Experimental study of chilled water by using aluminum (Al) Nanofluid

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ABSTRACT: The project study of experimental work the chiller water was carried out using a nano-fluid aluminum (Al) with ethylene glycol (EG) with different concentrations (0.02, 0.04, 0.06, 0.08, and 0.1 %) to enhancement the performance and efficiency of the chiller water system and the thermal conductivity. Therefore, the most important point to know is its thermal conductivity. The study focus of this work is on nanofluids including aluminum of 10 nm nanoparticles. Thermal conductivity was measured at room temperature. The specific objectives are the determination of the influence of volume fraction, ultrasonic time, concentration, on the thermal conductivity of nanofluid (Al/EG). The results of the thermal conductivity measurement show the best interval time of sonicated which was 6 hours in comparison with the other interval times. The result shows that the thermal conductivity of different concentrations of nanoaluminum (Al) with base fluid ethylene glycol (EG) have increase linearly with increment of concentration of nanoaluminum (Al) in base fluid. The volume fraction concentration of the nanoaluminum (Al) with ethylene glycol (EG) increases with increase in the coefficient of performance COP and compared with ethylene glycol (EG) gives value enhancement very good 29% when addition nanoparticles. The temperature of the entering nanofluid increases with the increase of the coefficient of performance.

KEYWORDS: Nano-aluminum, Thermal conductivity, coefficient of performance COP, Nanofluid

INTRODUCTION

The fluids that contain ultrafine solid particles suspended in the liquid to be called "Nanofluids" such as liquids ethylene glycol, water, ethanol, oils, etc. The addition of these nanoparticles will change the heat transfer properties of this liquid. Nanoparticles are suitable for medical and engineering applications. There is no heat transfer equation for nanofluids. Investigated experimental effect of two types from nanoparticles Al2O3 and Cu with the base fluid of water the volume fractions of nanofluids ranges from 0.26% - 0.83%. So, the ability of this nanoparticle presents a high potential for energy transfer [1]. The study of effected nanoparticles (Al2O3) sizes 7 nm the suspension in water with concentration up to 2%, investigated experimentally performance of nanofluid in the heat exchanger and low flowrate in the exchanger [2]. The influence of particle size alumina Al2O3 on the thermal conductivity of nanoparticle suspension in water and ethylene glycol (EG) base fluid, with the average particles size 8-282 nm [3, 4]. Investigated experimental force convection used nanofluid (Al2O3 + water) and five different concentrations and applied in the radiator to vehicles so, calculated nuselt numbers, Reynolds number [5]. The studied four types of nanofluids such as CuO/ ethylene glycol /water, SiO2 / water, CuO/ water and multiwall carbon nanotube (MWCNT). The enhancement in thermal conductivity of multiwall carbon nanotube was 11.3 % at a volume concentration of 0.01 % [6]. The studied the thermal conductivity of various nanofluids scuttles of nanoalumina (Al2O3) in base fluid ethylene glycol (EG) which are measured at temperatures from 298 K to 411 K [7]. The measured the influential thermal conductivity of oxid copper (CuO) of 36 nm with water and oxid aluminum (Al2O3) of 33 nm with water [8]. The studied of the thermal conductivity improvement of alumina Al2O3 and CuO suspensions in distilled water and ethylene glycol (EG) [9]. The studied thermal properties of multi wall carbon nanotube MWCNT / epoxy composite [10]. The iron (Fe) and
titanium dioxide (TiO₂) nanofluids were prepared in the ethylene glycol [11]. It studied the effective thermal properties of gold (Au) with base fluid toluene, alumina with water, titanium dioxide with water, oxid copper with water and Carbon nanotube (CNT) with water [12]. Further, it shows the effects of different variations such temperature and volume fraction on the steady-state active thermal conductivity of nanofluids [13]. The studied influence of nanoalumina (Al₂O₃) size on the thermal conductivity in base fluid water has been investigated using steady-state method [14]. The thermal conductivity of (TiO₂), (Al₂O₃) and (ZnO) suspended in ethylene glycol (EG) and water [15, 16]. The measured thermal conductivity of three types of Al₂O₃ nanofluids was sonicating monodisperse in water [17]. The purpose of this research is to improve the chiller system and add nanofluids that have a high potential for energy transfer, the thermal conductivity is an important role in the heat transfer. So, the heat transfer of ethylene glycol is weak if it is used in the cooling system. This increases the global competition to develop fluids with high heat transfer Precision and high thermal conductivity. In this study, the enhancement of the efficiency and performance of the chiller water and the thermal conductivity by using nanoaluminum (Al) with base fluid ethylene glycol (EG). The study focuses of this work is on nanofluids including aluminum of 10 nm nanoparticles, and thermal conductivity was measured at room temperature. The specific objectives are the determination of the influence of volume fraction, ultrasonic time, concentration, on the thermal conductivity of nanoalumina (Al) with base fluid ethylene glycol (EG).

EXPERIMENTAL SET UP

The cooling system is shown in Figure (1) consists of the main elements of the cooling cycle, such as the reciprocating compressor model (MTZ 144-4VI), air cooler Condenser, the evaporator several types use the plate cooler and expansion valve device as shown in the figure (3) and through the ethylene glycol (EG) path in the cooling system during which flows rate and temperature inside and outside are measured.

![Figure 1. Experimental rig](image-url)
PREPARATION OF NANOFLUID SAMPLES

The investigation of nanofluid thermal conductivity requests effective arranger executions for making steady suspensions of nanoaluminum in fluid ethylene glycol (EG), which are count on the requisites of a specific implementation, several collections of ultrafine materials and liquids are of possibility interest. Researchers studied many methods of sundry rational technique for nanoparticle dispersal in fluid ethylene glycol (EG). Here, we applied one-step technique method to supply; a nanoaluminum (Al) with fluid ethylene glycol (EG) . The single step method is favorite to the multi-step process to reduce oxidation of the materials. With one step method the nanoaluminum (Al) is directly scattered in the ethylene glycol (EG) in a single process. The Aluminum Al nanoparticles of particle 10 nm, was dispersed in base fluids. The Al nanoparticles were prepared at five various concentrations (0.02%, 0.04%,
0.06%, 0.08%, and 0.1 %). So, the numbers of nanofluid samples are twenty (20) samples, part of my samples are shown in Figure (4). The nanoaluminum and ethylene glycol (EG) were mixed and preserved in an ultrasonic vibration bath for more than 10 hours to ensure properly dispersion. Acetyl trimethyl ammonium bromide was used as a Surface tension for the mixture. The (ATAB) was used as the dispersion stabilizer to prevent aggregation of the nanoparticles.

![Aluminum (Al) nanofluid samples](image)

**Figure 4.** Aluminum (Al) nanofluid samples

**MEASUREMENTS**

The parameters, the flow rate, temperature, and pressure were measured. The Bourdon pressure gauge was used. The Bourdon gauges pressures are classified: a high-pressure gauge (10 kg/cm² -25 kg/cm²) and a low-pressure gauge (1 kg/cm²-15 kg/cm²). As well as the use of thermocouples T type whose measurement ranges (-80 °C - 90 °C), were distributed at different points to measured temperatures. So, flow rate device is used of type a G1/2 flow meter and high pressure of 1.75 MPa and flow rate range (1 L/ min - 30 L/ min). The thermophysical property which comprises the thermal conductivity, specific heat, viscosity and density of Al and ethylene glycol (EG) at 25°C will be further used in the subsequent calculations. The volume fractions, V of 0.02%, 0.04%, 0.06%, 0.08%, and 0.1 % are used for thermophysical calculations from the following Equations (2) to (5). Use equations to calculate the volume fraction and the influence of density on the nanoaluminum (Al)/ethylene glycol (EG) are [18]:

\[
V\% = \frac{m_p}{m_p + m_f} 
\]  

(1)

Density of nanofluid:

\[
\rho_{nf} = (1 - V)\rho_f + V\rho_p 
\]  

(2)

Viscosity of nanofluid:

\[
\mu_{nf} = \mu_{bf} (1 +2.5V) 
\]  

(3)

Specific heat of nanofluid:

\[
(\rho C_p)_{nf} = (1 - V) (\rho C_p)_f + V(\rho C_p)_p 
\]  

(4)

Thermal conductivity of nanofluid

\[
k_{nf} = \frac{k_p+(n-1)k_f-(n-1)V(k_f-k_p)}{k_p+(n-1)k_f+V(k_f-k_p)}k_f 
\]  

(5)
Assume $n=2$ for the spherical nanoparticles.

The Reynolds number from equation (6). In this case, Reynolds number is measured using two different inlet velocity ($u_m$), which is $2 \text{ m/s}$.

Reynolds number, $Re$

$$Re_{nf} = \frac{\rho_{nf}u_mD}{\mu_{nf}}$$

Prandtl number, $Pr$

$$Pr_{nf} = \frac{\mu_{nf}C_p_{nf}}{\kappa_{nf}}$$

Nusselt number, $Nu$

$$Nu_{nf} = 0.021Re_{nf}^{0.8}Pr_{nf}^{0.5}$$

Measurement is made when the cooling system reaches a steady state, as shown Figure(3) diagram for the cycle of the cooling system under of the vapor-compression.

The equation (9) of the evaporator load capacity [19].

$$Q_{evp} = \dot{m}_r (h_1 - h_4)$$

The equation (10) of the condenser heat rejection.

$$Q_{con} = \dot{m}_r (h_2 - h_3)$$

The equation (11) of the actual compressor work.

$$W_{act} = \dot{m}_r (h_2 - h_1)$$

The coefficient of performance is loading capacity to the actual work of the compressor:

$$COP_{act} = \frac{Q_{evp}}{W_{act}}$$

RESULTS AND DISCUSSION

In this study, we have presented the data collection and processing of the thermal conductivity of the nanoaluminum (Al) /ethylene glycol (EG) samples. To establish the dependability of the experimental measurement, firstly we measured the thermal conductivity of ethylene glycol (EG) then compare the result with the nanofluid aluminum (Al) /ethylene glycol (EG). The influence of concentration, sonication time, and study prepare experimental results for the coefficient of performance of the chiller system.

Influence of ultrasonic on the Thermal Conductivity of Nanofluids

The study of the influence of sonication time on thermal conductivity is very paramount parameters in the beneficent thermal properties of nanofluids. The objective of this study is to determine the best interval time of sonication through the five interval sonication time which are 4, 5, 6, 8 and 10 hours. However, we tested the influence of sonication time for some samples of nanofluids which are nanoaluminum (Al) (10 nm) dispersal in EG at concentration 0.1%. First, we vary the sonication time of the nanofluids and measure the thermal conductivity of ethylene glycol (EG). We spotted a slight increase in thermal conductivity with increasing in sonication time of nanofluids, and we observed that after 6 hours of sonicated, the thermal conductivity properties of nanoaluminum (Al) /ethylene glycol (EG) does not change after this time. Figures 1 represented the thermal conductivity as a function of ultrasonic...
vibration time. For example, the thermal conductivity of a 0.1 % concentration of nanoaluminum (Al) in ethylene glycol (EG) at sonication 5 hours less than the thermal conductivity after 6 hours ultrasonic time. However, the thermal conductivity has increased as the ultrasonic time increments up to 6 hours. It shows fullness, at a 6 hours ultrasonic time. Hence, the best sonication time was taken for preparing nanofluids in this work is 10 hours. A very small increase in thermal conductivity with variable the ultrasonic time was spotted as shown in Figures (5). Thus, we have understood that each nanofluid achieves a better dispersion which can be achieved by the supersonic cell confusion by 10 hours.

![0.1 % Al/EG](image)

**Figure 5.** Influence of ultrasonic time on thermal conductivity of nanoparticle suspension in (EG)

**Measurement of the Thermal Conductivity of Nanofluids**

The measurement of the thermal conductivity of aluminum Al (10 nm) nanofluid samples was conducted. The influence of concentration on the thermal conductivity has been studied. The aluminum (Al) nanoparticles were intended at five various concentrations (0.02, 0.04, 0.06, 0.08, and 0.1 %) suspension in ethylene glycol (EG). Figure (6) shows the difference in the thermal conductivity of nanoaluminum (Al) / ethylene glycol (EG) as a function of volume concentration. The enhancements in thermal conductivity have a clear increase with the increment concentration of nanoaluminum (Al). It is also noticeable that thermal conductivity increments linearly with the volume concentration of nanoaluminum (Al). This notice can supply prudence into the mechanism of heat exchanger transport in nanoaluminum (Al) / ethylene glycol (EG). We especially remind the volume concentration of nanoaluminum (Al) reliance of thermal conductivity in conformity with Figure 6, because thermal conductivity would show more achievements if the nanoaluminum (Al) created suspensions in ethylene glycol. This could be deeper in nanofluids including higher volume concentration of nanoaluminum Al base fluid ethylene glycol exhibits 20.5% enhancement with 0.1% concentration nanoaluminum. However, at a concentration ranging 0.02 % to 0.1 % the thermal conductivity increment 0.273 W/m.K to 0.331 W/m.K for nanoaluminum (Al) / ethylene glycol (EG). Where, the increase of the thermal conductivity of nanoaluminum (Al) / ethylene glycol (EG) at the ranging of volume concentration from 0.02 % to 0.1 % was 5.82 % to 20.5 %. The results of thermal conductivity with a volume concentration of nanofluids have listed in Table (1).

**Table 1.** The thermal conductivity of nanoaluminum (Al) suspension in Ethylene Glycol (EG)

<table>
<thead>
<tr>
<th>Nanofluids</th>
<th>Volume fraction concentration %</th>
<th>Thermal conductivity of nanofluid</th>
</tr>
</thead>
</table>
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<table>
<thead>
<tr>
<th>Volume Concentration</th>
<th>Thermal Conductivity (W/m.K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>0.268</td>
</tr>
<tr>
<td>0.04</td>
<td>0.289</td>
</tr>
<tr>
<td>0.06</td>
<td>0.295</td>
</tr>
<tr>
<td>0.08</td>
<td>0.311</td>
</tr>
<tr>
<td>0.10</td>
<td>0.351</td>
</tr>
</tbody>
</table>

Figure 6. Thermal conductivity with volume concentration nanoaluminum (Al) / Ethylene Glycol

Influence of concentration of nanoaluminum (Al) on the COP in chiller system

The firstly, the experimental results for the coefficient of performance the chiller system use fluid only ethylene glycol (EG). So, figure (7) observed the influence of increment the temperature of entrance ethylene glycol (EG) to the plate cooler (evaporator) in cooling cycle at the stable velocity of the fluid, so the coefficient of performance is increasing with increment entrance temperature.

Figure 7. The coefficient of performance (COP) with entrance temperature
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The influence of utilizing nano-fluid aluminum (Al) through the plate cooling of the evaporator with ethylene glycol (EG) at $T_{\text{inlet}}$ is 35°C. The coefficient of performance (COP) increment when utilizing concentration (0.1%) nanoaluminum (Al) in ethylene glycol (EG) by (18%) atrn is $29 \frac{L}{\text{min}}$. So, we can observe increment of the improvement in the thermal conductivity of the ethylene glycol as shown in figure (8).

**Figure 8.** Influence of utilize volume concentration nanoaluminum (Al) / Ethylene Glycol on the coefficient of performance (COP)

The influence of the nanoaluminum (Al) addend to ethylene glycol (EG) observed of the enhancement the coefficient of performance in the chilled system. So, it used various five concentrations with ethylene glycol (EG). The coefficient of performance (COP) increases with increment the volume fraction of nanoaluminum (Al). This action is because of the enhancement of the thermal properties of nanoaluminum (Al) /ethylene glycol (EG). Also, The coefficient of performance (COP) is increasing with an increment of the temperature of nanoaluminum (Al) /ethylene glycol (EG) as shown in figures (9 - 13). So, the heat capacity of nanoaluminum (Al) /ethylene glycol (EG) is driving to increment the refrigeration influence in plate cooler (evaporator).

**Figure 9.** Influence of 0.02 % Al volume fraction on the coefficient of performance (COP)
Figure 10. Influence of 0.04 % Al volume fraction on the coefficient of performance (COP)

Figure 11. Influence of 0.06 % Al volume fraction on the coefficient of performance (COP)
CONCLUSION

The nanoAluminum Al of particle 10 nm was dispersed in base fluids ethylene glycol (EG). The Al nanoparticles were prepared at five various concentrations (0.02%, 0.04%, 0.06%, 0.08%, and 0.1 %). The influence of ultrasonic time on the thermal properties of nanoaluminum/ethylene glycol was conducted. The results show the best interval time of sonicated was 10 hours when compared with the other periods. Further, it shows that the thermal conductivity of all samples of nanoaluminum/ethylene glycol has increased linearly with an increment of concentrations of nanoparticles in ethylene glycol (EG). The coefficient of performance of the cooling system with nanoaluminum/ethylene glycol is more than the coefficient of performance of itself system with ethylene glycol (29%). The coefficient of performance has been established the increment with increasing concentrations (0.02%, 0.04%, 0.06%, 0.08%, and 0.1 %) of nanoAluminum of particle size 10 nm. The coefficient of performance is increment with increasing of inlet temperature of nanofluid in the cooling system.

REFERENCES


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