacity of the working fluid and promoted better energy transport within the heat exchanger. The combined effect of the plain twisted tape insert and CuO nanofluid produced a considerable enhancement in heat transfer performance. The experimental investigation showed that the Reynolds number, Nusselt number, and convective heat transfer coefficient increased with increasing fluid flow rate. The higher turbulence intensity generated inside the tube improved fluid mixing and reduced thermal resistance, leading to enhanced heat transfer. The effectiveness and Number of Transfer Units (NTU) values obtained during the investigation indicated satisfactory thermal performance of the heat exchanger. The counter-flow arrangement maintained a larger temperature difference throughout the test section and provided efficient heat transfer between the hot and cold fluids. Although the twisted tape insert introduced additional flow resistance and increased the friction factor, the improvement in heat transfer performance was significantly greater than the corresponding hydraulic penalty. Therefore, the overall thermohydraulic performance of the heat exchanger remained satisfactory.

In conclusion, the combined use of a plain twisted tape insert and CuO nanofluid proved to be a simple, economical, and effective passive heat transfer enhancement technique. The findings of this investigation provide useful information for the design and development of energy-efficient heat exchangers used in power plants, chemical industries, refrigeration systems, process industries, automotive cooling systems, and other thermal engineering applications.

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