Experimental Investigation to Heat Transfer Augmentation in A Car Radiator Worked with (Water - Magnesium Oxide) Nanofluid.

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Abstract

In this work, effect of adding MgO nanoparticle to base fluid (water) in car radiator has been implemented experimentally. In this investigation, an experimental test rig has been designed to study effect inlet temperature of nanofluid, the flow rate and nanoparticle volume fraction on heat transfer rates. Six different concentrations of nanofluid of 0.125%, 0.25%, 0.5%,1% ,1.5% and 2% have been prepared by mixed of MgO nanoparticles with water. Reynolds number of nanofluid was between 4500 and 19000.Thermal behavior of an automobile radiator worked with nanofluid has been compared with using pure water in it. So, the fluid circulating rate in radiator has been varied in the extent of the range of 1-8 L/min and fluid inlet temperature is also varied for all experimental. Results emphasized that Nusselt number increases with an increase of liquid inlet temperature, nanoparticle volume fraction and Reynolds number. As well as, the enhancement in heat transfer coefficient due to presence of nanoparticles is more than that without noanoparticles. These results can be achieved to optimize the dimension of an automobile radiator. A good agreement was seen with theoretical and experimental results with many authors.

Keywords: Convective heat transfer ; MgO-water nanofluid ; Car radiator ; Heat transfer ; cooling system; pressure drop.

الخلاصة

في هذا العمل أجريت دراسة عملية لمائع نانوي متكون من جسيمات اوكسيد المغنيسيوم تم تعليقها في الماء المقطر بستة تراكيز حجميه مختلفة. يتدفق المائع النانوي خلال جهاز التبريد لمحرك السيارة وهو احد أنواع المبادلات الحرارية المدمجة وهو جزء مهم في محرك السيارة التي تديرها في مختلف ظروف العمل. في هذا البحث تم عمل وتصميم جهاز عملي لجهاز التبريد و تم دراسة مجموعة متغيرات مثل درجة حرارة الدخول ومعدل التدفق والتركيز الحجمي للمائع النانوي .رقم رينولدز للمائع النانوي كان يتراوح ما بين 4500 الى 19000 .تم أيضا مقارنة معدلات انتقال الحرارة لجهاز تبريد السيارة يعمل بوجود المائع النانوي مع جهاز تبريد السيارة عندما يعمل بوجود الماء فقط. سرعة دخول المائع النانوي تتراوح من 1 لتر / دقيقة إلى 8 لتر / دقيقة ودرجة حرارة دخول المائع النانوي متغيرة في كل التجارب. النتائج التي تم الحصول عليها أكدت زيادة عدد نسلت بزيادة كل من درجة حرارة الدخول وعدد رينولدز والتركيز الحجمي للمائع النانوي .تمت التجارب باستخدام ستة تراكيز مختلفة من المائع النانوي وهي 0.125٪ ، 0.25٪ ، 0.5٪ ، 1٪ ، 1.5٪ و 2٪ حضرت بخلط مسحوق اوكسيد المغنسيوم مع الماء المقطر مختبريا بالتراكيز اعلاه . كذالك بينت النتائج أن معدلات انتقال الحرارة لجهاز تبريد السيارة الذي يعمل بوجود الجسيمات النانوية تكون أعلى منها في حالة استخدام الماء فقط وتزداد بزيادة التراكيز لكن أيضا زيادة التراكيز تؤدي إلى زيادة طاقة تدفق المائع. وكذالك تم الحصول على توافق بالنتائج مع النتائج النظرية والتجريبية مع العديد من الباحثين.

الكلمات المفتاحية: انتقال الحرارة بالحمل، اوكسيد المغنيسيوم–ماء ، مائع نانوي، مشع سيارة، منظومة تبريد السيارة، هبوط بالضغط

Nomenclature		Unit	Greek symbols		Unit
A	Area	m^2	μ	Dynamic viscosity	kg/m.sec
C_p	Specific heat	J/kg.ºC	$\dot{V}$	Volume flow rate	m^3/sec
D	Diameter	m	ρ	Density	kg/m^3
F	Friction factor	-	φ	Volume concentration	%
k	Thermal conductivity	W/m ºC	**Subscripts**		
L	Length of pipe	m	bf	Bace fluid	-
m	Mass	kg	f	liquid phases	-
Nu	Nusselt Number	-	in	Inlet	-
q	Amount of heat transfer	W	nf	Nanofluid	-
P	pressure	N/m^2	out	Outlet	-
r	Radius of pipe	m	p	Solid particle	-
Re	Remolds Number	-	s	Surface	-
T	Temperature	ºC			
u	Velocity	m/sec			

1-Introduction

Radiator is an significant auxiliary of vehicle engine operated by different working conditions. Ordinarily, it is utilized as a cooling system of the motor and mostly water is used as working fluid. Nanofluids are suspension of metallic or nonmetallic nanoparticle mixed with base fluid to enhance the heat transfer rate at various applications and to improve thermal efficiency and the engine's performance too. Car radiator is device performed to cool by circulating fluid in it, which consist of water as a coolant or a mixture of water and some external additives added to water like ethylene glycol to prevent freezing, this mixture called as a base fluid. There are several paper used nanofluid to enhance the performance of radiators by enhancing the properties of base fluid.

Peyghambarzadeh *et.al.*, 2011 studied the heat transfer enhancement of nanofluids in radiator at turbulent conditions. Fluid based nanofluids containing Al_2O_3 nanoparticles of the size 20 nm and in the range of concentrations 0.1-1 vol. %. Result sowed that the interesting enhancement of 45% comparing with the pure water application under highly turbulent flow condition. **Bhimani *et.al.*, 2013** compared experimentally the heat transfer in fresh water and water based nanofluid in a car radiator. Five different volume fractions of nanofluids from 0.1 vol. % to 1 vol. % were prepared by adding of TiO_2 nanoparticles to water. Liquid circulation rate was changed in the gauge of (90-120) L/min to make the fully turbulent regime. Results indicated that the heat transfer performance improved with increasing the fluid circulating rate. Also, the heat transfer performance can enhance up to 45% for nanofluid with low concentrations as compared to pure water. **Chavan *et.al.*, 2014** compared experimentally the forced convection in an Al_2O_3/water nanofluid to that of fresh water in automobile radiator. Using different concentrations of nanofluids in the range of (0 vol. % – 1 vol. %) were prepared by mixing of Al_2O_3 nanoparticles with the water. Flow rate of fluid was varied in range of 3-8 L/min to make fully turbulent regime. Outcome showed that when the nanofluid flow rate increased the heat transfer performance increased too. **Rahul and Kothawale, 2014** built an experimental system to study impact of adding Al_2O_3 nanoparticle to base liquid (EG - water) in radiator was examined experimentally. Enhancing the thermal efficiency of motor led to enhance the motor performance, reduced the fuel utilization and lessening the pollution emissions. Results showed that Nu, total heat transfer, effectiveness and overall heat transfer coefficient increased with increasing , nanoparticle volume fraction, air Reynolds number and mass flow rate of nanofluid through radiator. **Heris *et.al.*, 2014** examined tentatively traditional heat transfer liquids, for example, water and ethylene glycol, utilized for cooling liquids as a part of auto radiators. CuO (60 nm) nanoparticles were utilized as a part of a blend of EG/water as a base liquid. The experiments was performed for various volumetric fraction (0.05 vol.%-0.8 vol.%) of nanofluids of various flow rates (4-8 L/min) and inlet temperatures (35 ºC, 44 ºC, 54ºC). Results indicated that when the fluid circulating rate increased the heat transfer performance increased too. The heat transfer coefficient upgrade of around 55% contrasted with the base liquid was recorded in the best condition. **Tomar *et.al.*, 2015** presented experimental study of the mixture Ethylene glycol and water (50:50) combination with Al_2O_3 nanoparticle (size 40 nm) used in car radiator. In their experimental study volume concentration used 0.1%, 0.5%, 1% .It is watched that overall heat transfer coefficient and heat transfer rate expanded diverse volume fraction by blending Al_2O_3 molecule and flow rate run 2 - 5 l/min separately. **Ali *et.al.*, 2015** centered in this study on the utilization of MgO- water nanofluids for heat administration of an auto radiator. Nanofluids of various volume fractions (0.06 , 0.09 , and 0.12) vol.% to study heat transfer performance. The heat transfer enhancement for 0.12% volumetric fraction of MgO in base fluid was higher by about 31% than the others. **Jabade *et .al.*, 2015** built an experimental system for measuring the thermal conductivity by using copper oxide and iron oxide in automobile car radiator experimentally. Alumina / water nanofluid with low volume fraction (0.1 vol. %) was increased the efficiency of heat transfer over to 45% compared with pure water. The nanofluids of (CuO/Water) and (Fe_2O_3/Water) with volume fraction 0.15, 0.4, and 0.65 vol. % increased the overall heat transfer coefficient compared with water over to 9%. **Sureshkumar *et.al.*, 2016** studied experimentally, impact of adding copper nanoparticles to the base liquid (water) in radiator for the purpose of increasing the heat transfer rate. Results showed that, thermal efficiency can be improved, then reduction in fuel consumption and decrease in the pollutant emission. At last that the overall heat transfer coefficient of nanofluid was more prominent than that of conventional fluids and in this way the total heat transfer range of the radiator can be decreased. **Kumar *et.al.*, 2016** built an experimental system to investigate of three distinct liquids of nano-fluid and water mixture on heat transfer coefficient through level tube vehicle radiator and demonstrate that the nano-fluid with higher volume fraction of nano particles has more ability of heat transfer when compared with base liquid (water). The governing equation for heat transfer of radiator is given and investigation in various percentage of volume contraction of nano fluid. **Gajendiran *et.al.*, 2016** focused experimentally on the impact of Copper Nanoparticles on transformer oil heat transfer in Maruthi Suzuki Omni Motor Radiator utilizing water as a heat transfer specialist, however it is be very prescribed to utilize thermic liquids to get a viable heat transfer rate by utilizing nanofluids. Water has more heat transfer rate when contrasted and thermic liquids. Result demonstrate that ,by utilizing Nanofluids heat transfer rate is expanded contrasted with water and oil. And heat transfer rate for Nanofluids is 15% more than that of water. Likewise, heat transfer rate for Nanofluids is 66% more than base transformer oil. **Choure *et.al.*, 2016** researched experimentally the impact of including Al_2O_3 nanoparticle as a base liquid in radiator to enhance motor effectiveness, decrease weight of vehicle and size of radiator. Ethylene glycol based nanofluid and forced convective heat transfer of water will be compared experimentally with water, water- ethylene glycol (60:40), water/ethylene glycol nanoparticles have been achieved. The experimental result showed that Al_2O_3 based coolant showed better heat transfer as compared to other coolants.

In this study, the primary point is to improve the heat transfer characteristics for compact heat exchanger (auto radiator) with utilization of (MgO-water) nanofluid as a working liquid.

2. Thermo-physical properties of nanofluid and preparation of MgO/Water

The physical properties of nanofluid like thermal conductivity , viscosity, density, specific heat, and at various volume fraction of nanoparticles compute by used the following correlations (**Kannan *et.al.*, 2014**)

$$\rho_{nf} = \varphi\, \rho_p + (1-\varphi)\rho_{bf} \qquad (1)$$

$$Cp_{nf} = \frac{\varphi\, \rho_P\, Cp_P + (1-\varphi)\rho_{bf}\, Cp_{bf}}{\rho_{nf}} \qquad (2)$$

$$\mu_{nf} = \mu_{bf}\,(123\varphi_2 + 7.3\varphi + 1) \qquad (3)$$

$$k_{nf} = \frac{k_p + (n-1)k_w - \varphi(n-1)(k_w - k_p)}{k_p + (n-1)k_w + \varphi(k_w - k_p)} k_w \qquad (4)$$

The symbol n is the empirical equation calculated by n = 3/ψ where ψ is the particle sphericity which is characterized as the proportion of the surface area of a sphere with volume equivalent to that of the particle, to the surface area of the particle (**Kannan *et.al.*, 2014**). In this study, n is thought to be 3. **Table (1)** delineates physical properties of MgO, pure water and air with various concentrations of nanofluid obtained from the experimental work. **Table (2)** illustrates calculation of properties of nanofluid at different volume fraction.

Tables (1) properties for MgO nanoparticle, water and air.(Holman, 2010 and Zena,2016)

	ρ (kg/m^3)	**c_p(J/kg °C)**	**k (W/m.°C)**	**μ (kg/m.s)**
MgO	3560	955	45	-
Water at 75 °C	973.7	4191	0.668	0.000372
Air at 30 °C	1.1614	1005	-	0.00001846

Table (2) calculation of properties to nanofluid at bulk temperature 75 °C.

φ(%)	k_{nf}(W/m. ºC)	μ_{nf} (kg/m.s) x10^{-4}	$C_{p(nf)}$ (J/kg ºC)	ρ_{nf} (kg/m^3)
0.125	0.67	3.75466	4183.618	976.9329
0.250	0.6728	3.79466	4176.26	980.1658
0.5	0.6776	3.86722	4132.619	986.6315
1	0.6873	4.037316	4075.748	999.568
1.5	0.69717	4.23029	4020.33	1012.496
2	0.707	4.44614	3966.31	1025.426

The measure of nano particles required for arrangement of nanofluids is calculated utilizing the following equation .(**Sonage and Mohanan, 2015)**.

$$m_{MgO} = \left(\frac{\varphi}{1-\varphi}\right)\left(\frac{\rho_{mgO}}{\rho_{water}}\right) m_{water} \quad (5)$$

by the headings of the supplier, and after that the wicker compartment was placed in the bath. MgO nanoparticles are added to pure water after weighting it by sensitive balance. A three liters of water are used in all volume fraction. Six volume fraction of MgO/water nanofluid is used with weights in this work are seen in **Table (3)**. Set the mix of the water and (MgO) nanoparticles in the magnetic stirrer device to be mixed well for a hour. By then the mixture will be sent to the ultrasonic cleaner device to be kept for 6 hours to mix well and to ensure that the mixing happen impeccably checking the mix in the oscilloscope. After that the mix or nanofluid is set up to be sent to the lab to start the required examinations.

Table (3) Weights of (MgO) nanoparticles with volume fraction

Volume Concentrations (%)	0.125	0.25	0.5	1	1.5	2
Weight of MgO nanoparticals (gram)	13.6	27.2	54.53	108.86	163.3	217.733

3. Experimental apparatus and procedure

Figs. 1 to **4** show the experimental equipments and measuring system.

The experimental equipments include the following:

- Pump centrifugal type gives a maximum flow rate of 30 l/min.
- Fluid stockpiling tank whose aggregate volume is 5 litters (height of 100 cm) and diameter of 10 cm created from PVC .
- A forced draft fan.
- Vehicle radiator comprised of 41 vertical tubes with curved cross segment.
- 5 layer protected tubes (Isopipe 0.5 in measurement) are utilized as associating lines.
- Electrical heater.
- Thermocouples type K.
- U- tube manometer.
- Globe valve.
- A Platon type flow meter has ranging from (1- 10) L/min.

3.1.The Experimental Procedure :

Twenty eight experiment sets were conducted in this work in order to study and analyze . Each experiments was repeated three times to ensure confidence of the results.

The experimental procedure for each volume concentration (φ) of working fluid to determine pressure drop across radiator by monometer and it was calibrated by pressure sensor in order to correct the pressure readings, temperature at nine thermocouples were placed on pipe wall of radiator to measure pipe wall temperature and two thermocouples to measure the temperature at inlet and outlet of radiator ,consist of the following steps:

1- The prepared MgO /water nanofluid was utilized in six different volume fractions.
2- The working liquid fills 75% of the capacity tank whose aggregate volume is 5 litters.
3- The tank has electrical heater attached to an AC power supply.

4- Turn on the centrifugal pump with initial value of water discharge (10 L/min).
5- Supply the air from the a forced draft fan with initial value of air discharge (3 L/min).
6- Record the pressure and temperature at inlet and outlet of radiator and temperature on pipe wall of radiator .
7- Repeat the above steps by changing air discharge of working fluid that measured by a Platon type flow meter.The liquid flow meter was calibrated by measuring the actual flow rate using stopwatch and volumetric flask to interest allowing calibration curve being represented.
8- Repeat the above steps by changing the discharge of air When discharge of nanofluid is constant.
9- Repeat the above steps for another value of for each volume concentration (φ) of working fluid.
10- Repeated the same above steps for each concentration (0.125%,0.25%, 0.5%,1% ,1.5% , and 2%) with heating of nanofluid until 80 °C.

The steady state of the flow is considered when the pressure values across radiator is approximately steady and the specification of experimental setup as shown in table 4.

Table (4) The specification of experimental setup

1	Wind tunnel	Dimensions of Radiator , 58 X 48X 1000 (cm) Material- wood
2	a centrifugal pump	A centrifugal pump is driven by electrical motor having (220-240V), (0.5 hp), (50 Hz) and it has a maximum flow rate of (30 liter\min) with 2850 rpm
3	Tank	Capacity- 5 litre Material- **PVC** Height - 100 cm Diameter -10 cm
4	Liquid flow meter	A Platon type flowmeter Flow rate ranging from (0.4- 12) L/min
5	fan	Variable air discharge from 3 to 7 m/sec
6	Radiator	Radiator type is compact heat exchanger. The properties are shown in table 5

Table (5). Radiator Dimensions.

Dimensions of Radiator , L X H X W	57 X 47 X 2.5 (cm)
Number of fins	380
Number of tube	40
Space between tubes	1.175 cm
Dimensions of the tube	2.5 cm X 57 cm X 2.9 mm
Material of pipe and fins	Aluminum
Hydraulic diameter	$D_{hydralic}$=2.4105 cm
Width of fin	W_{fin} =W_{tube} =2 cm
Height of fin	H_{fin} =0.6 cm
Length of fin	L_{fin} = 0.1 cm

4. Theoretical calculations

4.1. Heat exchanger analysis

hydraulic diameter is calculated according **Cengel, 2012 .**

$$D_{hydralic} = \frac{4 \text{ x } A_{tube}}{P_{tube}} \tag{6}$$

$$A_{tube} = (D-d)*d+\frac{\pi}{4}\,d^2 \tag{7}$$

$$P_{tube} = \pi*d+2*(D-d) \tag{8}$$

Sub. in equation (5) get.

$$D_{hydralic} = \frac{4 * (D - d) * d + \pi\, d^2}{\pi * d + 2 * (D - d)} \quad (9)$$

Area of radiator represented area of rectangle with length is $L_{radiator}$ and width $W_{radiator}$ and the value of theses according table 5.

$$A_{radiator} = W_{radiator} \times L_{radiator} \quad (10)$$

The total length of fin is calculated according equation (11) see figure 3.

$$L_c = L_{fin} + H_{fin} \quad (11)$$

$$A_{fin} = 2W_{fin} \times L_c \quad (12)$$

The area between the fins is calculated according the following equation **Sureshkumar, 2016**

$$A_{unfin} = 2 \times L_{radiator} \times W_{tube} - H_{fin} \times W_{fin} \times N_{fin} \quad (13)$$

The total area for all radiator ($A_{fin,base}$) is represented summation A_{fin} and A_{unfin} according the following equation.

$$A_{fin,base} = N_{fin} \times A_{fin} \times +A_{unfin} \quad (14)$$

External and internal area of radiator is calculated according the above equation as.

$$A_{external} = A_{fin,base} \times N_{tube} \quad (15)$$

$$A_{internal} = A_{tube} \times L_{radiator} \times N_{tube} \quad (16)$$

In the radiator the amount of heat transferred between the air flow and (MgO-water) nanofluid coolant calculate as follow:

$$q = m_{air} \times C_{p,air} \times \left(T_{air,out} - T_{air,in}\right) = m_{nf} \times C_{p,nf} \times \left(T_{nf,in} - T_{nf,out}\right) \quad (17)$$

4.2. Reynolds and Nusselt Numbers of Nanofluid Calculations.

To get the heat transfer coefficient[h] and relating Nusselt number[Nu] as indicated by Newton's cooling law the following procedure followed as **Sureshkumar, 2016**:

$$Re_D = \frac{\rho_{nf} \times v_{nf} \times D_h}{\mu_{nf}} \quad (18)$$

$$v_{nf} = \frac{V^{\cdot}_{nf}}{A_{tube} \times N_{tube}} \quad (19)$$

$$q = m_{nf} \times C_{p,nf} \times \left(T_{nf,in} - T_{nf,out}\right) = h_{nf,exp} \times A_{internal}\,(T_b - T_s) \quad (20)$$

$$T_b = \frac{T_{in} - T_{out}}{2}$$

$$T_s = \left[\frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8 + T_9}{2}\right] \quad (21)$$

The heat transfer coefficient can be evaluated from Eqs. (20) as:

$$h_{nf,exp} = \frac{m^{\cdot} C_p (T_{in} - T_{out})}{A_{internal} \times (T_b - T_s)} \quad (23)$$

Nusselt number can be calculated according **Cengel, 2012 .**

$$Nu_{nf,exp} = \frac{h_{exp}\, D_h}{k_{nf}} \quad (24)$$

4.3. Reynolds and Nusselt Numbers of Air Calculations.

$$v_{air} = \frac{V^{\cdot}_{air}}{A_{radiator} - (H_{tube} \times L_{radiator} \times N_{tube})} \quad (25)$$

$$Re_D = \frac{\rho_{air} \times v_{air} \times W_{fin}}{\mu_{air}} \quad (26)$$

It can be assumed that the flow of air is similar to parallel flow over a flat plate according to **Cengel, 2012** is given as:

$$Nu_{air} = 0.037 \times Re^{0.8} \times Pr^{0.333} \quad (27)$$

$$h_{air,exp} = \frac{Nu_{air} \times k_{air}}{W_{tube}} \quad (28)$$

4.4. Overall Heat Transfer Coefficient calculation according Cengel, 2012 .

$$\eta_{fin} = \frac{\tanh(aL_c)}{L_c} \quad (29)$$

$$a = \sqrt{h_{air}\, P / K_{Al}\, A_c} \quad (30)$$

The overall surface efficiency is needed for the external flow of air because the imperfections of the flow around the fins must be considered according to **Sureshkumar, 2016** is given as:.

$$\eta_{overall} = 1 - \frac{\mathrm{N_{fin}}}{A_{,fin\,base}}(1 - \eta_{fin}) \quad (31)$$

$$UA = \frac{1}{\left[\frac{1}{\eta_{overall} \times h_{air,exp} \times \mathrm{A_{external}}}\right] + \left[\frac{\ln\left(\frac{Do}{Di}\right)_h}{2\,\pi\, k_{Al}\, L_{tube}}\right] + \left[\frac{1}{\eta_{fin} \times h_{nf,exp} \times \mathrm{A_{internal}}}\right]} \quad (32)$$

4.5. calculation the rate of heat transfer.

To determine the overall heat transfer coefficient, the surface area and the rate of heat transfer according to **Cengel, 2012**:

$$\mathrm{Q = U_i A_i\, F\, \Delta T_{lm,CF}} \quad (33)$$

$$\Delta \mathrm{T_{lm,CF}} = \frac{\Delta T_1 - \Delta T_2}{\ln[\Delta T_1 / \Delta T_2]} \quad (34)$$

$\Delta \mathrm{T_1 = T_{h,in} - T_{c,out}}$, and $\Delta \mathrm{T_2 = T_{h,out} - T_{c,in}}$

Furthermore, according to **Cengel, 2012** calculated the correction factor (F **)** depends on two temperature ratios *P* and *R* defined as:

$$\mathrm{P} = \frac{\mathrm{t_2 - t_1}}{\mathrm{T_1 - t_1}} \quad ,and \quad \mathrm{R} = \frac{\mathrm{T_1 - T_2}}{\mathrm{t_2 - t_1}} \quad (35)$$

4.6. Pressure drop and pumping power calculation.

Pressure drop is calculated from U-tube manometer at inlet and outlet manometer.

$$\Delta \mathrm{P_{nf} = P_{out} - P_{in}} \quad (36)$$

The friction factor in a elliptic tube and Pumping power according to **Cengel, 2012** is given as:

$$\dot{\mathrm{W}}_{\mathrm{pump}} = \dot{\mathrm{V}}_{\mathrm{nf}} \times \Delta \mathrm{P_{nf}} \quad (37)$$

5. Validation of experimental setup.

Keeping in mind the end goal to concentrate the reliability and the accuracy of the experimental setup, the heat transfer coefficients are experimentally measured utilizing water as the working liquid before adding Mgo nanofluids. Examination was done between the aftereffects of the experimental results as well as three empirical correlations: one of them recommended by **Dittuse Boelter 1930** correlation, and the other created by **Petukhov *et.al.*, 1970**. These Two relations are shown in equations (38 – 40), respectively.

$$Nu = 0.0235\, Re^{0.8} Pr^{0.3} \tag{38}$$

$$Nu = \frac{\left(\frac{f}{2}\right)(Re - 1000)Pr}{1 + 12.7\left(\frac{f}{2}\right)^{0.5}\left(Pr^{\frac{2}{3}} - 1\right)} \tag{39}$$

Where:

$$f = \frac{1}{(1.82 * \log\,(Re) - 1.64)^2} \tag{40}$$

The result of two above equation and experimental data in this work is drown in **fig. 5**. In this figure sensibly good agreement can be shown between the measurements over the Reynolds number range used in this work and Petukhov equation.

6. Results and Discussion

Fig 6. shows relation between pumping power and volume fraction of MgO-water nanofluid when flow rate of nanofluid was fixed at 5 L/min and velocity of air is 7 m/sec but the volume concentration of MgO nanofluid was shifted. Results show that about 6 % increase in pumping power was seen at 2% addition of MgO nanofluids contrasted with pure water , however it around 3% increment in pumping power was seen at 1% addition of MgO nanofluids contrasted with pure Water. The results may valid to many authors such as **Tomar *et.al.*, 2015**. **Fig 7**. shows relation between heat transfer rate and mass flow rate of MgO nanofluid at different volume fraction. Results showed that increment the mass flow rate of nanofluid and volume fraction enhanced the total heat transfer rate. **Fig. 8** demonstrates impact of (MgO) particles to the overall heat transfer coefficient at constant mass and air flow rates. It demonstrated that it expanded overall heat transfer coefficient in view of air side up to 40 % from above figure at constant air velocity (7 m/sec) and constant mass flow rate (3 L /min). **Fig. 9** explain the impact of the mass flow rate on the radiator performance at a constant air velocity (7 m/sec). It has been that when overall heat transfer coefficient increased as mass flow rate and the volume concentrations increased. **Fig. 10** explain the relation between Nussult number and flow rate of coolant at different of volume fraction. It is found out the values of Nussult number increased as volume concentrations and flow rates increased. This is due to one reason, when the volume concentrations and the nanofluid thermal conductivity increment, the number of nanoparticles increased and subsequently their total contact area was basically higher, it coursed a more effective heat exchange between the nanoparticles and water. The results closed to numerous papers, for example **Heris *et.al.*, 2014**. **Fig. 11** demonstrates the Nussult numbers as an element of Reynolds numbers at various volume fraction of (MgO) nanofluid. As depicted in **fig. 11**, Nussult number increases with the increment in Reynolds number and nanoparticle volume fraction. This is expected to high flow rates the dispersion impact and disordered development of the nanoparticles intensified the mixing fluctuations and increased heat transfer coefficient. Additionally, increasing the volume fraction nanoparticles intensified the mechanisms responsible for the enhanced heat transfer. The results closed to many papers such as **Sultan *et.al.* 2016.**

7. Conclusions

In this study the overall heat transfer coefficients in the car radiator have been measured with two fluids: pure water and water based nano-fluid (littile amount of MgO nano-particle in water) at various volume fraction. The study leads to the following conclusions **:**

1. The nearness of MgO nano-particle in water increases the heat transfer rate of the car radiator. The increment of heat transfer relies on upon the amount of nano-particle added to pure water. At the volume fraction of 0.125 vol.%, the heat transfer increment of 6 % contrasted with pure water was recorded at 2 vol %, increment up to 40%

2. The size of the radiator (total heat transfer area) can be decreased with the assistance of the nanofluid.

3. Increment the heat dissipation rate (Q) with nanoparticle volume fraction increment in the water, the maximum increment percentage (40%) over the base liquid, happens at (2 vol %) nanoparticle volume fraction.

4. Increment the volume fraction of nanoparticle in the nanofluid substantially affect upgrade of heat transfer coefficient , properties of fluid for example thermal conductivity , density , and viscosity , but it caused decreasing the specific heat .

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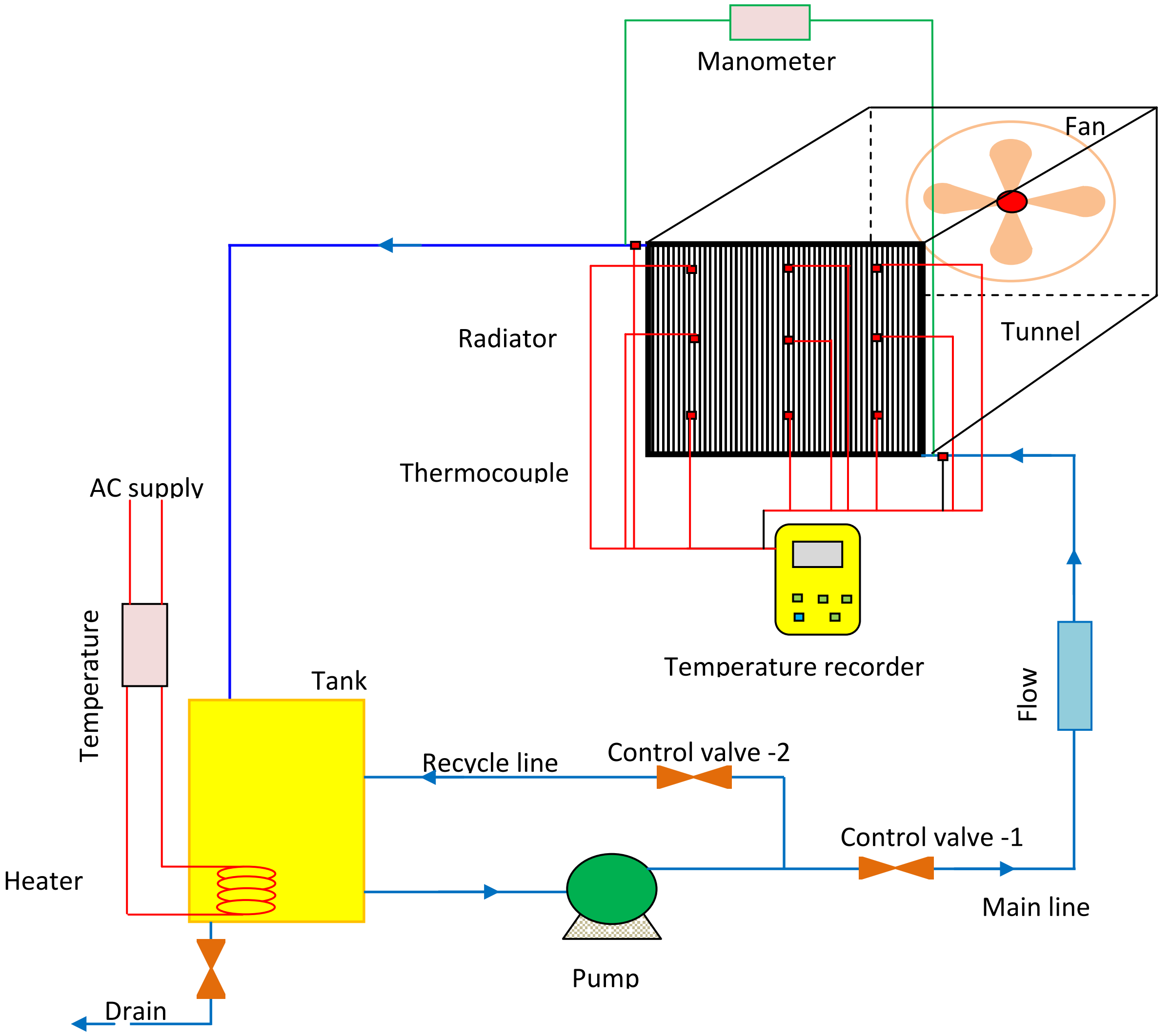


Fig. 1 Schematic of experimental rig.

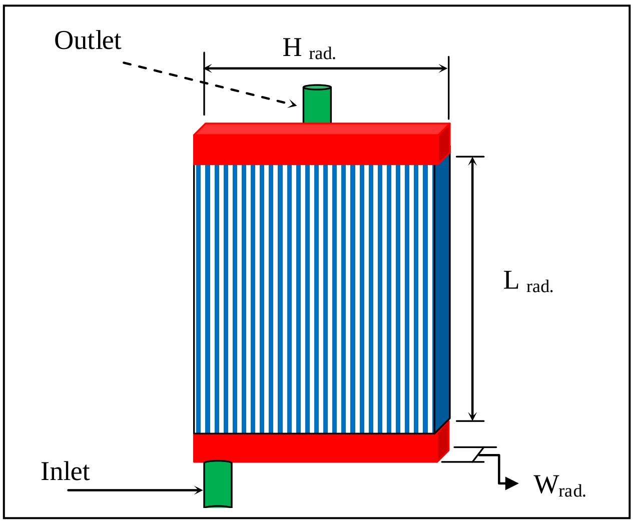


Fig. 2 Schematic of radiator

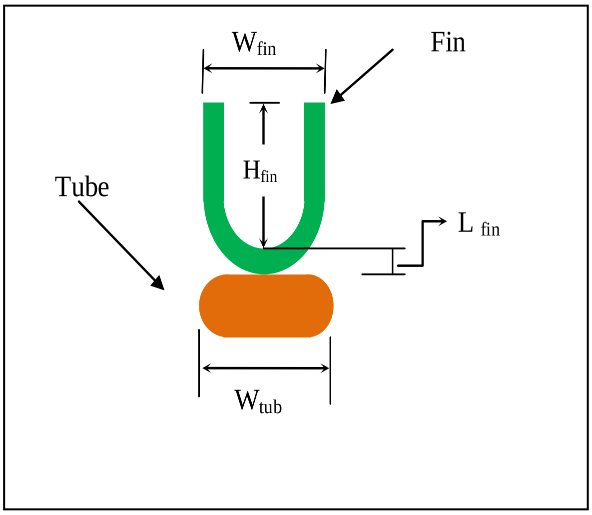
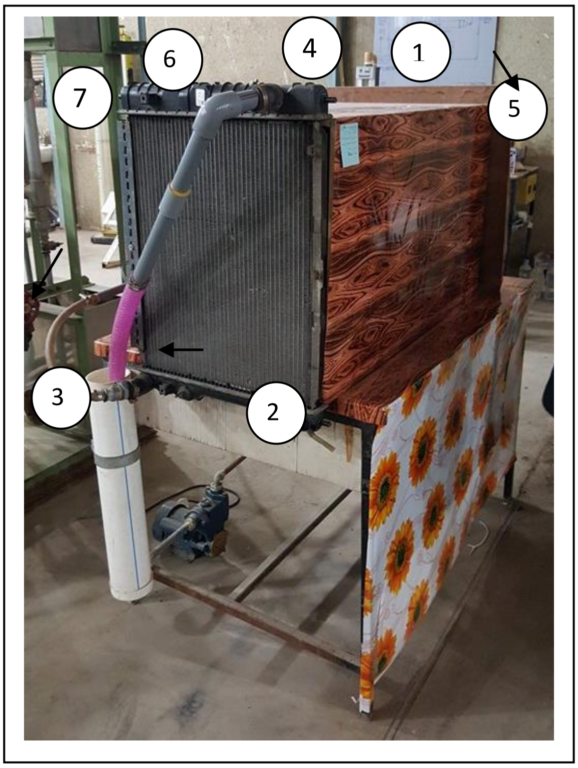


Fig. 3 Schematic of fin and tube.



1	Wind tunnel
2	Pump
3	Tank
4	Liquid flow meter
5	fan
6	Radiator
7	Manometer

Fig. 4 Photograph of experimental test rig.

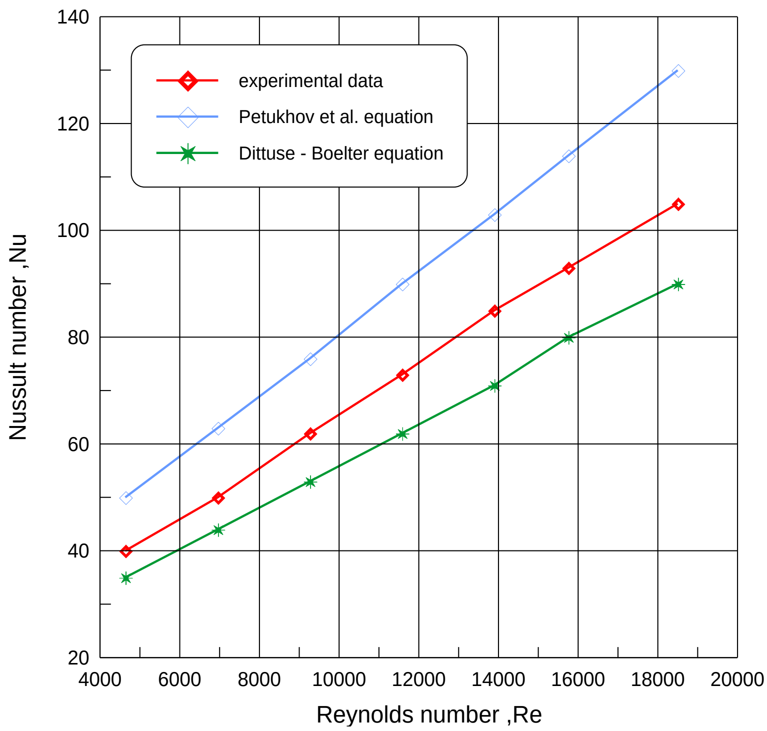


Fig. 5 Experimental results for pure water in comparison with the results obtained in previous studied.

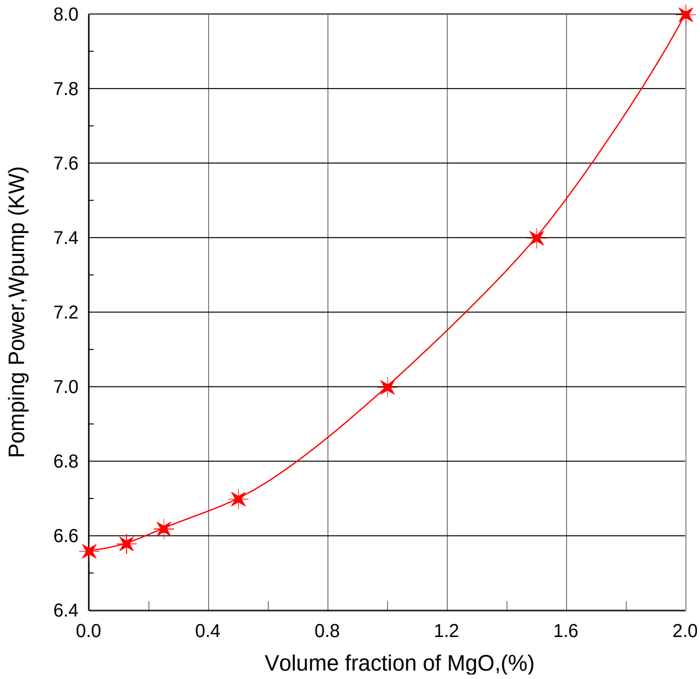


Fig.6 Relation between pumping power and volume fraction of MgO nanofluid.

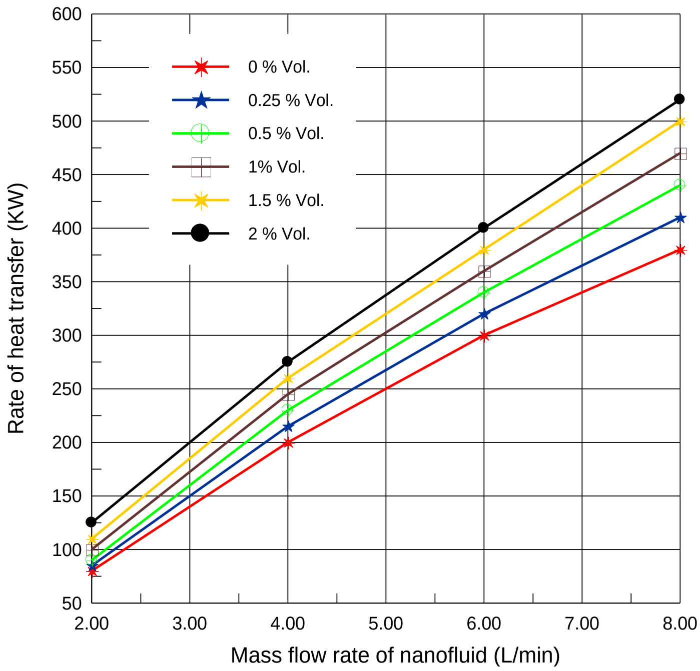


Fig.7 Relation between rate of heat transfer and mass flow rate of MgO nanofluid at different concentrations.

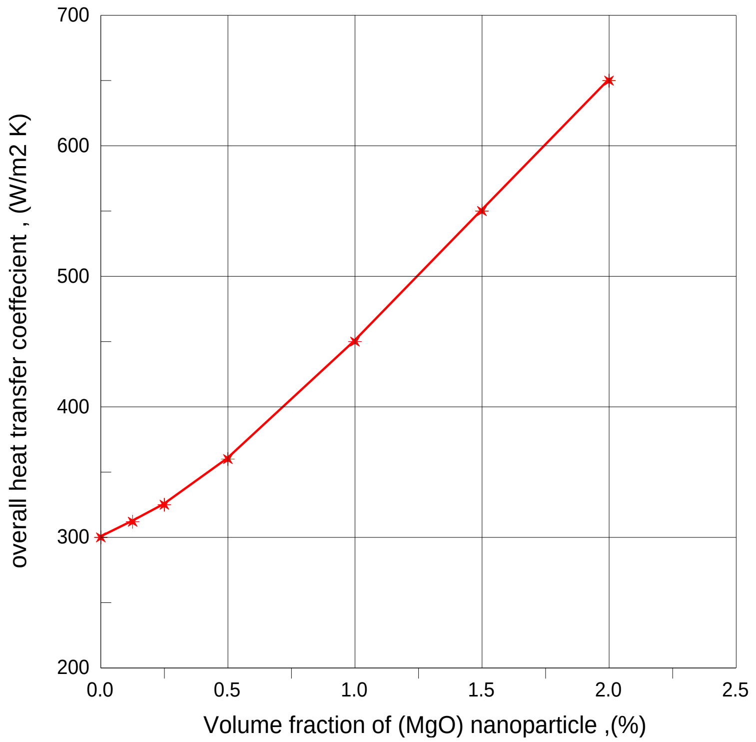


Fig. 8 Effect of (MgO) particles to the overall heat transfer coefficient at constant mass and air flow rates.

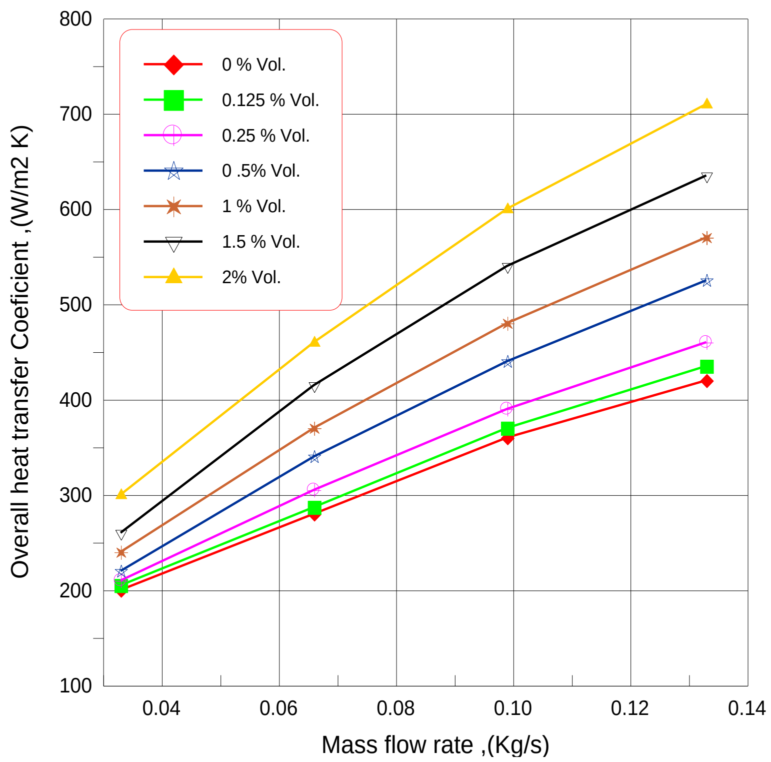


Fig. 9 Effect of the mass flow rate to overall heat transfer coefficient based on air side

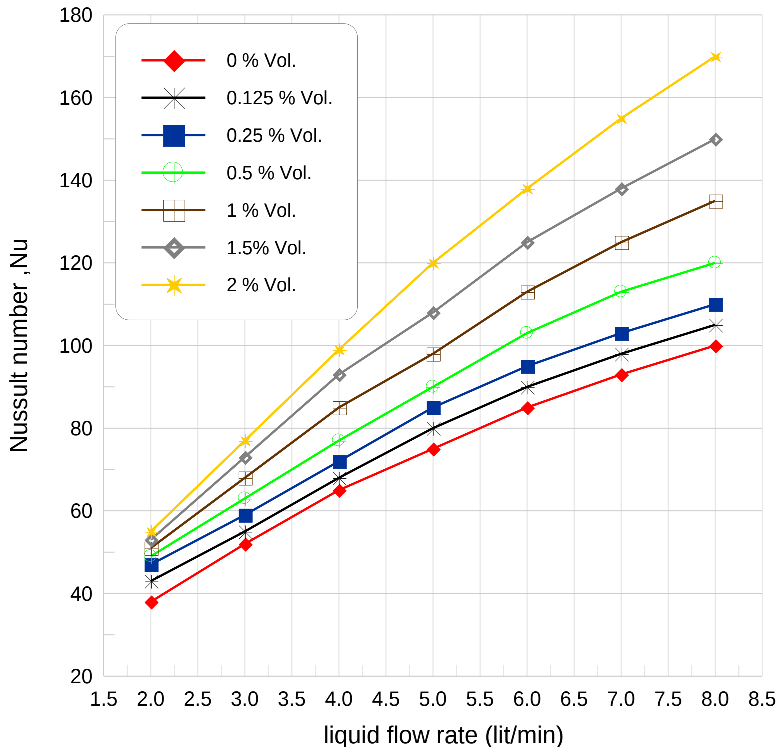


Fig. 10 relation between Nussult number and mass flow rate of MgO nanofluid at different concentrations velocity of air is 7 m/sec

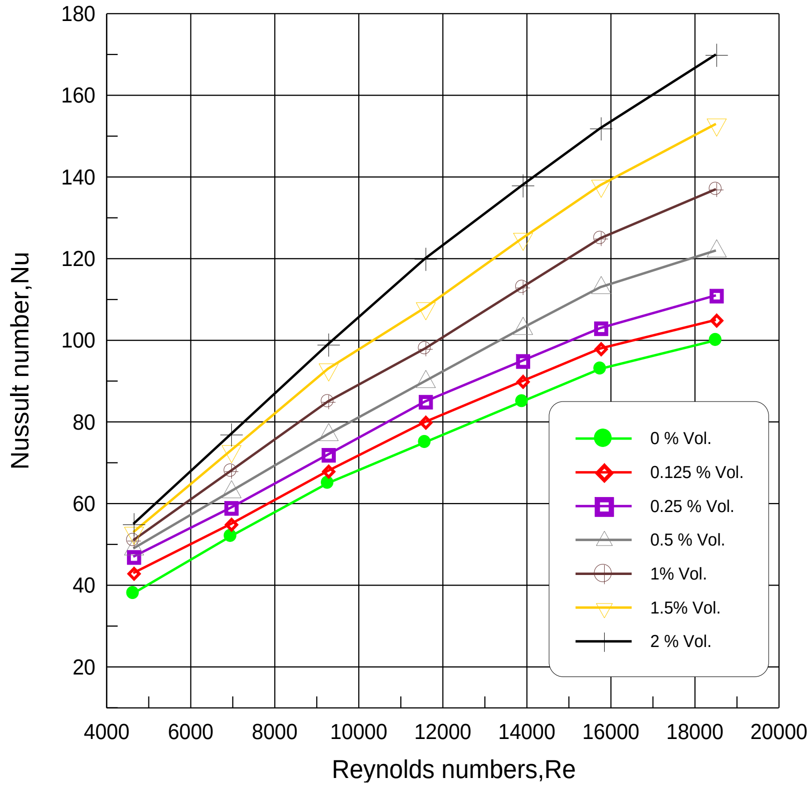


Fig. 11 relation between Nussult number and Reynolds number of MgO nanofluid at different fraction. Velocity of air is 7 m/sec