CHAPTER 7

PERFORMANCE OF Al₂O₃/WATER AND
CuO/WATER NANOFLUID

7.1 INTRODUCTION

The heat transfer performance of nanofluid through tube was defined in terms of the Convective heat transfer coefficient. Convective heat transfer coefficient and Nusselt number for the nanofluid is obtained through following equation

\[
h_{\text{nf}}(\text{exp}) = \frac{C_{\text{p,nf}} \cdot \mu_{\text{nf}} \cdot U \cdot A \cdot (T_{b2} - T_{b1})}{\pi \cdot D \cdot L \cdot (T_w - T_b)} \tag{7.1}
\]

\[
N_{\text{uf}(\text{exp})} = \frac{h_{\text{uf}}(\text{exp}) \cdot D_b}{k_{\text{nf}}} \tag{7.2}
\]

The experimental results obtained from the investigation were compared with the theoretical results by using Seider-Tate equation. In this equation nanofluid convective heat transfer enhancement is due to the thermal conductivity increases as follows:

\[
N_{\text{uf}(\text{th})} = 1.86 \left( \frac{Re_{\text{nf}} \cdot Pr_{\text{nf}} \cdot D_b}{L} \right)^{1/3} \left( \frac{H_{\text{uf}}}{H_{\text{w,uf}}} \right)^{0.14} \tag{7.3}
\]

\[Re_{\text{nf}}\] and \[Pr_{\text{nf}}\] are the nanofluid Reynolds and Prandtl number respectively which are defined as follows:
\[ \text{Re}_\text{nf} = \frac{\rho_\text{nf}U_D}{\mu_\text{nf}} \]  
(7.4)

\[ \text{Pr}_\text{nf} = \frac{C_p_\text{nf}}{\mu_\text{nf}} \]  
(7.5)

The physical properties used for nanofluid were calculated from water and nanoparticles properties at average bulk temperature using following correlation [19].

\[ \mu_\text{nf} = \mu_w \left( 1 + 2.5\nu \right) \]  
(7.6)

\[ \rho_\text{nf} = \nu \rho_w + (1 - \nu)\rho_w \]  
(7.7)

\[ C_p_\text{nf} = \nu C_p + (1 - \nu)C_p_w \]  
(7.8)

Lee and Choi [2] correlation was used for determination of nanofluids effective thermal conductivity as follows:

\[ k_\text{nf} = \left[ \frac{k_s + (n - 1)k_{bf} - (n - 1)\nu(k_{bf} - k_s)}{k_s + (n - 1)k_{bf} + \nu(k_{bf} - k_s)} \right] \]  
(7.9)

In this equation ‘n’ is the solid particle shape factor, and \( n=3 \) were used to calculate the nanofluid thermal conductivity for spherical particles. The rheological and physical properties of the nanofluid were calculated at the mean temperature. Then the Nusselt number and convective heat transfer coefficient at different concentrations were calculated. The uncertainty of the calculated heat transfer coefficient, Nusselt number, and Reynolds number was calculated 1%, 2%, 3%, and 4% respectively.
7.2 PERFORMANCE VARIATION OF Al$_2$O$_3$/WATER AND CuO/WATER NANOFLUID WITH 1 %, 2 %, 3 % AND 4 % OF VOLUME CONCENTRATION

At first, some examinations are carried out using water to find the responsibility and correctness of investigational measurements. Then experimental outcomes are likened with the results calculated by using Seidar-Tate equation under turbulent flow regime for varying flow conditions. Figure 7.1 presents the valuation between the results of experimental and expected values of Nusselt number for distilled water and achieved the worthy settlement between tested records and Seidar-Tate equation outcomes which highlights the correctness and reliability of the experiments.

![Graph](image)

Figure 7.1 Nusselt number versus Reynolds number for pure distilled water

In the surviving study CuO/water and Al$_2$O$_3$/water nanofluid at different concentration of nanoparticles (1%, 2%, 3% and 4% of volume
fraction) in water have been used for investigating the performance of heat transfer rate of nanofluids in condensing unit of air conditioner. And the results are compared by varying the flow rate between 2.5 lpm to 5 lpm.

Figure 7.2 and Figure 7.3 represent the heat transfer coefficient of Al₂O₃/water and CuO/water nanofluid versus Reynolds number at different concentrations. As displayed in the Figure 7.2, outcomes show that the heat transfer coefficient of Al₂O₃/water nanofluid is much higher than that of base fluid. The observed results indicate that for increase in Reynolds number and volume fraction of nanoparticles in base fluid, heat transfer coefficient increases upto 49.84%.

![Figure 7.2](image-url)  
**Figure 7.2** Heat transfer coefficient of Al₂O₃/ water nanofluid and Water versus Reynolds number
Figure 7.3  Heat transfer coefficient of CuO/ water nanofluid and Water versus Reynolds number

Figure 7.3 displays heat transfer coefficient of CuO/water nanofluid as against Reynolds number at varying concentration of nanoparticles. As exhibited in Figure 7.3 heat transfer coefficients of nanofluid are better than that of base fluid, water. The observations conform that for intensification in volume concentration the heat transfer coefficient is amplified remarkably upto 58%.

Figure 7.4 and Figure 7.5 demonstrate the path followed by the Nusselt number for Al₂O₃/water nanofluid and CuO/water nanofluid at different Reynolds number and different concentration of nanoparticles.
Figure 7.4  Nusselt number of Al₂O₃/ water nanofluid and Water versus Reynolds number

Figure 7.5  Nusselt number of CuO/ water nanofluid and Water versus Reynolds number
Both the nanofluids exhibit enhanced Nusselt number than that of base fluid and for increased value of nanoparticles volume fraction Nusselt number also starts to increase. Figure 7.4 demonstrates the Nusselt number variation for Al$_2$O$_3$/water nanofluid with increased volume concentration. The results are showed that Nusselt number enhances in the series of 1.81% to 33.86%. Figure 7.5 displays the increase in Nusselt number for CuO/water nanofluid set against Reynolds number. The results show that Nusselt number improves in the range of 7.5% to 39.48% with increase in volume fraction. The development of heat transfer coefficient is an outcome from due to the increase in thermal conductivity of nanofluid by the diffusion effect of nanoparticles in the base fluid and particle migration; stochastic movements are also the feasible causes for improved heat transfer of nanofluids.

In order to compare the enactment of two working nanofluids in this work, Nusselt number for concentrations 1% and 4% are calculated through the experimental data. As presented in the Figure 7.6 between that two employed nanofluids there is no noteworthy difference. Based on the calculated results, CuO/water nanofluid owns superior thermal conductivity compare to Al$_2$O$_3$/water nanofluid. As expected, CuO/water nanofluid companion with higher heat transfer augmentation. Summary of previous experimental studies on the comparison of two nanofluids are shown in Table 7.1.
Figure 7.6 Comparison of Nusselt number of Al₂O₃/water nanofluid and CuO/water nanofluid versus Reynolds number

Table 7.1 Summary of experimental studies on Nusselt number of nanofluids

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Fluid</th>
<th>Geometry</th>
<th>Dimensions</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasiri et al</td>
<td>Al₂O₃/water and TiO₂/water nanofluid</td>
<td>An annular duct</td>
<td>L=2100mm D₁=10mm D₀=22mm</td>
<td>For the concentrations 0.1% to 1.5%, Al₂O₃/water nanofluid increased upto 23.8% and for TiO₂/water nanofluid increased upto 10.1%.</td>
</tr>
<tr>
<td>Suresh et al</td>
<td>Al₂O₃/water and CuO/water nanofluid</td>
<td>straight circular duct fitted with helical screw tape inserts</td>
<td>L=1000mm D₁=10mm D₀=12mm (tape twist ratios 1.78, 2.44 and 3)</td>
<td>For same concentration of 0.1 vol%, Al₂O₃/water nanofluid increases upto 166.84% and CuO/water nanofluid augmented upto 179.82%.</td>
</tr>
<tr>
<td>Present author</td>
<td>Al₂O₃/water and CuO/water nanofluid</td>
<td>Tube in tube condenser of Air conditioning system</td>
<td>D₀ = 20 mm D₁ = 18 mm d₀ = 10 mm d₁ = 8 mm</td>
<td>Heat transfer coefficient of Al₂O₃/water nanofluid increased upto 49.84% and for CuO/water nanofluid heat transfer coefficient enhanced upto 58%.</td>
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</table>
7.3 CONCLUDING REMARKS

1. Heat transfer coefficient of Al$_2$O$_3$/water nanofluid and CuO/water nanofluid are superior to the base fluid, water. And keep on increasing the volume fraction, both fluids show significant increment in the heat transfer coefficient. This can be due to increased thermal conductivity of nanofluid and other reasons such as presence of Brownian motion and diffusion of nanoparticles in base fluid.

2. Heat transfer coefficient of Al$_2$O$_3$/water nanofluid increased upto 49.84% and for CuO/water nanofluid heat transfer coefficient enhanced upto 58%.

3. As shown in the results, Nusselt number also increases compare to the base fluid. Nusselt number for Al$_2$O$_3$/water nanofluid increases upto 33.86% and for CuO/water nanofluid upgraded upto 39.48%.

4. Comparison of two working fluids shows that CuO/water nanofluid has superior convective heat transfer coefficient compare to Al$_2$O$_3$/water nanofluid. This is due to enhancement in the thermal conductivities of nanofluid for increased concentration of nanoparticles.