Experimental and one dimensional investigation on nanocellulose and aluminium oxide hybrid nanofluid as a new coolant for radiator

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Abstract. Automotive engine cooling system handle a lot of excessive heat produced during engine operation. Furthermore, it regulates engine surface temperature for engine optimum efficiency. Recent advancement in engine for power forced engine cooling system to develop new strategies to improve its performance efficiency. Also to reduce fuel consumption along with controlling engine emission to mitigate environmental pollution norms. This paper throws light on parameters which analyse the radiator performance at high coolant temperature that is below 80°C and the comparison data from experimental and one-dimensional analysis data. A literature review has been done and ways were identified how to enhance radiator performance. In addition, A coolant is normally chemically combined with a high boiling point liquid to form a compounded fluid. This compounded fluid function as an antifreeze agent against extremely cold conditions and as well as solves the problem of overheating during hot weather. A coolant with relatively high boiling temperature can cool faster as the engine gets hotter. During an operation of an internal combustion engine, about a third of heat energy produced are considered as unwanted heat that ends up in the cooling system. Thermal conductivity values are maximum at 0.9% concentrations.

1. Introduction

The radiator plays a very important role in an automobile. It dissipates the waste heat generated after the combustion process and useful work has been done. The effectiveness with which waste heat is transferred from the engine walls to the surrounding is crucial in preserving the material integrity of the engine and enhancing the performance of the engine [1]. Various studies have been carried out on engine radiators focusing primarily on optimizing their performance [2]. The radiator plays a very important role in an automobile. It dissipates the waste heat generated after the combustion process and useful work has been done [3]. The effectiveness with which waste heat is transferred from the engine walls to the surrounding is crucial in preserving the material integrity of the engine and enhancing the performance of the engine.

Various studies have been carried out on engine radiators focusing primarily on optimizing their performance [4]. The use of Computational Fluid Dynamics (CFD) modelling simulation of mass flow rate of air passing across the tubes of an automotive radiator was carried out [5]. Studies on the use of nano fluids in compact heat exchangers were carried out by P.Gunnasegaran et.al. [6]. Some studies to increase the rate of heat transfer were carried using twisted tape [7]. Numerical study of heat transfer and pressure drop in a heat exchanger that is designed with different shape pin fins were carried out by
Hamid Nabati [8]. Some studies were also carried out for Improving Radiator Efficiency by Air Flow Optimization by Salvio Chacko et.al [9]. Studies on the effect of blockage of dirt on engine radiator in the engine cooling system was carried out by S. D. Oduro [10]. Much of the work is going on to increase the value of convective heat transfer coefficient on the similar patterns this work is being directed on increasing the value of $h$ by adjusting the rpm of the fan with the help of electrical regulator/ changing the windings of the motor [11].

Some studies were made on effects of variable mass flow rate of the coolant in the radiator, the rate of flow is controlled by the pump voltage for experimental and speed for the simulation. The main focus of the paper is to analyse the radiator in one dimensional. In fact, nanosubstance can be categorized into nanoparticle, nanorod, nanowire, nanosheet and nanotube. Each category is differentiated by its physical appearance such as size, shape and aspect ratio. Thus, variation in physical appearance produces different amount of thermophysical enhancement [12]. The selected type of nanosubstance and base fluid plays a major role in thermophysical property enhancement. Experiment conducted by [13] reveals that nanoparticle in sphere size enhances thermal conductivity better than cylinder shaped nanoparticle. It can be best explained by variation of surface area to volume ratio among type of nanosubstance. Thus, nanoparticle with high surface area produces better thermal conductivity enhancement [14].

2. Method

2.1 Coolant Preparation

Apparatus such as beaker, measuring cylinder and syringe is prepared and assured they are in perfect condition. Firstly, 368ml of distilled water is poured in the 1L beaker based on the ratio of 40% from the total solution. Due to its low density properties compared to Ethylene Glycol and cellulose, distilled water is poured first, followed by 60% of Ethylene Glycol at 552 ml and nanocellulose at 70ml which is dispersed in the base fluid of distilled water and Ethylene Glycol using a syringe. These procedures are repeated 4 times as less than 4L is needed but only 1L of beaker is used. Next, the beaker is placed on a magnetic stirrer (Figure 1) and a magnet is placed into the beaker to aid in mixing. Speed is set accordingly not to splash out the nanofluid mixture. The mixture is stirred for at least 30 minutes to ensure the nanocellulose is fully diffused into Ethylene Glycol and distilled water. Finally, the mixture is placed in a sonication bath (Figure 2) for 2 hours at the temperature of 50°C.

![Figure 1](image1.png) **Figure 1.** Magnetic stirrer used to stir the mixture nanofluid.

![Figure 2](image2.png) **Figure 2.** Ultrasonic bath used for the nanofluid.

2.2 Schematic Diagram

Based on Figure 3 and 4 the schematic of the layout is shown. Both experimental and simulation setup is using the similar component. Then, the 24V DC power supply is the main source of power for the pump and heater. The radiator test rig is a closed loop system whereby the water from the tank is redirected back to the tank to complete the cycle by using a 24V DC water pump. K-Type thermocouples are fixed at four points on the radiator wall to obtain the surface temperature of the radiator. A 12V
powered cooling fan is used as radiator fan. The cooling fan functions as normal radiator fan which are attached together onto the radiator. The design resembles as readily available automobile radiator. A 1kW heater is used to imitate the heat produced in an automobile engine system during its routine application. A 5 litre metal tank is used as water tank to store the 4 litre of fluids which are essential coolant fluids made up of nanofluid and distilled water.

Moreover, One-Dimensional simulation software expresses the flow in the component of the radiator model and these entire components are linked together to produce a whole system of the radiator. In addition, the simulation result will be analyzed by the pre-processor with the properties of the radiator model defined by the user, and all the calculation of involve during the analysis will be shown in the post processing result. The attribute related in the One–Dimensional simulation software are implying several equation and correlation in order to perform the analysis for the radiator cycle starting from radiator inlet and radiator outlet.

![Figure 3. Test Rig schematic diagram.](image1)

![Figure 4. One Dimensional Analysis diagram.](image2)

### 2.3 Equation

The governing equation in the experiment are given below velocity, Reynolds number and Nusselt number are analysed to show the variations in experimental results. Sample calculation for the analyse:

Velocity, \( v = \frac{Q}{A} \) \hfill (1)

From experimental data, at \( T = 80^\circ C \)

\[
\mu = 2.88 \times 10^3 \text{ kg/m/s} \\
\rho = 1077.9 \text{ kg/m}^3
\]

Reynolds Number, \( Re = \frac{\rho \times D \times v}{\mu} \) \hfill (2)

Nusselt Number, \( Nu = \frac{h_{exp} D_h}{k} \) \hfill (3)
3. Results and Discussion

3.1 Simulation Compare Between Experimental

Figure 5 represent the data achieve from the one-dimensional analysis which is in case setup template, the case setup was created with different parameter for the radiator before it can run and develop result. The case level is named so that it will be easy to edit the parameter. The case setup is set up to 10 cases with different engine speed. The engine speed is started from 500 rpm and ended with 5000 rpm with the increment of 500 rpm for each case.

![Figure 5. Speed versus Temperature for simulation analysis data.](image)

Figure 6 indicate the data accomplish from the experimental of the test rig. Moreover, the experimental procedure follows with the immersion heater is switched on and 0.5% of volume concentration of nanofluid is heated to target value which is 80°C. Once the target is reached, the valve will be opened to let the nanofluid flows into the pump. Later, the radiator fan and the pump adaptors are switched on. Then, the nanofluid is let to be flown and circulate the system. Readings of the temperature from data acquisition at the both inlet and outlet of the radiator together with the temperature at the radiator flat tubes are taken. Lastly, the set-up of test rig turned off.

![Figure 6. Pump voltage versus temperature for experimental data.](image)
Figure 7 and 8 indicate the data obtain from simulation and experimental. Furthermore, he dimensionless reynolds number plays a prominent role in foreseeing the patterns in a fluid’s behaviour. The reynolds number, referred to as Re, is used to determine whether the fluid flow is laminar or turbulent. It is one of the main controlling parameters in all viscous flows where a numerical model is selected according to pre-calculated Reynolds number. Although the Reynolds number comprises both static and kinematic properties of fluids, it is specified as a flow property since dynamic conditions are investigated. Technically speaking, the reynolds number is the ratio of the inertial forces and the viscous forces. In practice, the reynolds number is used to predict if the flow will be laminar or turbulent. If the inertial forces, which resist a change in velocity of an object and are the cause of the fluid movement, are dominant, the flow is turbulent. Otherwise, if the viscous forces, defined as the resistance to flow, are dominant – the flow is laminar.

![Graph of Nusselt Number vs. Reynolds Number from simulation analysis.](image1)

**Figure 7.** Relationship between Reynolds and Nusselt Number from the simulation analysis.

![Graph of Nusselt Number vs. Reynolds Number from experimental.](image2)

**Figure 8.** Relationship between Reynolds Number and Nusselt Number from experimental.

Both heat transfer for simulation and experiments are compared for speed in RPM and also in term of flow rate. The data are presented in Figure 9 and Figure 10 below. Besides that, The relation is similar increment in heat transfer rates, the experimental is in proportional value however the experimental
values are generally lower as compared to the simulation, this may occur as the simulation is considering ideal conditions which is not captured in real life.

![Graph showing relationship between speed rate and heat transfer from simulation.](image1)

**Figure 9.** Relationship between speed rate and heat transfer from simulation.

![Graph showing relationship between flow rate and rate of heat transfer from experimental.](image2)

**Figure 10.** Relationship between flow rate and rate of heat transfer from experimental.

Based on the results above, it clearly states that when the flow rate of the coolant or working fluid in the radiator cooling system increases the rate of heat transfer also is increases. This is because at higher flow rate the more scrubbing action will occur at the surface of the radiator flat tubes, thus more heat energy will be transferred from coolant to radiator flat tube by the mean of conduction. Nevertheless, there is limit of the flow rate of the coolant is applicable in car cooling system. As the flow rate exceed the limit of the flow rate, the aeration or erosion on the radiator flat tube and foaming of coolant inside the system will likely to happen which is need to be avoided. This is because it can reduce the efficiency of the radiator.

### 4. Conclusions

The thermo-physical properties of Al₂O₃/CNC composite nanofluids is prepared at constant ratio 60:40 with different volume concentration of 0.1%, 0.5%, and 0.9%. Besides that, subjecting Al₂O₃/CNC composite nanofluids to sonication process for 2 hours separate the particles agglomeration and was observed stable under visual observation for more than a week. In addition, the thermos-physical properties is evaluated at temperature ranging from 30°C to 70°C. Furthermore, the thermal conductivity is a temperature dependent where thermal conductivity increase as the temperature increases. Furthermore, thermal conductivity was found to be maximum at mixture at volume concentration 0.9% occurred at temperature 70°C. The thermal conductivity Al₂O₃/CNC composite nanofluids enhancement
increases with temperature and volume concentration. From the observation, when the volume percentage of Al₂O₃/CNC increases, thermal conductivity enhancement also will increase except for 0.1% volume concentration, this is because the concentration is too low. The maximum enhancement compared to base fluid W/EG can be found at volume concentration 0.9% at temperature of 70°C. While for the dynamic viscosity, the increase in temperature affect the viscosity in an opposite way from the thermal conductivity. It is found the viscosity is exponentially decreased when temperature increased. The temperature at outlet and inlet radiator also show the difference which mean nanofluids help to reduces the heat efficiently. After all the data have been analyse it show that nanofluid is very efficient to be used in automotive cooling system.

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