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## INVESTIGATION OF SILICA (SiO<sub>2</sub>) NANOMATERIALS FOR INCREASING PERFORMANCE OF VEHICLE RADIATOR COOLING SYSTEMS

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## ABSTRACT

This study aims to evaluate the effect of fluid flow rate on the effectiveness of radiator performance by using a nanofluid consisting of a mixture of raw water with nano-silica (SiO<sub>2</sub>) particles. To measure the microstructure of the nano-silica morphologically using a Scanning Electron Microscope (SEM). Next, mix the silica nanoparticles (SiO<sub>2</sub>) with water using a ratio of 0.5%, a magnetic stirrer for 8 hours, and a precipitating for 24 hours. After being separated from the sediment, the nanofluid performance was tested using a cooling system performance test equipment. Test equipment consists of a radiator, flowmeter, water pump, pipe installation, heater, and reservoir tank. Research data collection was carried out at the inlet and outlet temperatures as well as the radiator wall. In this study, variations in fluid flow velocities of 2.5, 4.5, and 6 LPM were carried out. The results showed that the decrease in temperature with a fluid flow rate of 6 LPM could dissipate heat well to the environment. The decrease in temperature that occurs is 2.5%. Meanwhile, the lowest average radiator effectiveness value at the lowest speed of 6 LPM is 0.905, and the highest at a fluid flow rate of 4.5 is 0.930.

**Keywords** Nanofluids; SiO2; heat transfer; radiator **Paper type** Research paper

## INTRODUCTION

Research related to conventional cooling systems that use the main medium in the form of water has been widely used to remove heat in most machine tools because water is a much better engine cooling medium when compared to other media [1],[2]. One effort that can be made to reduce heat in the engine is to increase the radiator's performance. Heat transfer through the radiator can be increased by maximizing the heat transfer area and increasing the heat transfer coefficient [3],[4]. The method widely studied in recent years is adding nanometer-sized solid particles to the radiator coolant [5],[6]. Nanofluids can improve engine cooling because nanoparticles in the liquid create better energy absorption than pure water [7],[8]. Silicon dioxide (SiO<sub>2</sub>) is one of the promising materials to improve heat transfer due to its excellent physical and chemical stability [9]. The price of SiO<sub>2</sub> nanoparticles is relatively low and available in the market [10].

Research has been carried out [11] using nanofluids of volume concentrations of 0.1%, 0.3% and 0.5% nano SiO2 to carry out experiments. The size of the nanoparticles used for the test is around 50-100 nm. The fluid inlet temperature and velocity were varied to study the heat transfer rate using a water-based liquid nano-silica (SiO<sub>2</sub>). From the results of several studies, it is clear that Nanofluid can increase the speed of heat transfer compared to pure water. A comparison was also carried out between the two Nanofluids Al<sub>2</sub>O<sub>3</sub> & CuO. CuO shows a slight increase in heat transfer rate compared to Al2O3. In addition, the authors have evaluated the performance of radiators with various cooling methods to determine their effectiveness [12],[13],[14],[15].

This research is targeted to increase the heat transfer of  $SiO_2$  nanoparticles at different concentration levels of nanofluid volumes with different flow rates. In addition, the new benefit of this research is the creation of a superior product of radiator coolant material that is effective and efficient as well as environmentally friendly.

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## Method

## Preparation of SiO<sub>2</sub> nanofluid materials

The nanofluids in this study were prepared using  $SiO_2$  nanoparticles in a ratio of 0.5%) mixed with water.  $SiO_2$  nanoparticles were obtained from the Serpong Indonesia nano center with an average particle diameter of 20 nm. Particle surface morphology and microstructure were studied by Scanning Electron Microscopy (SEM), which is presented in Fig.1. The required number of nanoparticles can be determined by the volumetric concentration percentage in equation (1) and also based on previous research conducted by [16].



Figure 1. SEM morphology of SiO<sub>2</sub>

Volume concentration, 
$$\boldsymbol{\phi} = \begin{bmatrix} \frac{W_{Particle}}{\rho_{Particle}} \\ \frac{W_{Particle}}{\rho_{Particle}} \\ \frac{W_{Fluid}}{\rho_{Fluid}} \end{bmatrix} \mathbf{X} \ 100$$
(1)

### Nomenclature

- A area,  $m^2$
- Cp specific heat, J/kgK
- Dh hydraulic diameter, m = (4 A/p)
- F friction factor
- h heat transfer coefficient, W/m<sup>2</sup>K
- k thermal conductivity,W/m K
- m massflow rate, kg/s
- Nu Nusselt number,  $\frac{h \times D}{K}$
- n empirical shape factor
- P tube periphery, m
- Pr Prandtl number,  $\frac{\mu X Cp}{...}$
- Q heat transfer rate,W
- Re Reynolds number
- S cross sectional area of the tube,  $m^2$
- T temperature, K
- $\rho$  density, kg/m<sup>3</sup>
- $\mu$  viscosity, kg/m s
- ø volume fraction
- Subscripts
- b bulk

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exp. experimental nf nanofluid out output p particle

w wall

The nanofluid sample was prepared by weighing 100 g of water and mixed with  $SiO_2$  nanoparticles. The manufacturing process is continuously inserted into the ultrasonic mixer for 8 hours to achieve homogeneity. Nanofluids are prepared by dispersing nanoparticles in a base fluid, well water. The thermo-physical bonding of nanofluids is estimated based on solid-liquid mixtures. Table 1 presents the thermo-physical properties of SiO2, basic liquid (a mixture of water SiO2), and air at 300 Equation C. Pak and Cho [17] were used to estimate density, viscosity, specific heat, and thermal conductivity for the equations presented in formula (2).

$$\rho_{nf} = \phi \rho_P + (1 - \phi) \rho_{bf} \tag{2}$$

$$C_{pnf} = (1 - \phi) \left(\frac{\rho_{bf}}{\rho_{nf}}\right) C_{pbf} + \phi \left(\frac{\rho_P}{\rho_{nf}}\right) C_{PP}$$
(3)

$$k_{nf} = \frac{k_p + (n-1)k_{bf} - \phi(n-1)(k_{bf} - k_p)}{(4)}$$

## Experimental settings and procedures

Experimental test equipment was prepared by assembling a small vehicle cooling system consisting of a coolant reservoir tank, electric heater, high-temperature resistant water pump, radiator, and air fan. Other supporting equipment are thermocouples, anemometers, and temperature indicators to record the temperature and fluid flow rate. The schematic display of the test equipment used is presented in Figure 2. For the front view and rear view are shown in Figures 3 and 4. The coolant in the tank is heated to the desired temperature. The pump is turned on so the coolant flows through the aluminum radiator, and the liquid's speed is regulated through the control valve. It can be observed through the scale on the anemometer, then the fan is turned on to absorb heat from the liquid discharged into the environment. The temperature is measured at the radiator inlet, outlet, and wall.

TABLE 1. PROPERTIES OF BASIC FLUIDS AND SIO2 NANOPARTICLES [10].

DENSITY, VISCOSITY, THERMAL CONDUCTIVITY, S	SIO2 NANOFLUIDS AT A CONCENTRATION OF $0.1\%$ & $0.15\%$
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Property	Water	SiO <sub>2</sub>	Nano Fluid
	100%	0.1%	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 <sub>p</sub> )	4.185 J/gC	5.56 J/gC	6.50 J/gC

#### DISCUSSION

#### Base fluid in the radiator

Before conducting the analysis using nanofluids in the radiator, several experiments were carried out with basic fluids to check the reliability and accuracy of the tools used in the experiments so that they could be as expected. Comparisons were made between the experimental data and the data from previous studies [18]. The very close relationship in the published literature has proven the reliability of the results of the experimental test settings and the measured data.

## Nanofluid in radiator

As a nanofluid with a SiO<sub>2</sub> 0.5% concentration of raw water pumped through the radiator and other supporting installations, the flow rate is set among 2.5, 4.5, and 6 LPM. To know for sure about the effect of thermal efficiency on the radiator performance system, then analyzed the effectiveness of the radiator ( $\mathcal{E}$ ) against time as described in Figure 5.

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Figure 2. Schematic of cooling system test equipment



Figure 3. Front view of the cooling system test kit



Figure 4. Rear view of cooling system test equipment



Figure 5. Radiator inlet temperature (°C)

Based on the data obtained during the experiment, it can be seen that the inlet temperature of the nanofluid from the radiator has increased gradually and tends to be stable. It can be seen that the variation of the nanofluid flow velocity of 2.5, 4.5, and 6 LPM is quite influential on the heat absorption in the radiator. When the fluid flow rate is a 6 LPM, the temperature increases when the first second reaches the peak temperature, namely at the 1485th second (24th minute) with a peak temperature of 80 °C. But when the peak temperature has passed, the curve will decrease along with the process. the heat dissipation rate on the radiator is good where the radiator heat is dissipated to the environment [19]. Picture. 5 shows the radiator outlet temperature Tout, as a function of the volume flow rate of the fluid circulating in the radiator. The three data sets shown in the figure have the same base fluid and nanofluid concentration but different flow rates. All data in Figure 5 was obtained when the temperature of the fluid entering the radiator was 35°C.



Figure 6. Radiator outlet temperature (°C)

Figure 6 shows the increase in heat transfer due to the base fluid with nanofluids in the radiator at various flow rates, and there is a corresponding increase in the heat transfer coefficient with the addition of a volume of 0.5% SiO2 nanoparticles into the base fluid at 30 °C when compared to the heat transfer coefficient. In the recorded base fluids, this is because the physical properties of the nanofluids are slightly different from those of the base fluids. While the density and thermal conductivity increase and the specific heat decreases slightly compared to ordinary liquids, the viscosity increases significantly [20].

It is explained in Figure 7, that the radiator wall temperature during the experimental process tends to be more constant or stable. This happens because the variations in the speed or rate of the nanofluid used in this study are 2.5, 4.5, and 6 LPM, which significantly affect the radiator's ability to dissipate heat. It can be seen that the highest recorded temperature was at a rate of 2.5 LPM with a temperature

of 74.5 °C. When the heat passes the temperature peak, the curve decreases drastically, and the heat released in the heat exchanger is discharged to the surrounding environment, and a fan is turned on.



Figure 7. Radiator effectiveness

Based on the results, the heat exchanger's effectiveness on nanofluids flows rate (LPM) with the suitability between the temperature in and temperature out where the effectiveness of the radiator has increased, which then decreases with increasing speed. Thus the heat exchanger used for the experiments in this study is functioning quite well. The effectiveness of the minimum heat exchanger is at a nanofluid flow 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 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% can increase the heat transfer rate in the vehicle radiator. The rate of increase in heat transfer depends on the percentage of nanoparticles added to the base fluid. At a concentration of 0.5%, a 35% increase in heat transfer compared to the base liquid. Increasing the flow rate of the working fluid increases the heat transfer coefficient for pure water and distant nanofluids, while variations in the fluid inlet temperature to the radiator within the tested range slightly affect the heat transfer obtained. It is seen that the increase in effective thermal conductivity of about 3% in this study and other physical variations are not solely responsible for the significant increase in heat transfer. Despite recent advances in the study of heat transfer with nanofluids, further research on understanding the particle mechanism is needed to determine the heat transfer behavior of nanofluids.

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