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Experimental comparison of heat transfer coefficient and pressure drop of graphene oxide, titanium oxide and aluminum oxide on the radiator of a car

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In this research, the effect of using three Nano fluids contain graphene oxide (GO), titanium oxide (TiO_2) and aluminum oxide (Al_2O_3) was analyzed on the heat transfer of the car radiator by experiment in physical conditions on the car engine. Distilled water and ethylene glycol (60:40) as the base fluid was companied with three nanoparticles contain graphene oxide, titanium oxide and aluminum oxide that each one separately with 0.1, 0.2 and 0.3 weight percent and flow rates of 10, 20, 32 and 40 liters per minute were used at normal engine temperature. After the temperature of the radiator cooling fluid reached 90 degrees Celsius and the fan was turned on for one minute, the results showed that increasing the weight percentage of nanoparticles to the base fluid increases the displacement heat transfer coefficient and most increase in the coefficient of heat transfer at 0.3 weight percent to an approximate value of 5.2% in aluminum oxide, 11.9% for titanium oxide and 28.7% for graphene oxide compared to the base fluid was received. With the increase in weight percentage, the pressure drop and Nusselt number increased. The highest percentage increase in the radiator pressure drop for all three Nano fluids with 0.3 weight percentage and 2.2% for aluminum oxide, 3.5% for titanium oxide and 5.24% for graphene oxide were received.

1. Introduction

Nanoparticles are particles whose sizes are between 1 and 100 nanometers. In nanotechnology, a particle is defined as a small object that behaves as a complete unit due to its transport and properties. Nanoparticles used in nanocooling are usually made of metals, oxides, carbides or carbon nanotubes. They can be classified as metal oxides, metal-non-metal, carbon nanotubes and nanodroplets, which are currently used with base fluids to increase the thermal performance of cooling systems. The most common fluids are water, ethylene glycol and oil.

Nanoparticles cause a significant increase in fluid heat transfer. According to Figure 1, the interesting properties of nanofluids and the great potential they show to increase heat transfer have caused this group of fluids to be the focus of researchers' attention in recent years [1]. Nano coolants are considered as alternative and new generation liquids for thermal energy transfer and can be used as heat transfer fluids in heat exchangers instead of pure single phase fluids. Among the applications of nano in cooling heat transfer, radiators in automobile manufacturing, chemical engineering and process industries, solar

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water heater, refrigeration, cooling of electronic devices can be mentioned.

In recent decades, nanocooling has been implemented to overcome the need for better heat transfer due to the low thermal conductivity of common fluids such as water and ethylene glycol [2]. In continuation of the research on nanofluids, currently researchers have also used hybrid nanofluids that are synthesized by suspending dissimilar nano particles in a mixed or composite form.

Sinaq and Hamyaran [3] put the effect of using nanofluids in the radiator of vehicles as a monitoring option. According to their studies, the use of nanofluid instead of water can reduce the required front surface of the radiator by 10%. This order causes a reduction in aerodynamic resistance force and ultimately a reduction in fuel consumption up to 5%.

Sarpila and Hamyaran [4] in a numerical studied using the impact software of CuO-water-ethylene glycol nanofluid (50:50) with volume fractions of 2% and 4% in the radiator of a truck. The result of their research was a 40% increase in the Nusselt number and a 5% increase in engine power on the one hand and a 2.5% reduction in vehicle fuel consumption.

Putra and Maulana [5] numerically investigated the effect of using alumina water nanofluid with volume fractions of 1% and 4% in car radiators. Their results showed a 31 to 48 percent improvement in heat transfer coefficient for a volume fraction of 1% and an improvement of 52 to 79 percent for a volume fraction of 4%. The temperature period of their processing option was 50 to 70 °C.

Su and Hamyaran, thermal test and pressure drop of an example radiator for water, water-ethylene glycol (50:50) and water-alumina nanofluid with volume fractions of 1%-4% using the appeal option numerically. Their results indicated that the cooling capacity, total heat transfer coefficient and cooling pressure drop for water-alumina nanofluid with a volume fraction of 4% were 38.7%, 74% and 110.3%, respectively, compared to pure water for flow conditions. The cooling fluid and air are 12 kg/s and 8000 kg/hr, and the temperature of the cooling fluid and air is 80 and 20 70 °C.

Vaja and Hamyaran [6] studied numerically the heat transfer of nanofluids under a slow flow in a flat tube of a car radiator without the assumption of fins. They carried out their investigation for Reynolds numbers 100 to 2000 and inlet cooling fluid temperature 70 °C. The results showed that the heat transfer coefficient of the nanofluid compared to the base fluid at a Reynolds number of 1000 increases by 91% by adding 10% aluminum oxide nanoparticles and 86% by adding 6% copper oxide nanoparticles [7].

Kiaei et al. [8] the thermal performance of hybrid nanofluid with mono nanofluid and pure water base fluid compared.The heat transfer

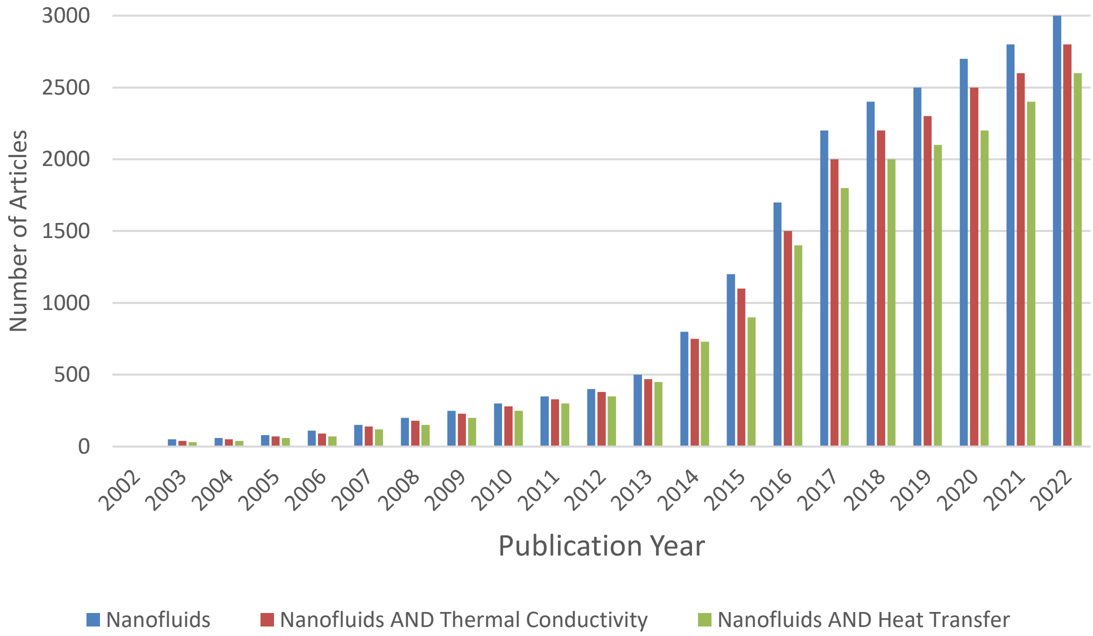

Figure 1: The number of scientific journal articles presented in the Science Direct database published between January 2002 and 2022 regarding nanofluids.

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performances of mono and hybrid nanofluids were determined using Nusselt number, overall heat transfer coefficient, convective heat transfer coefficient, and heat transfer rate. They showed an enhancement in the thermal performances of the radiator with an increase in Reynolds number and volume concentration**.**

Fakhari and Sheikhzadeh [9] studied heat transfer and pressure drop, ΔP, of a coolant nanofluid, obtained by adding alumina nanoparticles to an Ethylene Glycol-water mixture (60:40 by mass), in an automotive radiator. They indicated the performance evaluation using nanofluid in the car radiator and thermal efficiency enhanced.

Zhi et al. [10] reported the improvement of heat transfer with the help of aluminum oxide, titanium oxide and magnesium oxide nanofluids with a mixture of water and ethylene glycol with a ratio of 55% to 45% respectively. Aluminum oxide, magnesium oxide and tin oxide nanofluids had a high improvement in heat transfer compared to titanium oxide nanofluid which was the lowest value, less than 10% improvement compared to the base fluid. Regarding the magnesium oxide nanofluid at 1000 Reynolds number, a 252% improvement in heat transfer was reported.

Leung et al. [11] monitored the car radiator by using copper nanoparticles in ethylene glycol as a coolant. They monitored the effect of the volume fraction of copper nanoparticles and the Reynolds number effect of air and coolant on the thermal efficiency of the radiator as well as the pressure drop of the coolant and the power of the pump and found that the intensity of heat transfer increases with the increase in the volume concentration of nanofluids. During this thermal effort, the radiator is upgraded using nanofluid with ethylene glycol cooling with air and cooling Reynolds numbers. They also reported that about 12.13% increase in the pump limit at a concentration of 2% of copper nanoparticles at a volumetric flow rate of 0.2 m^3/s is required compared to the fluid axis.

Peyghambarzadeh and Hamyaran [12] tested the car radiator with aluminum oxide nanofluid with water base fluid. Volume concentration was variable at0.1% -1. The highest heat transfer improvement of 45% was reported with a volume concentration of 1%. Peyghambarzadeh and Hamyaran [13] tested a car radiator with copper oxide and iron oxide nanofluids with water-based fluid in three volume concentrations of 0.15%, 0.4% and 0.65%. The Reynolds number varied from 50 to 1000 and the cooling inlet temperature varied from 50 to 80 degrees Celsius. Both nanofluids showed a 9% improvement in the overall heat transfer coefficient compared to pure water.

Naraki and Hamyaran [14] reported the experimental results for the nanofluid of water and copper oxide, tested under the condition of laminar flow in the car radiator. The volumetric concentration varied from zero to 0.4% and the inlet temperature varied from 50 to 80 degrees Celsius. An 8% improvement in the overall heat transfer coefficient compared to pure water was reported for 0.4% nanofluid volume fraction.

Hossein and Hamyaran [15] tested titanium oxide and silicon oxide nanofluids with water-based fluid in a car radiator under sheet flow conditions. Volumetric concentration and inlet temperature were variable at 1-2% and 60-80 70 °C. The highest improvement of 11% and 22.5% compared to the pure fluid was obtained for titanium oxide and silicon oxide nanofluids, respectively.

Hafiz and Hamyaran [16] investigated the effect of water/zinc oxide nanofluid on car radiator. This treatment was performed for different volume percentages. The most appropriate improvement in heat transfer in this process was reported as 46%. This upgrade value was approved for a volume percentage of 0.2%.

Raja and Hamyaran [17] reviewed the characteristics of nanofluids, thermal transfer characteristics and its applications. They realized that different aspects of nanofluids, for example, thermal conductivity, viscosity, experimental studies, numerical studies of heat transfer, and applications of nanofluids have been an option.

Ta'ala Bigdali and Hamyaran [18] reviewed the phenomenon of heat and mass transfer of cooling nanofluid with special care for use in automotive. They indicated that nanoparticle engineering suspension is able to improve the thermal property characteristic. Taking into consideration the need for cooling systems with extremely high efficiency, recently nanofluids are known as car radiator coolants. However, at present, the nature of a nanofluid scale series implies micro-relationships, although with care among the implementation features, in favor of thermal physical properties that are not fully known.

Heydarbeigi [19] researched the effect of copper nanofluid, silver nanofluid, and aluminum oxide on the heat transfer measurement unit of the Ferguson 285 copper tractor engine radiator and awarded the

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logo in the working position of the engine and plowing field with a plow to a depth of 20 cm. Heat transfer with concentrations of 8 and 12% of copper and silver nanofluid and aluminum dioxide was improved by 16, 32, 11.3 and 13%, respectively.

Rahmatinejad et al. [20] applied the experimental heat transfer analysis of MF 285 radiator using nanofluid (Al_2O_3+water). For this purpose, a laboratory style was implemented and built. 20 nm particles were used with volume percentages of 1 to 4%. The temperature of the fluid entering the radiator was 85 degrees Celsius, and the flow rate of the cooling fluid was 3.18 liters per minute to 15.08 liters per minute, and the air flow rate was from varied from 3.3 m/s to 6.4 m/s. The results showed that increasing the coolant flow rate and air flow rate can improve the heat transfer effort, as well as increasing the volume fraction of nanoparticles in the base fluid, it improves the heat transfer rate and The output temperature decreases. In this way, by increasing the speed of the electric motor from 20 Hz to 40 Hz, the heat transfer coefficient of pure water is on average 26% and that of nanofluid is 29%. By adding 4 percent by volume Nanoparticles in the base fluid can improve the heat transfer rate by 37% on average and the transfer heat transfer coefficient by 28% compared to the base fluid**.**

Izadkhah et al. [21] researched the thermophysical coordinates of nanofluids based on water-ethylene glycol by using non-equilibrium molecular dynamics and computational fluid dynamics simulation methods. The result of the given symbol is that the addition of nanoparticles to the base fluid leads to the improvement of the thermal conductivity of the nanofluid, as well as the increase of the density and viscosity of the base fluid. The theoretical studies applied in this regard show a high regard for molecular dynamics simulations.

Ali Ahmad et al. [22] made the effect of TiO_2 nanocoolant with weight percentages of 0.1%, 0.2% and 0.3% with water and ethylene glycol on improving the performance of the car radiator a research option. The result indicated that nanosi water-ethylene glycol-based and TiO_2 nanofluid with a concentration of 0.2% can increase the effort of the car radiator by 47% compared to other concentrations.

Shankara, Sajan and Hamyaran [23] investigated the effect of graphene oxide with a weight percentage of 0.1% in water-based fluid and ethylene glycol with concentrations of (20:80, 30:70, and 60:60). The results showed that the nanofluid Graphene oxide with water-based fluid and ethylene glycol in the ratio (40:60) causes the improvement of heat transfer by 42.77% in 300 LPH flow rate and 18.14% in 360 LPH flow rate and 71.1% in flow rate. 240 LPH has been obtained.

In this present study, the effect of using nanoparticles of aluminum oxide (Al_2O_3), titanium oxide (TiO_2), and graphene oxide (GO) dissolved in distilled water and ethylene glycol with a ratio of 40% ethylene glycol and 60% (distilled water) in the car radiator system was investigated experimentally. This novel study test started with distilled water as the main fluid and then with distilled water and ethylene glycol (60:40) in the radiator of a TU7 engine in the distance when starting and finishing the circuit. It should be applied at a temperature of 90 degrees Celsius after one minute with a key at the normal engine temperature (after the string is activated after the start of the engine) and the temperature changes with fluid flow in 10, 21, 32 and 40 liter modes. Also with weight percentages of 0.1%, 0.2% and 0.3% of nanoparticles of aluminum oxide, titanium oxide and graphene oxide each dissolved separately in distilled water base fluid and Ethylene glycol with a ratio of (40% ethylene glycol and 60% distilled water) was applied in the distance between the bright light and the silence of the string, with flow rates of 10, 21, 32 and 40 liters per minute.

2- Materials and methods

Here we describe the type of nano materials and the method of preparing and mixing the nanofluid solution and explain about the materials and equipment used in this experiment and how they are used in the research process.

2-1- Preparation of nanofluid

In this investigation, we have purchased nano materials from Nano Sani Company with the brand (US Research Nanomaterials). The first nano particle used in this investigation was gamma aluminum oxide nano powder

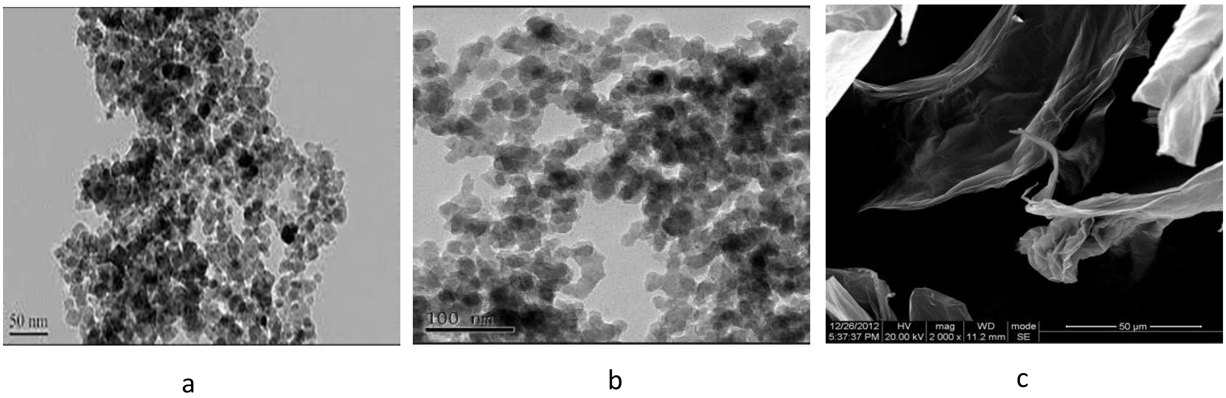

Figure 2: Pictures of nanoparticles a) aluminum oxide b) titanium oxide c) graphene oxide [10]

(hydrophilic), whose purity was +99% and the size of nano aluminum oxide particles was 20 nanometers and its specific surface area was 138 m^2 per gram and the morphology (particles shape) is relatively spherical. The color of nano aluminum oxide powder was white and the specific heat capacity of nano aluminum oxide gamma was 880 J/(kg-K) and its actual density was 3890 kg/m^3. The second nanoparticle used in

This study is titanium oxide nano powder (80% anatase + 20% rutile), which has an average particle size of titanium oxide (D50) of 20 nanometers and a purity of +99% and a specific surface area of 10-45 m^2 per gram and is white in color with a bulk density of 0.46 grams per cubic centimeter, the pH value of this nanoparticle is 5-6.5 and the weight loss is due to the effect of dehydration. 0.48% and weight loss was 0.99% on the effect of burning. The third nano particle used was nano oxide graphene with a size of 3.4-7 nanometers and a purity of 99% and the number of layers between 6-10 layers and a specific surface area of 100-300 m^2 per gram. The lateral dimensions of the particles (the diameter of graphene nano oxide plates) was 5-10 micrometers. Figure 2 show pictures of nanoparticles.

Clumping or the lack of desired suspension of nanoparticles in the liquid can be a multiple error in the measurement. There are different methods to avoid this phenomenon. The use of surfactant is one of the effective solutions in this case to the scale, a one-to-one ratio with the nanoparticle weight percentage to the surfactant titer for recording and dispersing nanoparticles into the axial fluid was added Gum arabic is a natural and edible gum that is obtained from a tree called Gum Senegal and is white in color and soluble in water. Figure 3 indicates the example of Gum arabic used in this experiment.

Figure 3: Gum arabic

Figure 4 digital scale gives the option to be used in this study After separating and weighing the nanoparticles and surfactants, an electric magnetic stirrer with a revolution of 1350 revolutions per minute is used for a period of 20 minutes to integrate the surfactant and nanoparticles with the foundation fluid (60% water and 40% ethylene glycol).

Figure 4: Digital scale

Figure 5 symbolizes the used magnetic stirrer Then, in order to disperse and separate small and nanometer particles and homogenize well, an ultrasonic device with a probe, W400 W400 ultrasonic homogenizer, which is prepared and set at a working frequency of 20 KHz, is used for a period of 20 minutes. It is used.

(a) (b) (c) (d) (a) (b) (c) (d) (a) (b) (c) (d)

Figure 7: Sedimentation of nano fluids of this experiment due to the passage of time((a): At the moment of composition (b): After 3 hours(c): After 3 days (d): After a month)

Figure 5: Magnetic stirrer

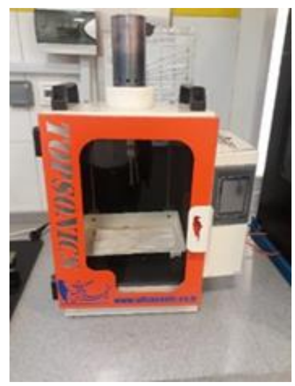

Figure 6: Ultrasonic with probe

For example, the features of this device are preparation and self-adjustment of the frequency in the range of ± 1 KHz, the ability and possibility to prepare and adjust the encounter opportunity, and the ability and possibility to use the period opportunity position (pulse). Figure 6 is the ultrasonic device with probe used in this appeal so far, nanofluids have been available for testing in the XU7 engine radiator, and for each nano material, three weight percent of 0.1, 0.2, and 0.3 have been considered, and the amount of surfactant for all weight percentages has a one-to-one ratio with nanoparticles.

It has been taken into account and the base fluid is ethylene glycol and distilled water with a ratio of 40% ethylene glycol (2.8 liters) and 60% distilled water (4.2 liters), totaling 6.6 liters. Figure 7 represents the effect of the passage of time at different time distances (at the moment of mixing, after 3 hours, after 3 days, and after a month) on the sedimentation of nanofluids of the test item.

2-2- Instructions for testing and collecting data

We installed the rotameter and thermomanometers and thermocouple thermometer on the XU7 engine. We installed the rotameter in the middle of the water outlet of the engine towards the top of the radiator after the thermostat and one of the thermomanometers after the rotameter and the inlet to the radiator.

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We installed the wheel thermomanometer at the outlet. We installed water under the radiator towards the engine .For a more accurate temperature study, we installed three thermocouple thermometers in one of the water inlet to the radiator, the second on the body of the radiator, and finally the third in the outlet of the water from the radiator. Figure 8 indicates the measurement possibilities installed on the engine to carry out the experiments, the prepared nano fluid with several weight percentages were poured independently into the radiator of the XU7 engine and after a full load, it was run by increasing the engine speed by gassing and holding it by the diag device.

Figure 8: Measuring equipment installed on the XU7 engine

In flow rates of 32, 20, 10 and 40 liters per minute, we record the temperatures in the distance when the string rotates in between and the string is interrupted.

After connecting the motor to a normal temperature at 90 70 °C, the filament will rotate for a period of one minute, and after it has passed, we note the temperature. In the distance between the delivery of the nano fluid and the replacement of the future nano fluid, the water paths and water channels of the engine and radiator are washed and cleaned with a unique salt-filled radiator device in order to wash the remaining possible sediments in the water paths.

Figure 9 shows the radiator washing machine.

Figure 9: Radiator washing device connected to the water path between the engine and the radiator.

2-3- Thermophysical properties of nanofluid

Assuming that the nanoparticles are well dispersed in the interior of the base fluid and the concentration of the particles in the overall system is uniform, the useful physical property of the composition of the treatment item can be determined by using some of the classical formulas that are usually used for two-phase liquids. The density of nanofluids can be calculated according to the rule of compositions from the relationship between Tamiz and Chu [24].

$$\rho_{nf} = (1-\varphi_p)\rho_b + \varphi_b\rho_p \qquad (1)$$

In this relation, φ is the volume fraction of nano particles, $\boldsymbol{\rho_{nf}}$ Density of nanofluid ، ρ is the density and index p represents the nanoparticles and b represents the base fluid. Equation 2 can be used to determine the specific heat capacity [25].

$$(C_p)_{nf} = (1-\varphi_p)(\rho C_p)_b + \varphi_p(\rho C_p)_p \qquad (2)$$

which can be written as relation 3

$$C_{p\text{،}nf} = \frac{(1-\varphi_p)(\rho C_p)_b + \varphi_p(\rho C_p)_p}{(1-\varphi_p)\rho_b + \varphi_p\rho_p} \qquad (3)$$

$C_{p\text{،}nf}$ the constant pressure specific heat of nanofluid is P index for nanoparticles and b index for base fluid. Equation 4 can be used to calculate the viscosity of nanofluids, [26].

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$$\frac{\mu_{nf}}{\mu_f} = 1 + 2.5\varphi \quad (4)$$

φ is the volume fraction of nano particles, μ_f is the dynamic viscosity of the base fluid and μ_{nf} is the dynamic viscosity of the nano fluid [26-30]. Table3 shows thermophysical properties of base fluids and nanoparticles.

Table3: Thermophysical properties of base fluids and nanoparticles Al_2O_3 ،TiO_2 و GO[31]

characteristic	Al_2O_3	TiO_2	GO	Gum arabic	Distilled water	Ethylene glycol
$c_p(Jkg^{-1}K^{-1})$	765	6890	2100	1400	4179	2420
$\rho(kgm^{-3})$	3970	4260	440	1350	997.1	1110.2
$K(Wm^{-1}k^{-1})$	40	11.7	1.89	190	0.613	0.253

Hamilton-Krosser relationship was used to determine the thermal conductivity coefficient of nanofluid [32].

$$K_{nf} = \left[\frac{K_p+(n-1)K_{bf}-\varphi(n-1)(K_{bf}-K_p)}{K_p+(n-1)K_{bf}+\varphi(K_{bf}-K_p)}\right] \times K_{bf} \quad (5)$$

In this relation, k is the thermal conductivity coefficient, and n is the particle shape coefficient, which is obtained from the relation $n = \frac{3}{\psi}$. ψ is the coefficient of sphericity and for spherical particles $\psi = 1$ and n=3 and for cylindrical particles n=6.

The displacement heat transfer coefficient is presented in the form of equation 6 [33].

$$h = \frac{q}{A\Delta T_b} \quad (6)$$

In this formula q is the heat transfer coefficient, A surface area and ΔT_b is difference temperature The dissipated thermal energy was calculated from equation (7).

$$q = \dot{m}C_{P_{nf}}(T_{in} - T_{out}) \quad (7)$$

The bulk temperature (T_b) is defined as the average temperature of the inlet and outlet of the radiator fluid

$$T_b = \frac{T_{in}+T_{out}}{2} \quad (8)$$

In this regard, $T_{in}$and $T_{out}$are the fluid temperatures at the inlet and outlet of the radiator, respectively. The displacement coefficient was calculated from equation 13.

$$h = \frac{\dot{m}C_{p_{nf}}(T_{in} - T_{out})}{A(T_b - T_w)} \quad (9)$$

In this regard, T_w is the temperature of the pipe wall

For fully developed laminar flow, the Nusselt number was calculated from the Keyes equation [34].

$$Nu = 3.66 + \frac{0.0668\left(\frac{D}{L}\right) Re \times Pr}{1 + 0.04\left[\left(\frac{D}{L}\right) Re \times Pr\right]^{\frac{2}{3}}} \quad (10)$$

Prandtl number was calculated from equation 11

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$$Pr = \frac{C\mu}{k} \quad (11)$$

Equation 12 can be used to calculate the Reynolds number of nanofluid flow

$$Re = \frac{4\dot{m}_{nf}}{\pi d_{hy} \mu_{nf}} \quad (12)$$

where $\dot{m}_{nf}$ is the mass flow rate of nanofluid and d_{hy} is the hydraulic diameter of the heat exchanger.

3-Results and discussion

In the current research, the effect of using three nanofluids of aluminum oxide, titanium oxide and graphene oxide homogenized in the base fluid of distilled water and ethylene glycol (40:60) on the heat transfer of the car radiator, experimentally and in a real state. It was run on the XU7 engine. Experiments in eleven distilled water conditions; Distilled water and ethylene glycol (40:60) and finally b Aluminum oxide, titanium oxide, and graphene oxide nanofluids with weight fractions of 0.1, 0.2, and 0.3% and flow rates of 10, 20, 32, and 40 liters per minute will be removed from the cool filament. applied. Give a sign by adding Gum arabic surfactant to graphene oxide for up to 30 days, titanium oxide for up to 25 days and aluminum oxide for up to 22 days.

By increasing the flow rate, the heat transfer coefficient is improved, and adding nanoparticles to the base fluid increases the heat transfer coefficient. As you can see, the highest heat transfer coefficient measurement unit associated with graphene oxide with a concentration of 0.3% by weight in the base fluid is at a flow rate of 40 liters per minute and it was calculated as 2570 W/(m^2 K), which is about 28.7% of the measurement unit of improving the heat transfer coefficient compared to the base fluid (distilled water 60% + ethylene glycol 40%). . It can be seen here that both increasing the flow rate and increasing the concentration of nanoparticles have a positive effect on improving the heat transfer coefficient of fluid transfer.

It can be seen that the Nusselt number increases with increasing Reynolds number. Also, increasing the weight fraction of nanoparticles to the fluid axis causes Nusselt to increase. In the following flow rates, with the small Reynolds number, the heat transfer measurement unit for nano fluid does not go up much compared to the base fluid, but with the increase of fluid flow rate, the kinetic energy of nanoparticles increased and the heat transfer is improved by them. The highest Nusselt number improvement scale compared to the axial fluid related to graphene oxide with 0.3% by weight at a flow rate of 40 liters per minute and the measurement unit is 234.2%.

Tests showed that the highest radiator pressure drop associated with graphene oxide at a weight fraction of 0.3% compared to the fluid axis at a proof flow rate of 40 liters per minute was calculated as 5.24%. The percentage of increase in Nusselt number and pressure drop of nanofluid compared to water at the highest Reynolds number in the Table 4 have been brought

Taking into account the percentage improvement of Nusselt number compared to the base fluid from formula (14), it can be seen that by increasing the concentration of nano materials in the fluid, with the increase in concentration from 0.1 to 0.3, the percentage increase of Nusselt number compared to the base fluid in Aluminum oxide has changed from 4.4 to 11.84, in titanium oxide from 11.67 to 17.26 and in graphene oxide from 53.94 to 234.2.

Experiments showed that the maximum pressure drop of the radiator related to graphene oxide at a weight fraction of 0.3% compared to the base fluid at a constant flow rate of 40 liters per minute was calculated as 5.24%. The percentage of increase in Nusselt number and pressure drop of nanofluid compared to water at the highest Reynolds number in the table (1-3) are given

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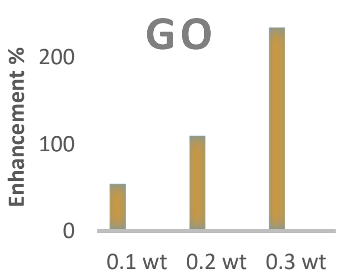
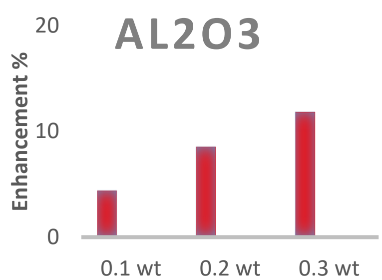
Table 4: comparison of the percent increase in heat transfer coefficient of displacement of tested nano fluids

a) 0.1% by weight b) 0.2% by weight c) 0.3% by weight

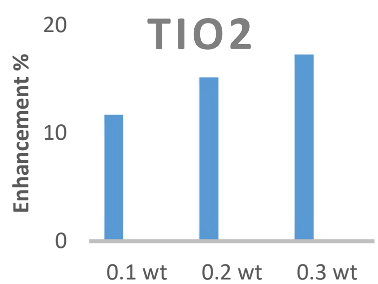
	nanofluid	percentage increase in thermal conductivity
a)	Graphene oxide (GO)	19.73
	Titanium oxide (TiO_2)	16.9
	Aluminum oxide (Al_2O_3)	5.5
b)	Graphene oxide (GO)	25
	Titanium oxide (TiO_2)	17.5
	Aluminum oxide (Al_2O_3)	4.2
c)	Graphene oxide (GO)	28.7
	Titanium oxide (TiO_2)	11.9
	Aluminum oxide (Al_2O_3)	5.2



(c)



(b)



(a)

Figure 10: Comparative diagram of the percentage increase in the Nusselt number of nanofluids compared to the Nusselt number of the base fluid.

a) Aluminum oxide b) Titanium oxide c) Graphene oxide

By calculating the percentage increase in Nusselt number compared to the base fluid from formula (14), it can be seen that with the increase in the concentration of nano materials in the base fluid, with the increase in concentration from 0.1 to 0.3, the percentage increase in the Nusselt number compared to the base fluid in oxide Aluminum has changed from 4.4 to 11.84, in titanium oxide from 11.67 to 17.26, and in graphene oxide from 53.94 to 234.2.

Here, by calculating the efficiency value of η from formula (15) at the highest concentration and highest flow rate of nanofluids, which performed best for us during the experiments, we can compare this index.

$$Enhancement\ Percent = \frac{Nu_{nf}-Nu_{bf}}{Nu_{nf}} \times 100 \qquad (14)$$

Here, Nu_{nf} is the Nusselt number of the nano fluid, Nu_{bf} is the Nusselt number of the base fluid. The graph (10) shows the percentage increase in Nusselt number according to the increase in concentration in three nanofluids compared to the Nusselt number of the base fluid i.e. distilled water and ethylene glycol (40-60).

$$\eta = \frac{\frac{h_{nf}}{h_{bf}}}{\frac{\Delta P_{nf}}{\Delta P_{bf}}} \qquad (15)$$

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Here, h_{nf} is the displacement heat transfer coefficient of the nanofluid, $h_{bf}$is the heat transfer coefficient of the base fluid, ΔP_{nf} is the pressure drop of the nanofluid and $\Delta P_{bf}$is the pressure drop of the base fluid. If the value of this index is higher than one, the beneficial effect of nanoparticles on increasing the heat transfer efficiency of the radiator can be confirmed.

Figure 11 shows the comparison of efficiency in three nanofluids. As can be seen, the highest

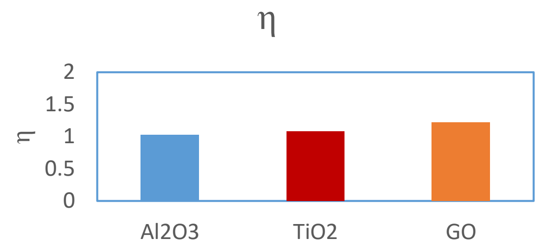

Figure 11: Shows the comparison of efficiency in three nanofluids with a concentration of 0.3 at a flow rate of 40 liters per minute.value of efficiency is related to graphene oxide with a concentration of 0.3% at a flow rate of 40 liters per minute with a value of 1.225.

Tables 5-7 compare the effect of increasing the weight percentage of three nanofluids separately on Nusselt and pressure drop at the highest Reynolds number.

Table 5: Comparing the effect of increasing the weight percentage of titanium oxide on Nusselt and pressure drop at the highest Reynolds number

weight percentage of nanofluid	Nusselt number increase percentage	Percentage increase in pressure drop
TiO_2(0.1 %wt)	11.67	1.1
TiO_2(0.2 %wt)	15.13	2.2
TiO_2(0.3 %wt)	17.26	3.5

Table 6: comparing the effect of increasing the weight percentage of aluminum oxide on Nusselt and pressure drop at the highest Reynolds number

weight percentage of nanofluid	Nusselt number increase percentage	Percentage increase in pressure drop
Al_2O_3(0.1 %wt)	4.4	0.55
Al_2O_3(0.2 %wt)	8.55	1.38
Al_2O_3(0.3 %wt)	11.84	2.2

Table 7: comparing the effect of increasing the weight percentage of graphene oxide on Nusselt and pressure drop at the highest Reynolds number

weight percentage of nanofluid	Nusselt number increase percentage	Percentage increase in pressure drop
GO(0.1 %wt)	53.94	1.65
GO(0.2 %wt)	109.3	2.7
GO(0.3 %wt)	234.2	5.24

To measure the fluid pressure drop inside the radiator, two pressure gauges were used at the inlet and outlet of the radiator. According to the tests, it was found that the best mode for measuring the pressure drop is at a flow rate of 40 liters per minute and in the slow mode of the cooling fan.

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The radiator pressure drop with weight fractions of 0.1, 0.2 and 0.3% compared to the base fluid at a constant flow rate of 40 liters per minute was the highest for all three nanofluids, and the maximum value among the three nanomaterials was related to Graphene oxide was calculated with a value of 5.24%. Figure 12 shows the radiator pressure drop versus the percentage of nanoparticles.

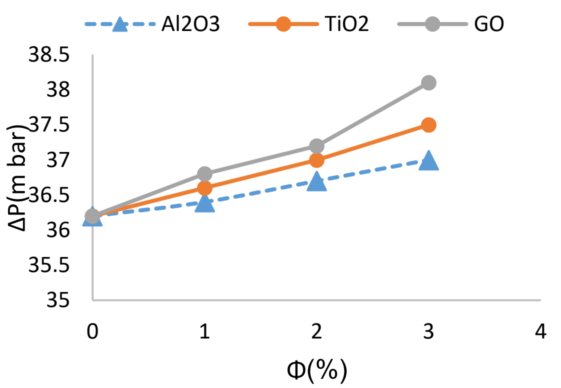

Figure 12: Radiator pressure drop at a flow rate of 40 liters per minute in terms of the percentage of nanoparticles

4-Conclusion

In the present study, the effect of using three nanofluids of aluminum oxide, titanium oxide and graphene oxide homogenized in the base fluid of distilled water and ethylene glycol (40:60) on the heat transfer of the car radiator, experimentally and in real conditions on XU7 engine was done. Tests in eleven cases of distilled water; distilled water and ethylene glycol (40:60) and finally with aluminum oxide, titanium oxide and graphene oxide nanofluids with weight fractions of 0.1, 0.2 and 0.3% and flow rates of 10 and 20, 32 and 40 liters per minute, in the slow speed of the cooling fan. The results showed that good stability was observed by adding Gum arabic surfactant to graphene oxide for up to 30 days, titanium oxide for up to 25 days and aluminum oxide for up to 22 days.

With the increase in flow rate, the heat transfer coefficient increases and adding nanoparticles to the base fluid increases the displacement heat transfer coefficient. So it was observed that the highest amount of heat transfer coefficient is related to graphene oxide with a concentration of 0.3% by weight in the base fluid. The flow rate was 40 liters per minute and it was calculated as 2570 W/(m^2 K), which showed an increase in the displacement heat transfer coefficient of about 28.7% compared to the base fluid (distilled water 60% + ethylene glycol 40%). was given Here, it was observed that both increasing the flow rate and increasing the concentration of nanoparticles have a positive effect on increasing the heat transfer coefficient of fluid displacement.

It was observed that the Nusselt number increases with the increase of Reynolds number. Also, the increase in the weight fraction of nanoparticles to the base fluid increases Nusselt. At low flow rates, as the Reynolds number is small, the amount of heat transfer for nanofluid does not increase much compared to the base fluid, but with the increase of fluid flow rate, the kinetic energy of nanoparticles increases and The heat transfer is increased by them. The maximum increase in Nusselt number compared to the base fluid related to graphene oxide with 0.3% by weight at a flow rate of 40 liters per minute was calculated as 234.2%.

Experiments showed that the highest pressure drop of the radiator related to graphene oxide in the weight fraction of 0.3% compared to the base fluid at a constant flow rate of 40 liters per minute was calculated as 5.24%.

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