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Experimental investigation of using Graphene Oxide with Ethylene Glycol and Water mixture to improve the performance of a car radiator

N. Chabok[1], H. Goshayeshi[1], M. Elnour Ismail[2],
S. Haddowe[2], M. Yebiyo[2] and I. Chaer[2*]

[1] Department of Mechanical Engineering, Mashhad Branch, Azad University, Mashhad, Iran

[2] Centre for Civil and Building Service Engineering, School of the Built Environment and Architecture, London South Bank University, London, England

Abstract

Nanofluids offer a good alternative heat transfer mediums with approximately five-fold heat transfer enhancement. This paper presents the results from a research study carried out on the use of Graphene Oxide/ Ethylene glycol Mixture (GnO/H_2O-EG) Nanofluid as the heat transfer medium in a car radiator. The radiator consisted of 30 vertical tubes with elliptical cross section. Air makes a cross flow inside the tube bank with constant speed. The system was tested with three different Nanofluid concentrations (0.1, 0.3 and 0.5% by weight). The tests were conducted for flow rates ranging between 2 to 5 lit/min which corresponds to Reynolds number between 14000 and 38000. The effect on fluid outlet temperature to the radiator was analyzed for different flow rates and constant inlet temperature. The data were compared to that obtained with potable water in the radiator. The result of the comparison revealed that the use of graphene oxide increased the temperature drop across can radiator by upto 22 % compared to 50% Glycol mixture.

Keywords: Nanofluids, Graphene Oxide, Car Radiator Performance, Nusselt number,
** Corresponding Author: Chaeri@Lsbu.ac.uk*

Nomenclature

C_p	Specific heat capacity, J/kg. K
D_h	Hydraulic diameter, m, $[D_h = \frac{4\times\left[\frac{\pi}{4}d^2+(D-d)\times d\right]}{\pi\times d+2\times(D-d)}]$
T	Temperature, K
U	Velocity, m/s, $[U = \frac{\dot{m}}{\rho A_c}]$
k	Thermal conductivity, W/m.K
f	Friction factor [f=(0.79LnRe-1.69)$^{-2}$]
Greek Symbols	
μ	Dynamic viscosity, Pa.s
ρ	Mass density, kg/m^3
ϕ	weight fraction of nanoparticles
Subscripts	
0	Reference value
Notations	
b	bulk
GnO	Graphene Oxide
nf	Nano fluid
Non-dimensional Numbers	
Re	Reynolds number, [$\rho U D_h/\mu$]
Nu	Nusselt number
Pe	Peclect number, [Re Pr]

1. Introduction

Conventional car engine coolants rely on a mixture of water and Glycol-based anti-freeze, to transfer the heat from the engine to the radiator/s. However, the use of glycol-based anti-freeze has significant disadvantages.

Glycols reduce water's ability to dissipate heat. Glycols also promote scale formation on the surface of radiators which adversely affects the performance of engines. At high temperatures, glycols decompose to form organic acids which adversely affect metals resulting in leakage of radiators.

The addition of Nano-particles to make the mixture nanofluid could offer heat transfer enhancement potentials which could overcome the reduce heat dissipation of the glycol-based anti-freeze. This builds on the Choi et al. [1] who introduced solid nano-sized (100 nm) materials to enhance heat transfer coefficient. The Nanofluids they used, showed an enhanced thermal conductivity and yielded higher heat transfer coefficient comparing to the conventional heat transfer fluid.

In recent years, carbon nanotubes (CNTs), graphene nanoplatelets (GnP), graphene oxide (GnO), nano diamond were used to increase the heat transfer coefficient fluids due to their high thermal conductivity [2]. The published literature reveals that the graphene oxide significantly increases the heat transfer coefficient as compared to other Nanofluids. The experiments on heat transfer coefficient of an automobile radiator using various Nanofluids as a coolant are reported by several researchers [3]. Looking into the available literature, it can be seen that the Nanofluids containing spherical nanoparticles show higher increase in heat transfer coefficient in comparison to carbon based nanostructures. Until now no work has been reported using graphene oxide dispersed in water ethylene glycol mixture at concentrations of 0.1, 0.3 and 0.5% by weight. The main aim of this work is to investigate the effects of Graphene Oxide-Nanofluids' on the convection heat transfers in automotive radiators and provide real performance results and observations to current knowledge relating to graphene oxide and water ethylene glycol mixture (GnO/H_2O-EG). The outcome of this investigation would provide advanced knowledge to the development of high efficiency automotive cooling systems.

2. Experimental Apparatus

The experimental setup used in this research is depicted in Figures 1, and 2. Figure 1 shows a schematic of the experimental facility while figure 2 shows geometrical characteristics of the radiator. The Nano-fluid circulate between fluid tank and the radiator with the aid of a centrifugal pump with adjustable speeds. The pump is capable of delivering flow rates between 1 to 5 L/min. A rotameter is used to control and measure the flow rate between the radiator and the tank.

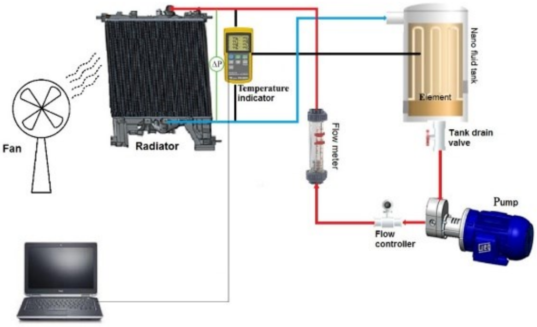

Figure 1: Schematic of experimental

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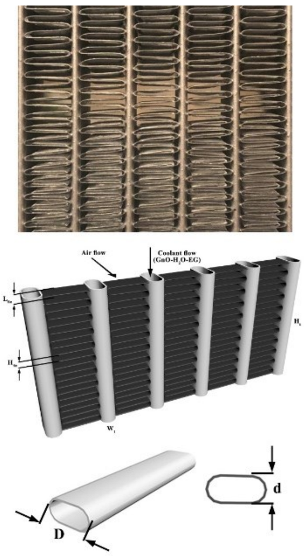

Figure 2: Radiator and flat tubes.

A thermostatic controller was used to control the immersion heat inside the tank. Two thermocouples as shown in Figure 1 were used on the flow line to record radiator fluid inlet with constant temperature of 50°C and variable outlet temperatures. The locations of the surface thermocouples have been chosen so that they give the average wall temperature. For this purpose, 3 thermocouples were attached using silicon paste to various positions of the external walls on each side of the radiator. When the experiment started, the location of the thermocouple which presented the average value of the readings was selected as a point of average wall temperature. Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. Table1 gives geometrical characteristics of the radiator and Table 2 illustrates characteristics of graphene oxide nanoparticles and H_2O/EG.

Table 1: Geometrical characteristics of the radiator

Radiator length (H_t)	46 cm
Radiator width (W_t)	34 cm
Fin width (L_{fin})	1.40 cm
Distance between fins (H_{fin})	0.8 cm
Diameter of tube (D)	0.22 cm
Tube width (d)	0.15 cm

Table 2: Physical properties of the base fluid.

Parameter	Ethylene glycol	H_2O/EG (50:50 by volume)	Graphene oxide
Thermal Conductivity [W/m K]	0.258	0.380	3000
Density [kg/m^3]	1113.2	1073	3600
Freezing point [°C]	-12.9	-37.0	-
Boiling point [°C]	197.3	107.4	-
Dynamic Viscosity [mPa.s]	20.9	3.94	-
Specific Heat kJ/kg	2.347	3.281	0.765

3. Preparation of Nanofluids

Graphene oxide nanoparticles were purchased from Merck Company; with an average diameter of 2 nm and used to prepare the Nanofluid. A 22 kHz setting was used on ultrasonic device during the preparation which was done for 4 h in total. The Zeta potential test was used to examine the stability of the prepared Nanofluid.

Fig 4 shows the ratios of physical properties of the GnO/H_2O-EG, to those of 50% water and 50% ethylene glycol according to equation 1 to 4. We can see that the addition of small amount of graphene oxide can increase μ, ρ, k and decrease C_p.

$$\rho_{nf} = \emptyset_p \rho_{np} + (1-\emptyset)\rho_{H_2O-EG} \quad (1)$$

$$(\rho c_p)_{nf} = \emptyset (cp)_p + (1-\emptyset)(\rho c_p)_{H_2O-EG} \quad (2)$$

$$\mu_{nf} = \mu_{H_2O-EG}\ 123\emptyset^2 + 7.3\emptyset + 1 \quad (3)$$

$$k_{np} = \frac{k_p + (n-1)k_{H_2O-EG} - \emptyset(n-1)(k_{H_2O-EG} - k_p)}{k_p + (n-1)k_{H_2O-EG} + \emptyset(k_{H_2O-EG} - k_p)} k_{H_2O-EG} \quad (4)$$

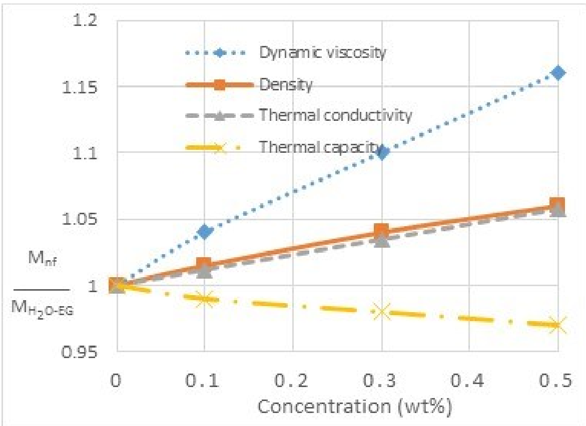

Figure 4: Dimensionless physical property of Nonofluid (GnO-H_2O-EG) comparison with pure water + EG

4. Experimental results

Before conducting experimental tests with the Nanoflulid in the car radiator, base-case tests with potable water were conducted and the results were used to obtain the Nusselt number using (Equation 5). The results were compared to outputs obtained using available correlations like the Dittus-Boelter correlation (Equation 6) and Gnielinsky correlation (Equation 7). Figure 5 shows good agreement between the test results and that obtained using the the Dittuse-Boelter. However there is a variation when this was compared to the output obtained using the Gnielinsky correlation. This is in line with the findings of Ebtahimi et al. [4]

$$Nu = \frac{\mathrm{hD}}{\mathrm{k}} = \frac{\dot{m}Cp(T_{in}-T_{out})D}{A(T_b-T_w)k} \quad (5)$$

$$Nu = (0.023Re^{0.8}) \times Pr^{0.3} \quad (6)$$

$$Nu = \frac{(\frac{f}{2})(Re-1000)\times Pr}{1+12.7\times(\frac{f}{2})^{0.5}\times((Pr)^{\frac{2}{3}}-1)} \quad (7)$$

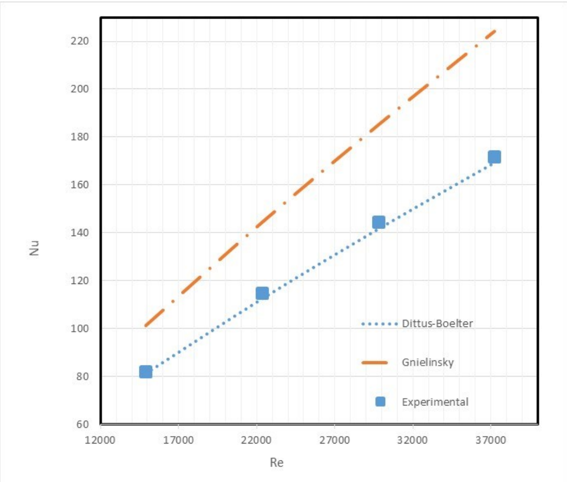

Figure 5: Comparison of experimental results for pure water with the existing correlations

Figure 6 presents the radiator outlet temperature versus the flow rate for the different fluid mixtures. One can clearly observe that the fluid's outlet temperature decreased as the concentration of the nanoparticle was increased.

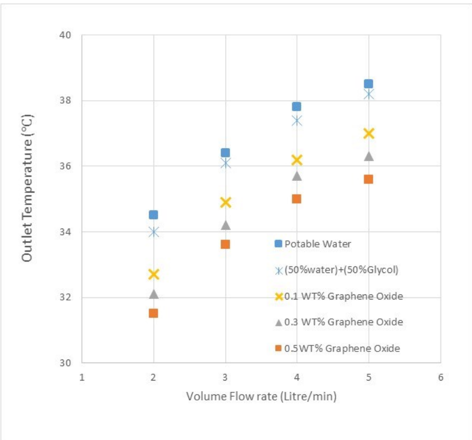

Figure 6: Comparison of the car radiator cooling performance when using Nanofluid (0.1, 0.3 and 0.5 wt%)

Furthermore figure 7, give clear indication of the temperature across the radiator for different fluids. It is clear that the temperature drop across the radiator was highest for the .5 wt.%. The percentage increase with this concentration was 15% at flow rate of 2 litre /min and 22 % for flow rate of 5 litre/min compared to the base (50% Glycol to Water mixture.

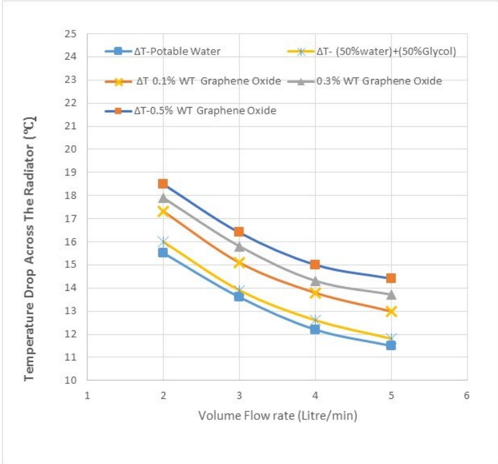

Figure 7: Comparison of the temperature across the car radiator versus flow rate for the different fluid.

5. Conclusions

This paper presents a study on the performance of an automotive radiator using graphene oxide as the working fluid. The following conclusions can be drawn:

1. The presence of Graphene Oxide nanoparticle in heat transfer fluid resulted in a better fluid temperature drop across the radiator. The degree of the temperature drop across the radiator increased with the increase in the % of graphene oxide in the mixture. The highest increase in ΔT was 22 % obtained with 0.5 wt.% Graphene compared to the base 50 Glycol fluid.

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