

Experimental Investigation of CuO – Water Nano fluid in Shell and Tube Heat Exchanger also CFD Approach

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Abstract: This project focuses on studying the thermal performance of a shell and tube heat exchanger using CuO–water nanofluid as the working fluid. The main aim is to analyze the heat transfer performance of CuO Nanofluid under heat transfer enhancement. Nanofluids, are considered due to their enhanced thermophysical properties which can influence the heat transfer mechanism. Experiments analysis are carried out to observe the system operating condition. In parallel CFD modeling perform to simulate the fluid flow and thermal distribution in the heat exchanger the combined approach provide a detailed framework to examine the heat transfer performance.

1. Introduction

A heat exchanger is a device used to transfer heat between two fluids without mixing them. The shell and tube type is one of the most common heat exchangers used in industries. In recent years, nanofluids—fluids containing nanoparticles—have been introduced to enhance heat transfer performance. Copper oxide (CuO) nanoparticles mixed with water form a stable nanofluid with better thermal properties.

This project aims to experimentally and numerically (using CFD) analyze how CuO–water nanofluid performs inside a shell and tube heat exchanger. The results are compared with those obtained using normal water to evaluate improvements in heat transfer rate and efficiency.

The primary objectives of this paper are as follows:

- To conduct experimental testing of shell and tube heat exchanger using

CuO Water Nanofluid

- [distilled] nanofluid compared to conventional fluid [water].
- To perform CFD analysis using ANSYS Fluent software to study temperature, velocity pressure profile and flow behavior of heat exchanger
- To compare experimental results with CFD results and evaluate heat transfer improvement.

2. Literature Review

According to M. A. Al-Rashed (2025), Title: Experimental Investigation of Heat Transfer Enhancement Using CuO and Hybrid Nanofluids in Shell-and-Tube Heat Exchanger

- Main Finding: CuO-water nanofluid significantly improved overall heat transfer coefficient compared to water.

According to Kunalkoushal Dew, Pankaj Shrivastava (2018) Title: CFD Analysis of double

tube heat exchanger using different nanofluid .

- Main Finding: This analysis show nanofluid properties calculation also observed the heat transfer is higher in case of CuO nanofluid as compared to other nanofluid

According to Rajput Nitish Singh, Pandey Rajat, Ishan Lav, Pankaj K. Pandey (2016). Title: Experimental studies of nanofluid TiO₂/CuO in a heat exchanger (double pipe)

- Main Finding: Nanofluid physical properties and experimental results show the application TiO₂/CuO based nanofluid enhance coefficient of heat transfer with concentration and flow increase by 5%

According to Elcio Nogueira Title: Efficiency and Effectiveness Concepts Applied in Shell and Tube Heat Exchanger Using Ethylene Glycol-Water Based Fluid in the Shell with Nanoparticles of Copper Oxide (CuO)

- Main Finding: To Understand the Analytical Method (e-NTU) For Calculation of System Performance

According to Lazarus Godson Asirvatham, Nandigana Vishal, Senthil Kumar Gangatharan

and Dhasan Mohan Lal Title: Experimental Study on Forced Convective Heat Transfer with Low Volume Fraction of CuO/Water Nanofluid

- Main Finding: The CuO-

Water Nanofluid Increase

8% heat transfer enhancement even at very low concentration

3. Methodology

3.1. Preparation of CuO – Water Nano fluid

Preparation of nanofluid by using Two Step Method: nanoparticles are already prepared in the powder form (CuO nanoparticles), then mixed with base fluid (distilled water), this is simple and suitable for lab experiments.

- Base Fluid: Distilled water is used as the base fluid
- Nanoparticles: Copper oxide (CuO) are taken by 1% of weight concentration

3.2. Mixing Process:

Measured amount of CuO nanoparticles (1% wt) are added slowly into distilled water.

The mixing is carried out using magnetic stirrer with hot plate in the range of 30–45 minutes also add sodium dodecyl sulfate (SDS) surfactant to enhance stability

Observation: The prepared nanofluid should appear uniform without visible particles settling down

3.3. Experimental Setup:

Equipment Used: Shell and tube heat exchanger with hot and cold fluid lines, flow meters, thermometers, and control valves.

Working Fluids:

- Cold Water is circulated through the shell side.
- The Hot Fluid CuO–water nanofluid is circulated through the tube side
- Record inlet and outlet temperatures of both fluids.
- Calculate heat transfer rate and overall heat transfer coefficient by using LMTD and NTU Method

3.4. CFD Simulation (Using ANSYS Fluent)

1. Modeling:

A 3D model of the shell and tube heat exchanger is created in (Ansys Design Modeler) Design parts :

- Shell Fluid Domain
- Tube Wall
- Tube Fluid Domain

2. Meshing:

- To generate the fine mesh near tube wall and tube fluid contract regions

Meshing Tools:

- **Edge Sizing:** Tube fluid inlet and outlet.
- **Face Sizing:** Near tube wall and tube fluid contract regions.
- **Inflation layers:** To capture the boundary layer in tube wall and tube fluid regions.

3. Material Properties:

- Ansys Fluent has the material properties of standard fluids (like water, oil etc.)

Nanofluid Properties:

- Thermophysical properties of the nanofluid were calculated using standard correlation.
- The viscosity of nanofluid calculated using Brinkman model
- Density was calculated using -

- Heat capacity equation - Xuan and Roetzel
- Effective thermal conductivity - Maxwell thermal conductivity model

4. Boundary Conditions:

- Set inlet temperatures, flow rates, and material properties for water and CuO–water nanofluid.

.Note: Shell Side: **Water**, Tube Side: **Nanofluid**

- **Inlet Parameters:** Cold Fluid Inlet and Hot Fluid Inlet

- **Outlet Parameters:** Cold Fluid Outlet and Hot Fluid Outlet

- **Wall Condition:** Tube Walls

5. Postprocessing:

Obtain temperature distribution, velocity profile, heat transfer coefficient and Overall heat transfer rate

3.6.TheoreticalCorrelation:

Nusselt number was calculated using the observations obtained from the experimental data at different conditions. Assumption of steady state was considered for this study and, coefficient of heat transfer and Nusselt Number was determined by following equations respectively.

$$\bullet Q = mC_p\Delta T = mC_p(T_{in} - T_{out})$$

$$\bullet h = Q / A \times \Delta T_{LMTD}$$

$$\bullet Nu = k$$

Where,

- Q = Heat transfer rate (w)
- m = mass flow rate (kg/s)
- C_p = Specific heat capacity (J/kg.k)
- ΔT = Temperature difference
- T_{in} = Inlet temperature
- T_{out} = Outlet temperature
- h = Heat transfer coefficient (W/m²k)
- A = heat transfer area (m²)
- ΔT_{LMTD} = Log mean temperature difference
- Nu = Nusselt number equation
- d = Tube diameter (m)
- K = Thermal conductivity (W/mk)

3.7.Project Work Flow

The duration of the development of this study will be over 12 weeks and weekly objectives are as follows

Week1–

2: During this period, we will be conducting research study of nanofluid preparation and physical properties.

Week3–5: Budget planning and purchase

During this week estimated the budget required for the preparation of nanofluid. Based on budget plan necessary material such as CuO-nanoparticles, sodium dodecyl sulfate (SDS), flow pipes, connecting valves and other laboratory requirements will be purchased for experiment setup.

Week6–7: Nanofluid Preparation:

During this week, the CuO-Water nanofluid will be prepared using two-step method.

The required amount of CuO-nano particles (1%wt) is mixed with distilled water to stirrer the mixture using magnetic stirrer with hot plate to enhance the stability of nanofluid. We use to add sodium dodecyl sulfate (SDS) surfactant. Also, we take conventional and nanofluid reading will be carried out this stage.

Week8-10: CFD Analysis

We design the shell and tube heat exchanger by using PTC Creo software and this model is imported to Ansys fluent model. During Ansys design modular we modify the geometry like (Add share topology

tool, fill tool, and Boolean operation). Fine and sweep mesh will be created on model with inflation layers. And assign the material, boundary condition of the model. to accurately calculated the conjugate heat transfer rate, temperature, velocity and pressure profile regions. And given results will be compared to experimental results.

Week11–12.Resultanalysisandreporting

During this week the experimental and CFD results will be analyzed and compared. The performance of the CuO-water nanofluid in shell and tube heat exchanger will be evaluated, and the final report will be prepared.

4.Applications

- Applied in power plant for efficient cooling system
 - Used in automobile radiators for better engine cooling .
 - Applied electronics device cooling system
 - 5. Used solar thermal system to enhance heat dissipation.
- Conclusion

This project studies the thermal performance of CuO-Water nanofluid in a shell and tube heat exchanger using experimental and CFD analysis

This study also helps to understand the flow behavior inside the heat exchanger

Overall, this project shows that the nanofluid can be a promising solution for improving the overall heat transfer coefficient, temperature distribution of fluids and increases the efficiency of the system.

6.FutureScope

- Use of hybrid nanofluids ($\text{CuO} + \text{Al}_2\text{O}_3$)
- Application in industrial heat exchangers
- Optimization using AI or advanced CFD
- Study at higher concentrations and temperatures

7.References

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