The Heat Transfer from Fined Perforated Pipe Improved due to Nano-Fluid

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Abstract: In this research, experimental and numerical investigates were conducted on the effect of adding Nano fluid (α−AL₂O₃, γ−AL₂O₃, CuO) with different concentrations (1 %, 3%, and 5%) on the thermal properties of water. The heat exchanger system was designed with fin types with different holes (circular, triangular, elliptical and without holes). Thermal properties such as thermal conductivity, viscosity, specific heat, heat transfer coefficient, Nusselt number, Reynolds number have been studied experimentally and numerically. The results showed that the thermal properties increase with increasing the concentrations of nanomaterials and the Nusselt number increases with the increase of Reynolds number, and that the best type of fin is the fins with triangular holes. Copper oxide is the best at concentration (5%). Numerical simulation carried out on present heat exchange using consul computational fluid dynamic (CFD) the comparison between experimental and numerical results showed good.

Keyword: Nanofluid, finned tubes, AL2O3, CuO

1. Introduction

The heat exchanger is a device designed to efficient transfer heat from one medium to another, and it is widely used in heating, cooling, air conditioning, power plants [1]. Petrochemical and chemical factories, petroleum refineries, natural gas processing, aviation industry and sewage treatment, as well as used in internal combustion engines where the fluid known as engine coolant circulates [2]. Through the radiator coils, airflows through the coils, which cools the radiator and heats the incoming air fins are surface extensions that are widely used in different types of heat exchangers to increase the rate of heat transfer between solid surfaces and surrounding fluid fins. [3]. There are different type's fins such as rectangular, triangular, circular, wavy, stripe and perforated fins. Circular fins are one of the very effective ways to enhance heat transfer and improve the efficiency of the heat exchanger [4] [5]. Nanofluid it is a liquid that contain small nanoparticles and the nanoparticles applied in the Nanofluids liquids are composed of metals, oxide and carbide or nanotubes of carbon and the basic liquids are water, ethylene, glycol and oil.
The nanoparticles improve heat transfer of liquid and the high stability of dispersion with the main brown motion of the particles [6].

In many fields, including the nanoscale reactor, processing, space technology, industry, heat exchangers, and the most important properties of Nanofluids is thermal conductivity, and heat transfer coefficient for convection. [7]. Nanoparticles are particles of diameter from 1 to 100 nm. Nanofluids consist of a basal fluid and nanoparticles.[8]

Shokouhi et al. investigated experimentally of the use of Nano liquids in the area of entry circular tube at constant temperature and laminar flow system and the effects of the concentrations, particle size, and coefficient of heat transfer and pressure drop. At used concentrations of (0.5 % to 1 %) and Reynolds number (650 to 2300). Results revealed a large improvement in heat transfer relative to the base fluid due to the inclusion of nanoparticles in the base fluid the findings demonstrate that Nanofluids transported by heat increasing the particle volume fraction as well as increased the Amount of Reynolds and the pressure drop. [9] Shi, Hu, and et al studied experimentally using Nanofluids to increase thermal conductivity and obtain thermal transfer speed and efficiency are superior for tuning in a straight tube. The experimental results were the average efficiency of the heat transfer is 12.2%, although the local efficiency of the heat transfer can be improved more than 30, 2% under the magnetic field applied. [10]

Saffarian, and et al studied the Circular tubes and oval tubes at different angles were, and the results showed that circular tubes in the middle of the projectile were the highest heat transfer, but pressure drops in both sides of the tube and shelf [11]

From above researches, the authors used one type of finned tubes in current work; the many types of finned tubes were used such as circular fins with without holes, with triangular holes, with elliptical holes, with circular holes, which represent the originality of this paper. Nanofluids will used different at different concentrations for to increasing and improving thermal properties of water by using aluminum dioxide (Y-AL₂O₃) and (α - AL₂O₃) and (CuO) with different volume fraction Ø (1 %, 3%, 5%). Circular fins used in the system with different radii and different shape holes such as circular, elliptical, triangular shapes.

2. Experimental work

In this study, Aluminum - oxide Alpha (Al₂O₃) and aluminum - oxide Gama (AL₂O₃) and copper - oxide (CuO) were used as Nano fluid with distilled water as a base fluid. Table (1) shows the physical properties of nanoparticle used. These nanomaterials were selected due to high thermal conductivity low cost.

Table (1) physical properties of nanoparticle (α −AL₂O₃,γ − AL2O3, CuO)

| Nanoparticles | Average particle Diameter (nm) | Density kg/m³ | Thermal conductivity w/m.℃ | Specific heat J/kg.℃ | Purit | Color |
|---------------|-------------------------------|---------------|-----------------------------|----------------------|-------|-------|
| AL₂O₃, Alpha  | 30                            | 3.7           | 40                          | 3970                 | 99.9  | White |
| AL₂O₃, Gama   | 10                            | 3.7           | 40                          | 3970                 | 99.9  | White |
| CuO           | 40                            | 6.3           | 18                          | 6510                 | 99.9  | Black |
2.1 Rig of Heat Transfer system Design

Figure (1) represents the heat exchanger system used in the experimental work of this paper. The system consists of five tubes made of pure copper. The fins are distributed over the tubes in several types: tube with circular fins without holes, tube with circular fins with circular holes, tube with circular fins with elliptical holes, tube with circular fins with triangular holes, tube without fins. In addition, the system was connected to a pump, which suction the Nanofluid from tank, in addition the temperatures and manometers distributed over the various parts of the system. The system also contains a flow rate gauge to control of velocity of Nanofluid. The types of circular fins were indicted in figure (2).

![Figure 1. Rig of heat exchanger system used in the current work](image-url)
2.2 Nanofluid preparation

The Nanofluids was preparation by two steps; the first step is prepare Nanofluids by using nanoparticles for improving the efficiency of fluid convective heat transfer. The Nanofluids does not refer easily to a liquid–solid blend, but certain special conditions are such as "suspension, stable suspension, strong suspension, minimal particle agglomeration," and the chemical properties of the fluid not altered. This is a very complicated and complex procedure and these nanoparticles are costly and expensive. The second step is that the Nano-powder dispersed within the base fluid. In this work the (α-γAl₂O₃ colloidal) and CuO colloidal as Nanofluid mixed with the water as the basic liquid by the three volume fractions (1%, 3% and 5%) as shown in figure (3. a, b). The mixture mixed by hotplate stirrer device for 90 min then 30 min by ultrasonic homogenizer 1200 W power as shown in Figure (3 c).
3. Numerical Simulation Approach

Computational fluid dynamics (CFD) used in copper tube heat switching for predicting water flow and temperature fields. This is done numerically through the Navies Stokes solution of partial differential equations for the continuity, momentum and energy of conservation. In addition, applied to finite solver volumes in order to achieve a precise solution, including temperature and speed fields. The heat transfer smooth tube, the finned tube, the finned tube with and without Nanofluid perforation are equivalent.

3.1 Mesh Topology

FLUENT uses an unstructured solver during an unstructured mesh, which uses internal data structures to allocate the cells, faces, and grid points in one mesh to keep contact with the cells adjacent to them. For mesh topology, FLUENT code may use different element types. Element sort defines the number of the mesh node and the configuration of the node corresponds to the element form.[12]

A type of higher-order feature to use precisely estimate the borders of high curvature for mesh generation. Tetrahedral mesh kind employed in the present analysis since in complex geometry it is superior. The following has been included:

1- A higher-order triangular element with suspended nodes as seen in figure (4) for a surface mesh
2- A higher-order tetrahedral element is used for a three-dimensional mesh, as seen in figure (4). Figure (4- a, b, c, d) displays a solid fin tube mesh and the circular finned tube with different holes meshing details.

Figure 3. (a) AL₂O₃ Nanofluid    (b) CuO Nanofluid, (c) ultrasonic homogenizer
Figure 4 meshing with different type finned holes

(a) Mesh Circle solid fin
(b) Mesh circle solid fin with circle holes
(c) Mesh Circle solid fin with elliptic holes
(d) Mesh circle solid fin with triangle
3.2 Number of Iterations
Governing equations by the algebraic equations Method of the final volume. The methods of solution are second-order Dynamic and energy. There are the following: In the ANSYS FLUENT repeatedly algebraic equations are overcome with Water properties values were determined for each iteration to Continue the iteration until the convergence of The response [13]. That is the maximum number of iterations to finish the solver. (2000-2250) iterations, as seen in figure (5) needed in this study. There is convergence in iteration criteria show be supported by the stability of the physical property of interest which clears between (1000 and 2150) as shown in figure (5).

![Figure 5. Residual for numerical simulation of present study](image)

4. Results and Discussions:
Figures (6) to (11) and Table (3) show the effect of volume fraction on the Thermophysical properties of Nanofluid γ-AL2O3/water, α-AL2O3/water, CuO/water from these figures, it can be seen that. Increasing volume fraction leads to an increase in density, viscosity, and Thermal conductivity. Also increasing volume concentration causes decreasing in the specific heat of Nanofluid because nanoparticles dispersed in the base fluid (distilled water) have a high value of density, and thermal Conductivity from the base fluid (distilled water) but has less value of specific heat from the base fluid (distilled water). From the results in this study, the maximum increase of, viscosity, and thermal conductivity are 8.5%, and 37.23% respectively, (γ-AL2O3/water). The viscosity, and thermal conductivity are 26%, and 18.25 % respectively α-AL2O3/water. Viscosity, and thermal conductivity are 1.93%, and 43.07% respectively CuO/water.

Figure (12) show the effect of different Reynold's number on the heat transfer coefficient for hot water at 60 °C. It may see that the heat transfer coefficient increases by increasing Reynold's number. It
may note also that the heat transfer coefficient of hot water for circular finned tube increases than for smooth tube because of the increase in surface area by fins. The heat transfer coefficient for the circular finned tube with triangle perforations.

Figures (13) exhibit the variation of Reynold's number with Nusselt's number for distil water of different type of finned tube. The results show that the Nusselt's number increase due to increase in Reynold's number because the increasing in heat transfer coefficient.

Figure (14 and 15) show the effect of Reynolds number on the heat transfer coefficient of Nanofluid for γ-Al2O3/water and CuO/water at 5% volume fraction. From these figures, it may see that the heat transfer coefficient increases by increasing Reynold's number. The heat transfer coefficient of Nanofluid for triangular finned tube is higher than the recent type of finned tube because of the increase in surface area by fins. Figure (16 to 19) indicates the effect of Reynolds number on the Nusselt's number of Nanofluid for γ-Al2O3/water and CuO/water at 1%, 3% and 5% volume fraction for different types of finned tubes. From these figures, it may see that the Nusselt's number increases by increasing Reynold's number. The Nusselt's number of Nanofluid for triangular finned tube is best than the recent type of finned tube because of the increase in heat transfer coefficient.

Figure (20) explain the effect of Reynolds number on the Nusselt's number of Nanofluid for γ-Al2O3/water and distill water and Nanofluid at 1%, 3% and 5% volume fraction for triangle finned tube. From these figures, it may see that the Nusselt's number increases by increasing Reynold's number. The Nusselt's number of Nanofluid for 5% Nanofluid is best than the recent of Nanofluid volume fractions compared with distill water because of the increase in concentrations of Nanofluid lead to increase in thermal conductivity it. Figure (21) explain the effect of Reynolds number on the heat transfer coefficient of Nanofluid for CuO/water and γ-Al2O3/water at 5% volume fraction for triangle-finned tube. From these figures, it may see that the heat transfer coefficient increases by increasing Reynold's number. The heat transfer coefficient of Nanofluid for CuO/water is bigger than γ-Al2O3/water because of the thermal conductivity of CuO/water increase is higher than γ-Al2O3/water as shown in the table (3).

Figure (22) shows temperature contours of circular finned with triangle holes at along tube with Nanofluid at Reynolds Number (1000 to 5000) which carried out by ANSYS 18. The Numerical results showed that for the circular fins with triangle perforated. Surface temperatures increase in increase Reynolds Number. The surface temperature in the beginning of the tube is high, and then gradually decrease over the fins, and the high surface temperature at the is Reynolds Number 5000, while the temperature difference between water entering and leaving is better at Reynolds Number 1000, and it gradually decreases with more Reynolds Number.

| Material | concentration | μnf/μw | ρnf/ρw | knf/kw | cpnf/cpw |
|----------|---------------|--------|--------|--------|---------|
| Al2O3    | alpha 0.01    | 1.1996 | 1.0050 | 1.084  | 0.967   |
|          | alpha 0.03    | 1.2317 | 1.028  | 1.146  | 0.916   |
|          | alpha 0.05    | 1.263  | 1.0350 | 1.22   | 0.88    |
|          | gamma 0.01    | 1.0154 | 1.01119| 1.074  | 0.971   |
|          | gamma 0.03    | 1.0711 | 1.0259 | 1.1679 | 0.948   |
|          | gamma 0.05    | 1.090  | 1.030  | 1.372  | 0.894   |
|          | 0.01          | 0.97   | 1.0122 | 1.1126 | 0.971   |
| Cuo      | 0.03          | 0.9875 | 1.0325 | 1.323  | 0.94    |
|          | 0.05          | 1.0175 | 1.047  | 1.43   | 0.911   |
Figure 6. Relation between ($knf/\text{kw}$) of ($\gamma$-AL2O3/water) and different volume fraction.

Figure 7. Relation between ($\mu NF/\mu W$) of ($\gamma$-AL2O3/water) and different volume fraction.

Figure 8. Relation between ($knf/\text{kw}$) of ($\alpha$-AL2O3/water) and different volume fraction.

Figure 9. Relation between ($\mu NF/\mu W$) of ($\alpha$-AL2O3/water) and different volume fraction.

Figure 10. Relation between ($knf/\text{kw}$) of ($CuO$/water) and different volume fraction.

Figure 11. Relation between ($\mu NF/\mu W$) of ($CuO$/water) and different volume fraction.
**Figure 12.** Effect of (Re) on (h) of distil water of different types of finned tubes.

**Figure 13.** Variation of (Nu) on (Re) of distil water for different types of finned tubes.

**Figure 14.** Variation of (Re) with (h) for γ – AL2O3 at 5% Volume fraction

**Figure 15.** Variation of Re with h for CuO at 5% Volume fraction.

**Figure 16.** Variation of (Nu) with different (Re) for γ – AL2O3 at 1% Volume fraction.

**Figure 17.** Variation of Nu with different Re for γ – AL2O3 at 3% Volume fraction.
Figure 18. Variation of Nu with Re for $\gamma - \text{AL}_2\text{O}_3$ at 5% Volume fraction.

Figure 19. Variation of (Nu) with different Re for CuO at 5% Volume fraction.

Figure 20. Variation of Nu with different Re for $\gamma - \text{AL}_2\text{O}_3$ at different Volume fraction.

Figure 21. Variation of Re with h coefficient for CuO and $\gamma - \text{AL}_2\text{O}_3$ at 5% Volume fraction.
5. Validation

The comparison has been done between the present work and the reference [8] use circular fins with different perforations and apply the Sieder and Tate equations [14]. Figure 23 and Table 3 shows the variation of the Nusselt Number with Reynolds number of hot water at temperature 60°C along the inner tube. It can been noted that the behavior of the present experimental results are were very close Sieder and Tate equation behavior.

| Re     | Experimental | Equation |
|--------|--------------|----------|
| 1001.108 | 5.2          | 4.9      |
| 2002.216 | 7            | 6.5      |
| 3000.136 | 8.8          | 8.3      |
| 4001.244 | 10.5         | 10       |
| 5005.541 | 11.4         | 11.1     |

Figure 22. Temperature contours at different Reynolds Number for circle fin with triangle holes.
6. Conclusion

The present work mainly involves heat-transferred characteristics of the perforated and circular finned tube heat exchanger. Finned tube and Nanofluid are using for the present work to improve the heat transfer rate for the heat exchanger.

1. The average Nusselt number increased with an increase in Reynolds number and the Nusselt number of the circular fins with triangular perforated it would be better compared with finned perforated elliptic, finned circular perforated and without perforated, smooth tube 53.8%, 45.98%, 31.5%, 30.76% respectively with pure water on Reynold’s number 5000.

2. Increase thermal conductivity of Nanofluid had with the increase in volume fraction of (γ-A12O3), (α-A12O3) (CuO) 37.23%, 22.32%, 43.07% respectively at 5% fraction volume and temperature 60℃.

3. The viscosity of Nanofluids with significantly higher as compared to the base fluid Nanofluids tested (γ-a1203), (α- A12O3), and (CuO) 8.5%, 26%, and 1.93% respectively.

4. Nanomaterial (CuO) gives better results and (γ- A12O3) is better than (α- A12O3) at concertation 5%.

5. Best heat transfer enhancement at circler finned with triangular perforated than circler finned with finned perforated elliptic, circler finned with circle perforated and fin without a perforated and smooth tube.
6. An improved Nusselt Number between the fins perforated without perforated CuO at 5% is 21.37%, 20.29%, and 13.38% than a triangle, elliptic, and circle perforated respectively.

7. The effectiveness of the heat exchanger is directly proportional to the number of heat transfer units the circling fin with triangle perforated has the highest effectiveness value in comparison with (elliptic, circle, solid fin).

**Nomenclature**

| Symbol | Description |
|--------|-------------|
| A: Area (m²) |               |
| Re: Reynold Number |               |
| Nu: Nusselt Number |               |
| di: Inner diameter of tube (m) |               |
| h: Heat transfer coefficient (w/m.k) |               |
| kp: Thermal conductivity of nanoparticles (w/m.k) |               |
| Kw: Thermal conductivity of water (w/m.k) |               |
| K_{eff}/k_w | Ratio of thermal conductivity of Nanofluid to that of water |               |
| Nuf: Nusselt Number of Nanofluid |               |
| m: Mass flow rate |               |
| ρ | Volume fraction |               |
| Re_{eff}: Reynolds number of Nanofluid |               |
| μf: Viscosity of Nanofluid |               |
| Ti: Temperature inlet of the Nanofluid (°C) |               |
| T_o: Temperature outlet of the Nanofluid |               |
| T_m: Mean Temperature |               |
| Ts: Surface Temperature (°C) |               |
| u: Velocity (m/s) |               |
| L: Length of tube (m) |               |
| μw: Viscosity of water |               |
| pb: Density of particles kg/m³ |               |

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