Heat transfer and pressure drop characteristics of Air- liquid heat exchanger

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Abstract - *The total heat transfer coefficient and friction coefficient of the heat exchanger were estimated using antifreeze (Ethylene glycol) as an experimental coolant. An Ethylene glycol/water mixture (50%:50 %)by volume was used as the base liquid. Purified and mixture at temperatures 6°C, 8°C, 10°C and 12°C, and air v6elocities (1.30 m/s -2.30 m/s -3.54 m/s) with a 20liter tank. The results showed that the thermal heat transfer coefficient increases when ethylene glycol is added to water and the mass flow rate. It was found that the excess heat transfer coefficient increases with the increase in temperature, as it is at a temperature of 12° C and a flow rate of 0.016 kg / s and the highest is 100 % when it was The air velocity was 3.45 m. /s. The fluid pressure drops increases with respect to adding ethylene glycol to water in a ratio of (50:50) by volume, at 10 degrees Celsius, the coefficient of friction improved to 17% and an air velocity of 1.30 m/s. In all cases of ethylene glycol, it shows a higher thermal conductivity compared to the base liquid under the same weight and temperature concentration*

Key Words: Enhancement of heat transfer, Heat exchanger, ethylene glycol/water Mixture.

1. INTRODUCTION

Energy transmission plays a vital role globally and occupies a dominant position in a very large area in various fields such as mechanical, electrical, chemical, transportation, nuclear and petroleum industries. .When fluid is added in the heat exchanger, the coil and tube heat exchanger is a pressurized heat exchanger that is widely used in many industrial applications, because it can satisfy a large heat transfer area in a small space with high heat transfer coefficients and narrow residence time distributions, they flow into tubes with a limited flow area. The conductivity of these conventional fluids can be improved by seeding nanoparticles with high thermal conductivity in various shapes. [1-2] .Ahmed et al. [3] synthesis of ethylene glycol-treated Graphene Nano platelets with one-pot, microwave-assisted functionalization for use as a high performance engine coolant ,Water and ethylene glycol were used to improve the thermal, physical and rheological properties, and the evaluation was measured for the thermal performance ‹The results showed an increase in the pressure drop at different temperatures and concentrations, and the pumping force increased, and the performance index became greater than 1.The energy efficiency ratio of the shrouded fins was higher than that of the cooling and flat coil by 9% and 17.4%.

Bhanvas et al. 4] studied the effect of the solid volume fraction, the Nano fluid Flow rate and inlet temperature on the heat transfer performance of nanofluid. The A maximum enhancement of 105% is observed in the heat transfer coefficient of the Nano liquid with the solid the size of the fracture is 0.5. Naddaf et al. [5]studied the heat transfer performance and pressure drop of Nano fluids using graphene and multi-walled carbon nanotubes based on diesel oil. Heris et al. [6] investigate Nano fluids containing CuO and Al2O3 oxide nanoparticles in water as base liquid at different concentrations and convective heat transfer of laminar flow through a circular tube with two-wall constant temperature. Sathish et al. [7] experimental investigation of heat transfer coefficient by convection on the mixture of nanoparticles used in automobile radiators on the mass flow rate Selvam et al. [8]study the overall heat transfer coefficient improvement of an automobile radiator with graphene-based suspensions. Amir et al. [9] awards improving engine performance by using aqueous graphene-ethylene glycol-coated nitrogen coolant.

Bhanvase et al[.10] intensification of convective heat transfer in water/ethylene glycol-based Nano fluids containingTiO2 Nano particles. Subhea et al [11] . experimental investigation of overall heat transfer coefficient of Al_2O_3/Water–Mono Ethylene Glycol Nano fluids in an Automotive Radiator .Pandel et al. [12] reduction in the surface area of the coolant investigate performance of cooling effect on automobile radiator using CU–TiO2nanofluid ,Studying the performance of the cooling effect on the car coolant using copper - TiO2nano fluid is the main objective of thestudy. Ho et al. [13]present a natural convection heat transfer of alumina aqueous Nano liquids in vertical square containers. kumar et al. [14]experimentally investigate the increase of heat transfer in a car radiator that works with a nano-liquid (water - magnesium oxide). Hameed et al. Derive [15]an experimental study to enhance heat transfer in a car radiator using Al2O3/Water - Ethylene Glycol Nano coolant.

Nambeesan et al. [16]showed the heat transfer and hydrodynamic properties using different metal-oxide nanostructures in horizontal concentric annular tube. Alawiat et al. [17]present an experimental study for heat transfer enhancement of Graphene nano ribbon nanofluid ın an automobile radiator ,Kilince et al. [18]improve the car radiator performance by using TiO2-water nanofluid, Ahmed et al. Investigate the [19]viscosity of low volume concentrations of magnetic Fe3O4 nanoparticles dispersed in ethylene glycol and water mixture ,This Letter reveals an experimental investigation of rheological properties of Fe3O4 nanoparticles dispersed in 60:40%, 40:60% and 20:80% (by weight) ethylene glycol and water mixture The results indicate that the 60:40% EG/W based nanofluid is 2.94 times more viscous compared to the other base fluids. Sundar et al. [20] experimental study of the effect of diameter on temperature Conductivity and dynamic viscosity of iron/water Nano fluids the study is based on the development of different Nano fluids by mixing a Water-based liquid with magnetic nanoparticles.

2. EXPERIMENTAL SETUP AND PROCEDURES

To investigate the heat transfer potential of the nanofluid as a coolant ,Includes pressure cooling circuit and a centrifugal pump that works to pump cold water to the heat exchanger and a water flow rate meter, and the pump is controlled by a manual valve, and there is another manual valve that acts as a passage, heat detectors to record the temperature of the inlet and outlet temperature of the heat exchanger cooling, air gauges to record air speed, thermocouples from Type K, To record the temperature before and after the heat exchanger and the entry and exit of water .The specifications of the coolant used for research are: They are listed in Table 1 .A centrifugal fan with a power of 0.37 kW is used. with a Varic (to change the input voltage. The fan was installed at the beginning of the duct of the test section and in this way the flow of air and the cooled liquid have an indirect connection with the tangential flow and as a result the heat exchange occurs between the flow of coolant in the low-temperature heat exchanger and the hot air passing over the tubes. The inlet air temperature was about 30°C + -0.10°C at full search. Thermal centrifugal: a pump giving a constant flow rate of 30 L/min used to change the flow rate using a manual valve. In the test apparatus, coolant is stored in a 50-liter tank (0.4m x 0.3 m x .5 m). A device is used to control the flow rate of the water and so the total volume of the coolant is constant in the experiment. Two thermometers are used to record the inlet and outlet temperature of the coolant .Mercury manometer is used to measure the pressure difference between water and air. Before installing the thermocouples, all thermocouples are calibrated over a wide temperature range (0-100°C).

4.3 Data reduction

3.1Calculation of heat transfer coefficient

In order to evaluate heat transfer coefficients in the radiator, the Following equations for the coolant were used

$$\dot{Q}_w = \dot{m}_w \, Cp_w (T_{w,out} - T_{w,in}) \quad (1)$$

The heat transfer rate of air from the coolant side can be estimated as:

$$\dot{Q}_a = \dot{m}_a \, Cp_a (T_{a,in} - T_{a,out}) \quad (2)$$

The actual average heat transfer rate is used for Eq. (14) which calculated as [1, 2]

$$\dot{Q}_{av} = 0.5(Q_a - Q_w) \quad (3)$$

Fig. 1. Photographic view of the experimental system

The overall heat transfer coefficient (U_o) in Eq. (15) is estimated by:

$$U_o = \frac{\dot{Q}_{av}}{A_s . F . \Delta LMTD} \quad (4)$$

Where (F=1) correction factor for crossflow in the case of unmixed/unmixed heat exchanger flow configuration.

The coolant side non dimensional parameters were calculated as:

$$\mathrm{Re}_w = \frac{\rho_w . V . d_{in,w}}{\mu_w} \quad (5)$$

$$\mathrm{Pr}_w = \frac{Cp_w . \mu_w}{K_w} \quad (6)$$

$$Nu_w = \frac{h . d_h}{k} \quad (7)$$

The air side non dimensional parameters were calculated as:

$$\varepsilon_w = \frac{\dot{Q}_{av}}{m^{\cdot} Cp_{\min}(T_{a,in} - T_{w,in})} \quad (8)$$

$$Nu_a = \frac{h_a.D_{in,a}}{K_a} \quad (9)$$

$$pr_a = \frac{Cp_a.\mu_a}{K_a} \quad (10)$$

Where (D_{hy}) is the hydraulic diameter of the radiator tubes, which the following equation is obtained as:

$$D_{hy} = (\frac{4L_s A_{ff}}{A_s}) \quad (11)$$

The Darcy friction factor for radiator tubes is calculated by Darcy-Weisbach equation as:

$$f_w = (\frac{2\Delta P_w.d_{hy}}{W.N_{tu}.L_{Tu}.V_w^2}) \quad (12)$$

Where the pressure drop of the waterside is given by:

$$\Delta P = g.H_{Hg\,(\rho_w - \rho_w)} \quad (13)$$

The effectiveness of crossflow unmixed/unmixed compact heat exchangers is presented by

The Nusselt number in single phase fluids can be calculated by correlations for the laminar flow through pipes [4] and for the flow in the compact heat exchanger at $550 \le Re_w \le 1850$ as:

$$Nu = 1.86(\frac{Re.Pr}{L/D_h})^{1/3}(\frac{\mu}{\mu_s})^{.14} \quad (14)$$

Where, *Re* represents tube-side Reynolds number which is based on tube hydraulic diameter whereas Pr is Prandtl number.

Although, we used a high Reynolds number as an input parameter, experimental results were compared by using the equations for friction (Eq. (26)).

$$f_w = \frac{64}{Re_w} \quad (15)$$

3. RESULTS AND DISCUSSION

5.1. Validation of the experimental results.

In order to check the reliability and accuracy of the experimental Set-up, one of the results should be validated with the different data in open literature, in addition, to compare the results theoretically with Well-known different empirical correlations by taking into account The appropriateness of the empirical equations of the applied boundaries with the current research One of the famous empirical equations is used to compare the results With the present data which suggested by Heris and Etemad [6].

5.1.1 Friction factor validation:

Figure 2 shows the friction factor validation of distilled and Reynolds water with an air speed of 3.54 m/s and a water inlet temperature of 6°C and 8°C. Comparison of results shows good agreement. It is clear from the figure that the friction factor of the heat exchanger decreases when the Reynolds number increases in all cases. Increasing the fluid velocity through the exchanger tubes leads to a random increase in the movement of the fluid particles over time, as well as the irregular velocity fluctuations and thus the pressure drop in the wrinkles across the coolant tube, and the friction factor is also reduced. The reason for the inconsistency in the results is due to the lack of insulation of the tubes It can be seen from the Reynolds number 2500 that the friction factor in the current study was less than the reference [4] by 4%, 9% at 6°C‹8°C.

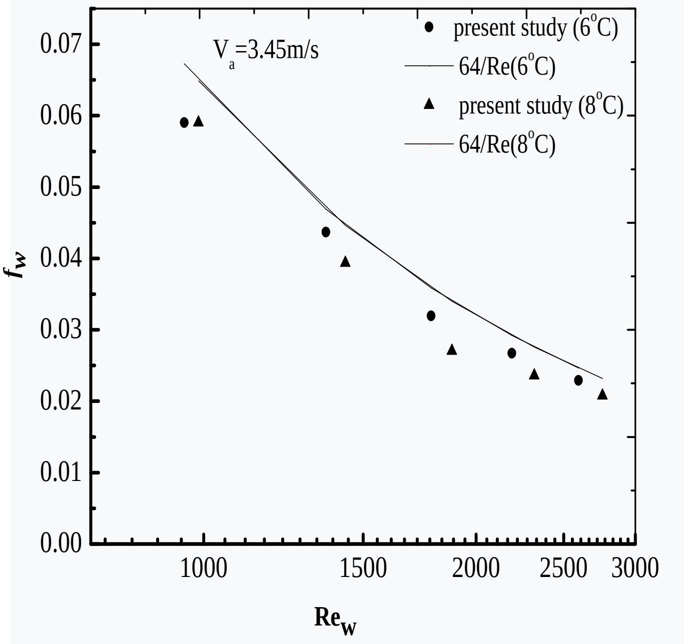

Fig 2 comparison between the measured f and Re and the predicted values for distilled water at6°C and 8°C.

Figure 3 shows the Nusselt number for the current study of distilled water against Reynolds number and the relationship between Sidr and Tate [20], and the current study at an air speed of 3.54 m/s and a water inlet temperature of 6°C degrees and 8°C. It can be seen from the figure at Reynolds number of 2000 that the nusselt number in the current study is lower than the sider and tate [20] corrlactions by 22% and 19%. This can be referred to the lack of insulation of the pipes.

5.2 The effect of temperature change:

Figure 4 shows the relationship between Nusselt number versus Reynolds number for different types of pure water

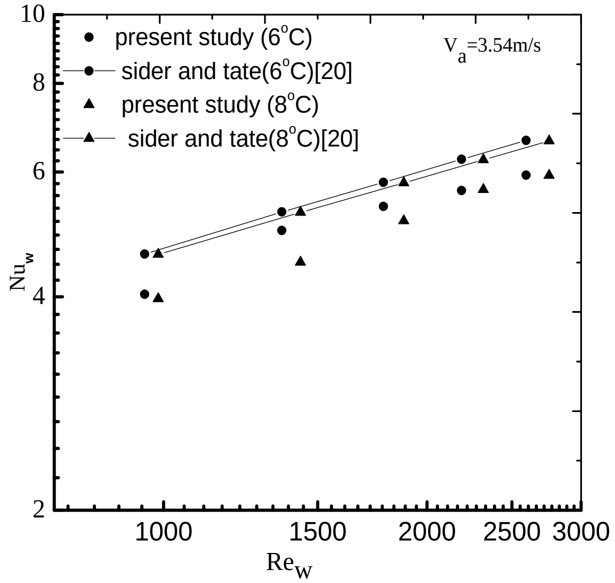

Fig 3 comparison between the measured Nusselt Number and Reynolds number and the predicted values for distilled water at 6°C and 8°C

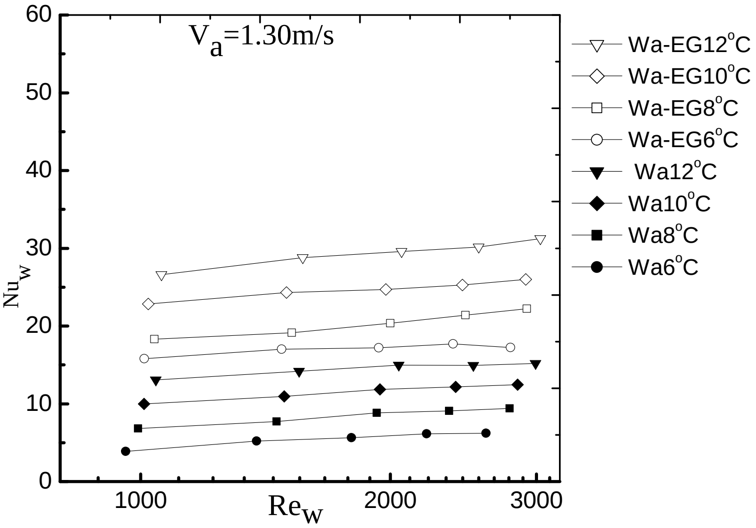

Fig .4 Comparison shows the relationship between Nusselt number versus Reynolds number for different temperature

(H_2O-EG) at different entering temperatures of 6°C, 8°C, 12°C. It is clear from the figure that the Nusselt number increases with an increase in the Reynolds number when the temperature changes, as an increase in the temperature of the working fluid increases the Reynolds number for all types of fluids. This is due to the change in the viscosity and density of the fluids used as a result of the temperature change, while the Reynolds number directly depends on the thermo physical properties of density and viscosity and therefore the Reynolds number is affected by changes in temperature, there to increase the temperature of the fluid increases the Nusselt number for all cases and values. The figure also shows the relationship between the Reynolds number and the Nusselt number at different temperatures when the mixture (water and ethylene glycol) is (50:50) % by volume and at an air speed of 1.30 m/s. The temperature and that the water temperature at 12ºC degrees Celsius is more than it was at 6ºC, and the Nusselt number at 2000 is higher than 6ºC, 8ºC and 10ºC by 200%, 50%and 36.6%. It is also clear from the figure that the Reynolds number increases with an increase in the Nusselt number when adding ethylene glycol to water at a ratio of (50:50) % by volume concentration. It may be related to the thermal expansion of the liquid and therefore the Reynolds number increases with Nusselt when ethylene glycol is added to water and that the Reynolds number at 12°C is more than it was at 6°C For water and ethylene glycol،Thermal conductivity of water increases with increasing temperature ،And at 12°C water showed a significant improvement over 6° C, 8 ° C and 10 ° C at Reynolds 2200 by 200%, 114.2% and 15.3%, respectively. When EG was added to water in a ratio (50:50) by volume at different temperatures, it showed a temperature improvement. At 12°C and the Reynolds 2200 is better than 6°C, 8°C and 10°C was 66% ،50%and 20% respectively. It is also clear from the figure that at a temperature of 12 ºC for the mixture and Reynolds number 2200 it was better than distilled water by percentage100% and at10 ºC for the mixture was better than distilled water by percentage 67% and at 8ºC for the mixture was better than distilled water by percentage110% and at 6 ºC for the mixture showed an improvement Marked percentage200% for distilled water.

Figure 5 shows the relationship between overall heat transfer coefficient and mass flow rate for different types of pure water (H_2O-EG) at different inlet temperatures of 6°C, 8°C, 12°C. It is clear from the figure that the mass flow rate increases with an increase in the overall heat transfer coefficient when the temperature changes, this is due to the change in that when ethylene glycol is added to water, it improves heat transfer and has a large heat capacity. As can be seen from the figure, the overall heat transfer coefficient increases with increasing mass flow rate at different temperatures when the mixture (water and ethylene glycol) is (50:50) % by volume and at an air speed of 3.54 m/s. And that the total heat transfer coefficient of purified water at 12 ° C is better than what it was at 10° C, 8 ° C and8° C by 25%, %,67%and 150%. When the mass impact rate is 0.018

kg/sec .It is also clear from the figure that the total heat transfer coefficient of the mixture increased with an increase in the mass flow rate when ethylene glycol was added to water at a ratio of (50:50)% in terms of volume concentration, and that the total heat transfer coefficient at 12 ° C is more than it was at 6 °C for water and ethylene glycol, the thermal conductivity of water increases with the increase in temperature, and at 12 °C water showed significant improvement over 6 °C, 8 °C and 10 °C at 0.018 °C mass flow rate of 67% ‹46 % and 11% respectively. As it can be seen from the figure that at a temperature of 12 ° C for the

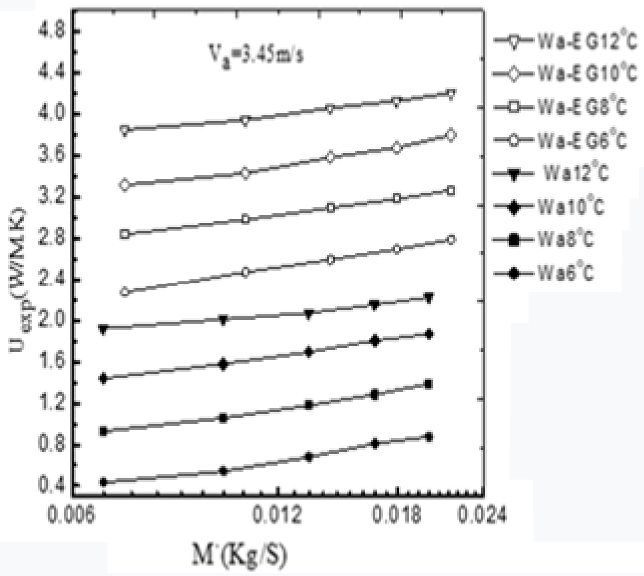

Fig.5. Effect of the heat transfer coefficient rate on mass flow when the temperature changes.

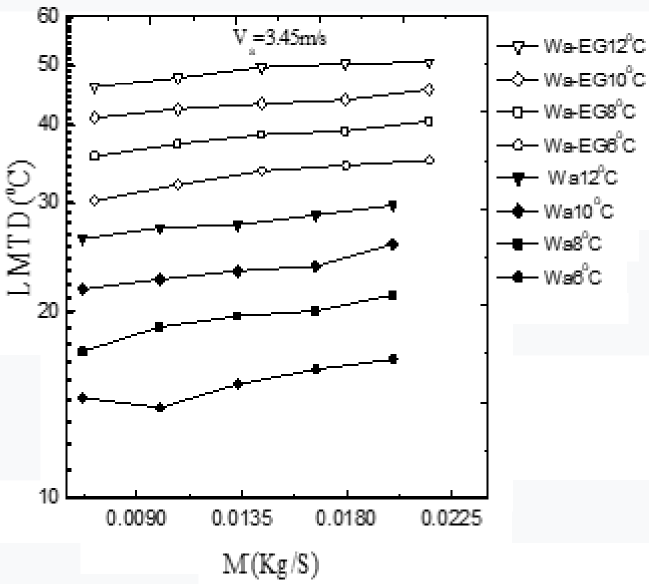

Fig.6. Effect of the logarithmic temperature difference mass flow rate on when the temperature changes

mixture and a mass flow rate was better than distilled water by 100% and at 10 ° C for the mixture it was better than the distilled water by 89% and at 8 ° C for the mixture. The mixture was better than distilled water by 150% and at 6°C the mixture showed improvement of 200% for distilled water. Figure 6 shows the flow rate versus logarithmic temperature difference (LMTD) of different types of pure water (H_2O-EG) at different temperatures of 6°C, 8°C, 10°C and 12°C. It is also evident from the figure that the mass flow rate increases with the increase of the logarithmic temperature difference ‹The logarithmic difference in temperature improves at higher temperatures and when ethylene glycol is added to water at a ratio of (50:50) % by volume and at an air speed of 3.54 m/s. it showed at 12c was beter than 10°C ‹8°C and 6°C by percentage 93% .‹45%.‹26% When the mass impact rate is 0.018 kg/sec .As it can be seen from the figure that the total heat transfer coefficient of the mixture increases with the increase in the mass flow rate when ethylene glycol is added to water at a ratio of (50:50)% in terms of volume concentration, and that the total heat transfer coefficient at 12 ° C is more than it was at 6 degrees Celsius for water and ethylene glycol, and the thermal conductivity of water increases with increasing temperature, and at 12 degrees Celsius water showed significant improvement above 6 °C, 8 °C and 10 °C at 0.018 °C mass flow rate 56% and25% and 11% respectively. As it can be seen from the figure that at a temperature of 12 ° C for the mixture, the mass flow rate was better than that of distilled water by 72 %, and at 10 ° C for the mixture it was better than that of distilled water by 28%, and at 8° C for the mixture ‹The mixture was better than distilled water by 100% and at 6 °C the mixture showed improvement of 94% relative to distilled water. when the air velocity increases, and thus the rate of heat transfer increases. The reason for this is that ethylene glycol has a low viscosity and low molecular weight that wasn't effects of the pumping process, as it has a large heat capacity and good thermal conductivity. It is also evident from the figure that at Reynolds Number 2000, the rate of heat transfer at 3.45 m/s was better than at 1.30 m/s and 2.30m/s by 43% and 12% for distilled water. It is also evident from the figure that in Reynolds Number 2000 the heat transfer rate of the mixture at a speed of 3.45 m/s is better than that of 2.30 m/s, 1.30 by 43%17.6 ‹% .It is also evident from the figure that in Reynolds Number 2000, the heat transfer rate of the mixture at 3.45 m/s is better than that of 3.45 m/s of distilled water at 100%, and at 2.30 m/s is better that of 2.30m/s of distilled water by 113% and at 1.30 m/s is better that of 1.30m/s of distilled water by117%.

5.3 The effect of changing air velocity

Figure 7 shows the overall heat transfer coefficient and mass flow rate of water, (water - ethylene glycol). It is clear from the figure that the overall heat transfer coefficient increases with the mass flow of water and the mixture when the air velocity increases, and thus the heat transfer rate increases.

The reason for this is that ethylene glycol has a low viscosity and low molecular weight that was not an effect for the pumping process, as it has a large heat capacity and good thermal conductivity. As shown in the figure at a mass flow rate of0 .016 kg/sec, the total heat transfer coefficient at 3.45 m/s was better than 1.30 m/s and 2.30 m/s at 150% and 50% for distilled water. It is also evident from the figure that at a flow rate of Mass at 0.016 kg/s, the overall heat transfer coefficient of the mixture (wa-EG) at 3.45 m/s was better than the heat transfer rate of the mixture 2.30 m/s, 1.30 m/s, 20%., 50% respectively. It is also clear from the figure that the mass flow rate at 0.016 kg/sec, and the total heat transfer coefficient at 3.45 m/sec for the mixture (WA-EG) is 3.45 m/s better than that of distilled water at100%, and at 2.30 m/s is better than 2.30 m/s. of distilled water at a rate of %150and at 1.30 m / s

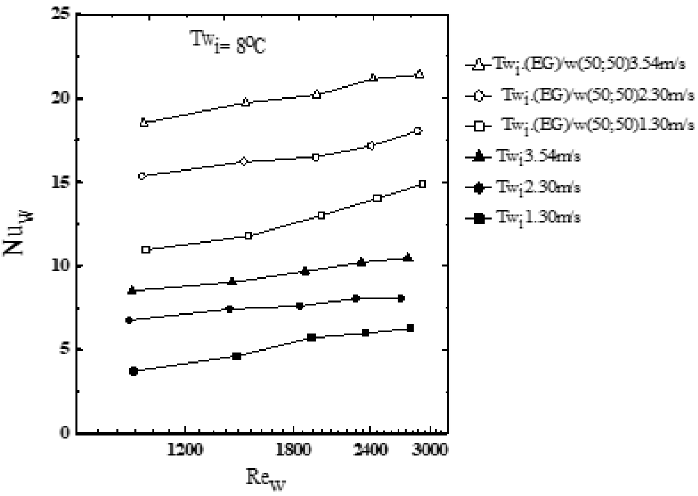

Fig. 7 The difference between the Nusselt numbers versus the Reynolds number for Different distilled water and(wa- EG) at different speed.

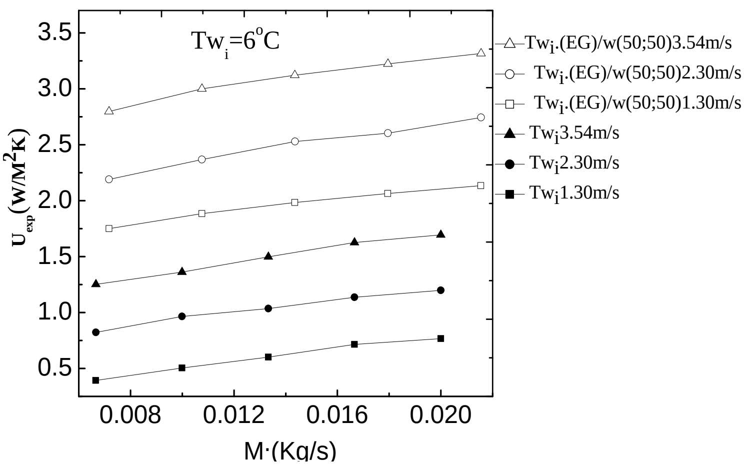

Fig. 8 Effect of mass flow rate on the excess heat transfer coefficient when air velocity changes.

5.4The effect of changing fluid:

is better than 1.30 m / s of distilled water at 186%. Figure 8 shows the mass flow rate of water (water - ethylene glycol) versus Logarithmic temperature difference (LMTD). It is clear from the figure that the logarithmic temperature difference (LMTD) increases with the flow of the mass of water and the mixture (wa-EG) when the air velocity increases, and thus the heat transfer and the logarithmic heat transfer coefficient increase. The reason for this is that with increasing speed, the logarithmic temperature difference (LMTD) increases as ethylene glycol has a large heat capacity and good thermal conductivity. It is also clear from the figure that at a mass flow rate of 0.016 kg/s, the logarithmic temperature difference (LMTD) at 3.45 m/s was better than 1.30 m/s and 2.30 m/s at100% and 34% for distilled water. It is also evident from the figure that at a mass flow rate of 0.016 kg/s, the logarithmic temperature difference (of the mixture) WA-EG) at 3.45 m/s was better than the heat transfer rate of the mixture 2.30 m/s, 1.30 m/s,11% and 20% respectively. It is also evident from the figure that the mass flow rate at 0.016 kg/s, and the logarithmic temperature difference at 3.45 m/s for the mixture (WA-EG) is 3.45 m/s better than that of distilled water by 50% and at 2.30 m/s better than 2.30 m/s. of distilled water at a rate of 80% and at a speed of 1.30 m/s is better than 1.30 m/s of distilled water at a rate of 150%.

6. Conclusion

An experimental study was performed on the overall heat transfer coefficient of (EG -H_2O) in heat exchanger for varying mass flow rate, and nanofluid inlet temperature and air velocity. The Using of EG as a base fluid tremendously enhances the convective heat transfer coefficient. Study on enhancing heat transfer in general .The mixture of (EG -H_2O) the experimental investigation results showed for the heat exchanger used the lowest concentration of 0 .33% of (EG -H_2O) has Significant effect on the convective heat transfer coefficient with respect to mass flow rate. When the temperature of entry of the stationary EG into the mass flow is increased. The rate of increase in the thermal heat transfer coefficient values the volume percentage of the mixture of EG- WATER is directly proportional to the coefficient of thermal heat transfer .The mass flow rate of the EG -WATER mixture is also directly proportional to the coefficient of thermal heat transfer size 96 % at a mass flow rate of 1.2 L/min It produced the highest convective heat transfer values.

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