

UTILIZATION OF SILICA NANOFUID FOR VEHICLE RADIATOR COOLING SYSTEM

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ABSTRACT

This research investigates the effect of a silica (SiO₂) nanofluid flow system on the radiator performance function. The initial preparation is to take SEM photos to find out the microstructure. Next, mix the silica nanoparticles with water using a variation of 0.1%, 0.3%, and 0.5%, using a magnetic stirrer, to disperse the mixture, an ultrasound device is used. The liquid that has been separated from the sediment is tested using a series of test equipment consisting of a radiator, flow meter, pump, heater, water tank, and term reader. Data taken is the temperature of the liquid entering and leaving the radiator and the walls entering and leaving the radiator. This research uses 3 variations of fluid flow velocity, namely 2.5, 4.5, and 6 LPM. The result is a decrease in temperature at a fluid flow rate of 6 LPM which is able to release heat to the environment properly. The temperature drop that occurred was 2.5%. then the lowest average radiator effectiveness value at the lowest speed of 6 LPM is 0.905, the highest is at a fluid flow rate of 4.5 of 0.930.

KEYWORDS

Keywords: Nanofluids, SiO₂, heat transfer, radiator



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INTRODUCTION

Combustion engines have been widely applied in various applications such as transportation, electricity production, and agriculture, and by considering the greater output power and other advantages (Effendy et al., 2021). Currently, the demand for motorized vehicles has increased, and this has resulted in a big challenge for the automotive industry to develop powerful and efficient engines. The engine cooling system is very important in a vehicle because it greatly affects engine performance (Bhatkar et al., 2017). Damage to the engine and decreased vehicle performance often occur due to temperatures that are too high to exceed the required heat, which results in fatal consequences for the vehicle's engine components (Elsaid, 2019). Various methods have been carried out to obtain maximum safety and optimal engine performance while working without disturbing

other components. Increasing the effectiveness of engine heat absorption is very important to avoid this. The process of heat transfer occurs due to the mass movement of molecules in the cooling system. Conventional cooling systems are used where raw materials consisting of well water as a base fluid are mixed with other ingredients such as ethylene glycol in certain ratios and ratios or other ingredients (Kumar Rai et al., 2020).

In recent years, research related to vehicle engine cooling systems as a breakthrough to obtain efficiency in conventional vehicle cooling systems has been carried out where the radiator component is a vital tool for managing engine cooling systems that are too excessive due to the friction process and the engine combustion process (Makau Kimulu et al., 2018). Various attempts have been made to identify and improve cooling efficiency through the performance of vehicle radiators (Arora & Gupta, 2020). Research on engine cooling systems made from raw water mixed with nanoparticles has been carried out a lot, this is because nanofluids have a higher potential as cooling media, and nanofluids can remove engine heat more optimally, effectively, and efficiently (Kumar Rai et al., 2020),(Sokhal, 2020),(Alazwari & Safaei, 2021).

Rahul et al have conducted research on nanofluid from raw water dispersed with nanoparticles Al₂O₃ and ethylene glycol used as coolants in radiators which provide maximum heat extraction from the engine and radiator (Golde, 2018). Siraj Ali et al conducted the same research with raw water mixed with TiO₂ nanoparticles. The results showed that the friction factor decreased when the Reynolds number and volume concentration were increased. In addition, TiO₂ water nanofluid with a concentration of 0.2% can increase the effectiveness of car radiators by 47% (Ahmed et al., 2018). Research conducted by S. Eiamsa et al showed that heat transfer increased as the volume concentration of TiO₂ nanofluid increased, due to increased contact surface and thermal conductivity in the engine cooling system (Eiamsa-ard et al., 2015).

The potential for using nanofluid for engine cooling in radiators will be better considering that radiators are vital components in internal combustion engine cooling systems which function as heat exchangers through water as the medium (Koçak Soylu et al., 2019). Research related to the thermal performance of nanofluid has been widely studied by many scientists, and its application as a cooling medium and engine lubricant (Bock Choon Pak, 2013),(Zheng et al., 2020). Research results prove that the effectiveness of heat exchangers increases when compared to ordinary fluids. This research evaluates the results of mixing ordinary water with silica particles (SiO₂) to be applied to vehicle radiator cooling systems. It is observed through measurements of its viscosity and thermal conductivity. In addition, other variables are also observed, such as fluid and air flow rates at various concentrations and fluid inlet temperatures. to get better information about the cooling efficiency of vehicle radiators.

Nomenclature

A	Area, m ²
C _p	specific heat, J/kgK
D _h	hydraulic diameter, m = (4 A/p)
F	friction factor
h	heat transfer coefficient, W/m ² K
k	thermal conductivity, W/m K
m	massflow rate, kg/s
Nu	Nusselt number, (h X D)/K
n	empirical shape factor
P	tube periphery, m
Pr	Prandtl number, (μ X C _p)/K

- Q heat transfer rate, W
- Re Reynolds number
- S cross-sectional area of the tube, m²
- T temperature, K

Greek letters

- ρ density, kg/m³
- μ viscosity, kg/m s
- ϕ volume fraction

Subscripts

- b bulk
- exp. experimental
- nf nanofluid
- out output
- p particle
- w wall

RESEARCH METHOD

Initial Steps to Prepare SiO₂ Nanofluid

The initial preparation in this research was by weighing the raw materials with a ratio of 100 g of water and 20 nm SiO₂ nanoparticles. The material was obtained from the Serpong Indonesia nano center, for a comparison of 0.1%, 0.3%, and 0.5%, the amount of nanoparticles used was obtained by the volumetric concentration percentage with the equation (1).

$$\text{Volume concentration, } \phi = \left[\frac{\frac{W_{Particle}}{\rho_{Particle}}}{\frac{W_{Particle}}{\rho_{Particle}} + \frac{W_{Fluid}}{\rho_{Fluid}}} \right] \times 100 \quad (1)$$

To mix silica material with water using a magnetic stirrer mixer which is a mixing process for 8 hours, dispersing it is processed through an ultrasonic device to obtain a homogeneous mixed material. Particle surface morphology and microstructure were documented by Scanning Electron Microscope (SEM) which is presented in Figure 1.

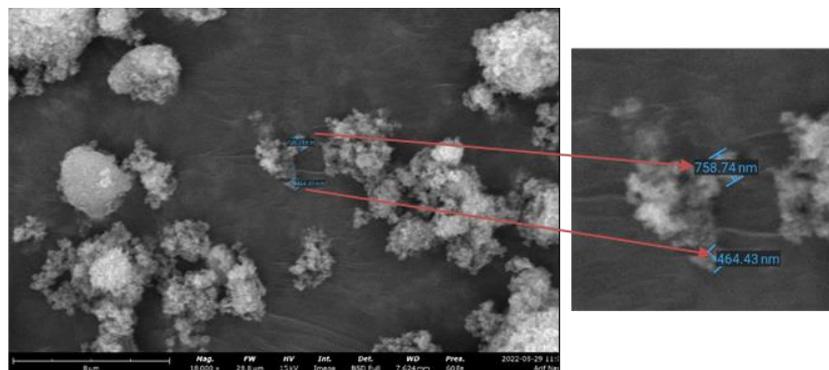


Figure 1. Microstructure on Silica (SiO₂) surface

Setting And Using Experimental Tools

The equipment used for testing this cooling system is a series of tools consisting of various components including a reservoir tank equipped with an electric heater, a water pump, a flow meter, a thermo reader, a radiator and a motor fan, a recording device is also installed which consists of a set of thermocouples anemometer, data storage device or data logger(Hussein et al., 2014). Figure 2 presents a schematic of the cooling system test equipment used in this research. Figures 3 and 4 present real photos of the series of test equipment used. The step used in this research is to heat the liquid that is already in the reservoir tank until it reaches a certain temperature point. Then the water pump is turned on to circulate the liquid in the circuit, the speed of the liquid is set through the control valve and can be observed through the scale on the anemometer, after the working temperature is reached, which is 85OC, the van motor is turned on to dissipate the fluid heat into the environment. The temperatures recorded included the temperature in the reservoir tank, the liquid entering and leaving the radiator, and the front and rear walls of the radiator which were made of aluminum.

Table 1. Basic properties of SiO₂ nanoparticles which include Density, viscosity, and thermal conductivity at concentrations of 0.1 and 0.15% (Senthilkumar et al., 2020).

Property	Water 100%	SiO ₂ 0.1%	Nano Fluid 0.15%
Viscosity	0.889cst	0.504 CST	0.546 CST
Thermal Conductivity	0.608 w/m K	0.5 w/m K	0.622 w/m K
Density	1 g/cc	1.08 g/cc	1.084 g/cc
Specific heat of fluid (C _p)	4.185 J/gC	5.56 J/gC	6.50 J/gC

Table 2. Properties of the base fluid and SiO₂ nanoparticles at 30°C

Material	Density kg/m ³	Viscosity, mPa s	Specific heat. kJ/kg K	Thermal conductivity W/m K
SiO ₂	4260.00	-	6.890	11.700
Water	1000.00	0.000894	4.184	0.6130
Air	1.1839	0.0000186	1.005	0.024
40:60%	1055.39	0.00226000	3.502	0.4120

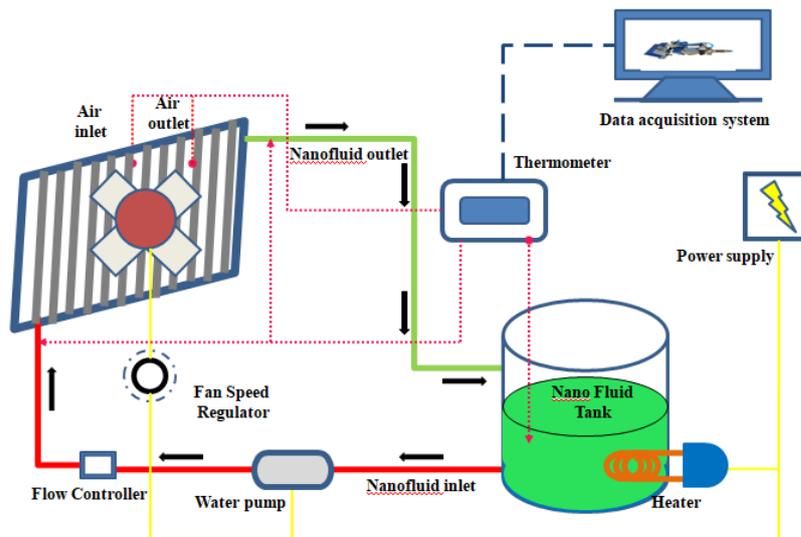


Figure 2. Schematic of the cooling system performance test equipment

RESULT AND DISCUSSION

The first step in the research is to ensure that the tool used can function properly, for this reason, a trial must be carried out using plain water so that when the tool is used it can function properly and accurately. Researchers have conducted various literature studies on several previous studies related to the topic to be examined (Jung et al., 2006). The link between published literature studies and the tools used for testing in this experiment is very close, both for the series of test tools and for the measurement data.

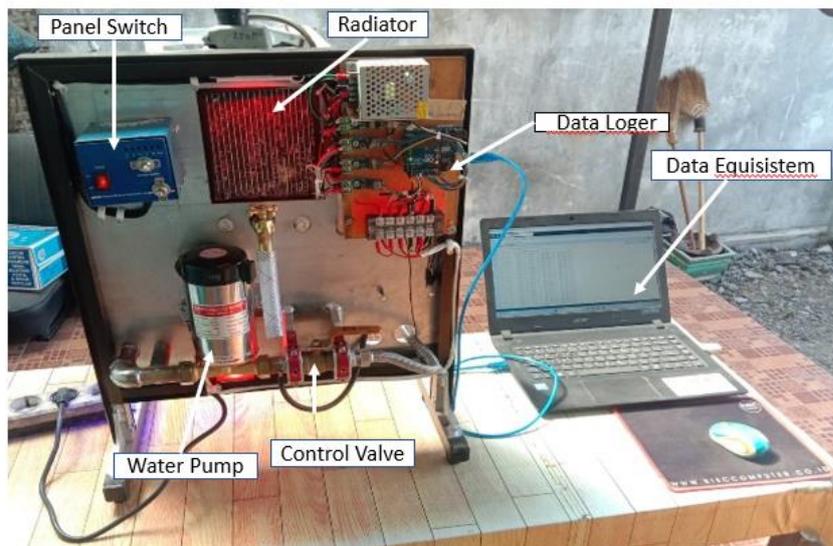


Figure 3. Front view of the cooling system test kit

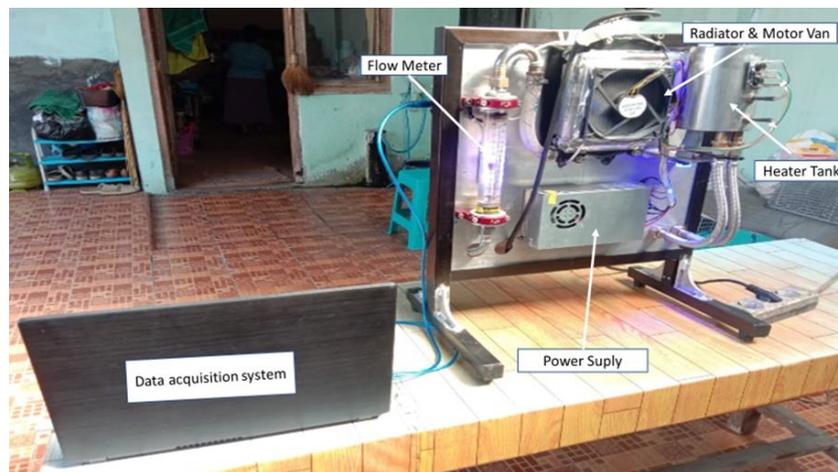


Figure 4. Rear view of the cooling system test kit

Nanofluid in the radiator

The raw material used in this research is nanofluid from a mixture of water and 0.5% silica (SiO₂) nanoparticles pumped through a pump that is resistant to high temperatures circulating through radiators and other supporting equipment components, the speed of the flow is set between 2.5 - 4.5 and 6 Lpm is useful for clearly knowing the thermal effectiveness which is then analyzed for radiator effectiveness (ϵ) against time as described

in figure 5. Apart from that the air velocity that passes through the radiator is also measured to adjust the speed to find out its effectiveness.

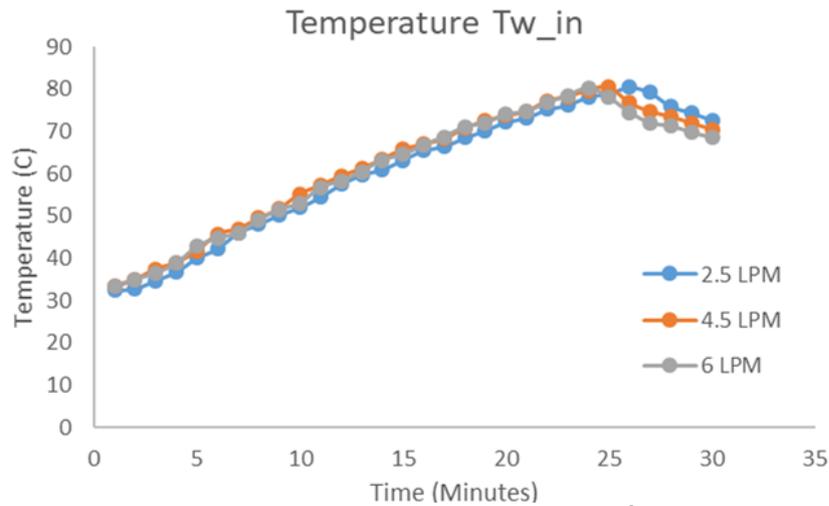


Figure 5. Radiator inlet temperature or °C

Figure 5 describes the acquisition of data when the expedition was carried out, the results were obtained that the state of the nanofluid at the inlet temperature experienced a gradual increase in movement and was gradually stable, at the position of the fluid flow rate of 2.5, 4.5, and 6 LPM sufficiently affecting the effectiveness of heat absorption in the radiator (Hussein et al., 2014). When the fluid flow rate is 6 LPM in the first second, the temperature increases until it peaks at 1485 seconds or 24 minutes with a maximum temperature of 80, The curve that occurs tends to decrease when the peak temperature is passed along with the release of heat in a good radiator at the same time. The radiator fan working. Picture. 5 shows the temperature of the fluid that comes out of Tout, as a result of the circulation rate function of the fluid capacity in the radiator. The three variations of the data obtained in the figure are based on fluids with the same concentration but are distinguished by their flow rates. Please note that the data in the figure is obtained when the temperature of the fluid entering the radiator is 35°C.

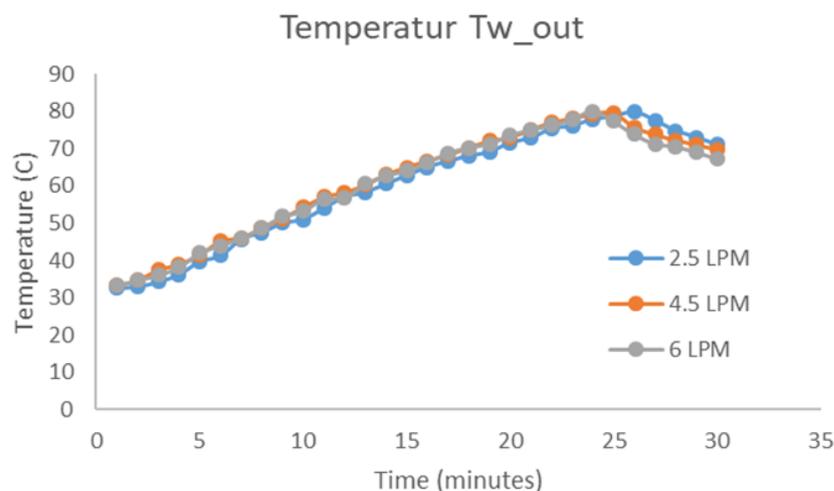


Figure 6. Fluid temperature leaving the radiator or °C

It is presented in Figure 6 that the temperature has increased or heat transfer occurs due to the influence of fluids with variations in flow rates. It can be seen that there is a concomitant increase in the heat energy transfer coefficient due to the addition of 0.5% volume of silica nanoparticles in the base fluid with a temperature of 30 °C when compared to the heat energy transfer coefficient in the recorded base fluid, this occurs because the physical properties of the nanofluids are slightly different. when compared to base fluids. Meanwhile, the density and thermal conductivity have increased and the specific heat has decreased slightly when compared to ordinary fluids, the viscosity has increased quite significantly (Said et al., 2019),(M'hamed et al., 2016),(Heris et al., 2006).

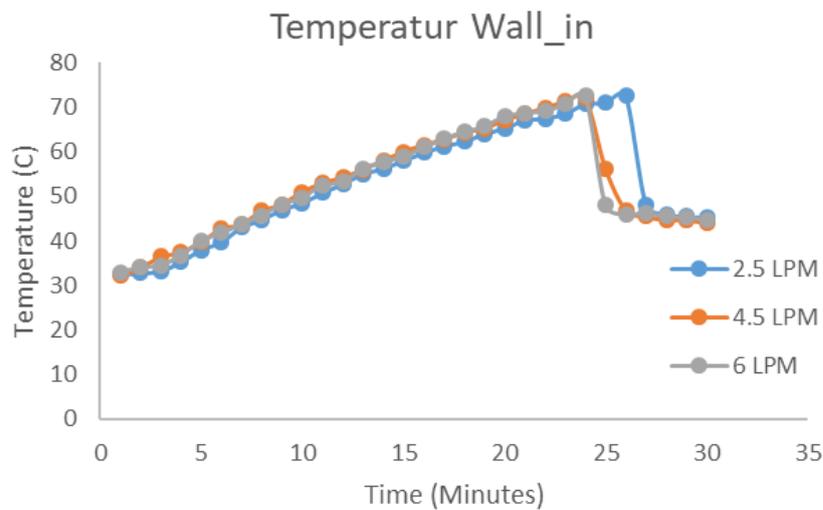


Figure 7. Radiator wall temperature

Figure 7 explains that the temperature on the radiator wall when data collection is carried out tends to be stable, this is because the variations in the nanofluid flow rate used in this experiment, namely 2.5, 4.5, and 6 LPM greatly affect the ability of the heat exchanger or radiator to release heat. It can be seen that the maximum recorded temperature is when the fluid rate is at 2.5 LPM with a temperature of 74.5 oC, but when the temperature exceeds the peak of the work that is formed it decreases drastically along with the release of heat that is discharged into the environment in the heat exchanger and radiator fan. enabled (M'hamed et al., 2016).

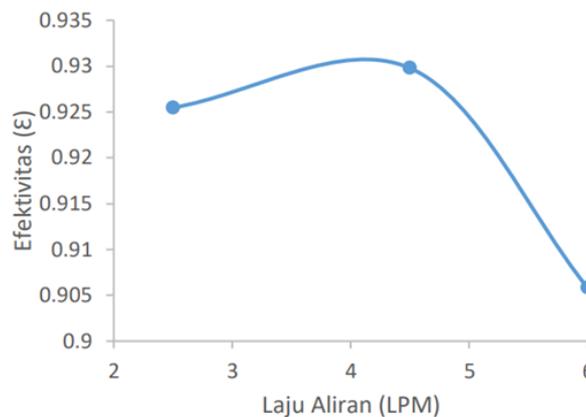


Figure 8. Radiator effectiveness

From the results of the calculation of the effectiveness of the heat exchanger for nanofluid flow (LPM) with the equation between the inlet and outlet temperatures the effectiveness of these components increases and then decreases with increasing speed (Kumar Rai et al., 2020). For this reason, the heat exchanger in this research experiment is functioning well. Its effectiveness is at a nanofluid velocity rate of 6 LPM of 0.905 while the highest is at a nanofluid flow rate of 4.5 LPM of 0.930.

CONCLUSION

Based on the results of observations, data analysis, and discussion it is known that the overall heat transfer coefficient in the radiator has been measured experimentally for 0.5% working fluid based on SiO₂ nanofluid as a function of concentration and temperature. It was found that the presence of SiO₂ nanoparticles in 0.5%, could increase the heat transfer flow in the vehicle heat exchanger. The effectiveness of heat transfer is highly dependent on the volume concentration of nanoparticles added to the raw fluid. At a concentration of 0.5%, it can increase the heat transfer by 35% when compared to plain water. Increasing the flow rate of the working fluid can significantly increase the heat transfer coefficient for pure water and nanofluids, while variations in the temperature of the fluid entering the radiator during experiments have little effect on the heat transfer obtained. It was observed that the increase in effective thermal conductivity was around 3% in this study, while the volume for other physical variations did not have a large effect on the increase in heat transfer, even though there are recent advances regarding studies in the field of heat transfer with nanofluids, further research related to nanofluids is needed to determine the behavior more about heat transfer in nanofluids.

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