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Thermophysical and stability investigation of Al_2O_3-TiO_2/water hybrid nanofluids

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Abstract

Currently, one of the big challenges in the cooling systems technology is producing coolant fluid with good thermophysical dan stability properties. The new cooling fluids, namely nanofluid-based coolant has been developed for facing this challenge. Nanofluid is the dispersion of nanoparticle into base fluid. In this experimental investigation, thermophysical and stability of Al_2O_3-TiO_2/Water hybrid nanofluid are studied. The Al_2O_3-TiO_2/Water based hybrid nanofluid have been prepared by using two step method. The experiment is carried out for the various combination of volume fraction (0.2-0.6 wt%), ratio of nanoparticles (70:30-30:70wt%), stirring time (30-90 min), and sonication time (60-120 min). The thermophysical properties of the prepared nanofluids were characterized using pycnometer method for density and viscometer fall ball for viscosity. Photograph capturing method is applied to investigate the stability of nanofluids. According to the obtained results, the viscosity, density and stability have influenced by the synthesis parameters.

Keywords: density, nanofluid, taguchi method, thermophysical, viscosity

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1. INTODUCTION

Nanofluids are a new class of working fluids applied in heat transfer applications which consist from a base fluid and nano particles with a diameter under 100 nm. These fluids consist from two or three solid materials into conventional fluids (water, ethylene glycol or water-ethylene glycol mixture, engine oil, kerosene, vegetable oil and paraffin oil). The solid nanoparticles used for working fluids are SWCNT-MgO, MWCNT-Fe_3O_4, MgO-MWCNT, Fe_2O_3-CNT, Fe_3O_4-Graphene, Graphene - Ag, Al_2O_3-CNT, SiO_2-CNT, Al_2O_3 – Cu, Al_2O_3-Ag, Cu–TiO_2, Cu-Cu_2O, Cu-Zn, Ag-SiO-carbon, Ag-TiO_2, Ag-MnO, Ag-CNT, diamond-Ni, ND-Co_3O_4, Al_2O_3-MEPCM, Al_2O_3-SiO_2 (Gupta et al., 2017; Huminic & Huminic, 2018).

Due to higher some thermophysical and stability of solid nano particles compared to liquids, it may be obtained working fluids with significant enhanced some properties that can be used in some application devices (Sadiq et al., 2018; Su et al.,

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2016). To realize the unique properties of nanofluids and their potential, in last years, an innovative class of nanofluids, which consist from two solid particles suspended in the base fluid, called hybrid nanofluids, was developed. These novel hybrid nanofluids showed a great promise as next-generation heat transfer fluids for heat transfer applications.

Numerous studies have been conducted to investigate the thermophysical properties of nanofluids and hybrid nanofluids, but most studies are focused on to evaluation of viscosity and density, especially of alumina nanofluids. So far, many researchers have studied on coolant (Darminesh et al., 2017; Hamid et al., 2015; Sadiq et al., 2018). However, very limited research has been reported on applying hybrid nanofluid-based coolant. All these studies available in the literature review mainly focus on single nanofluid. There is still limited study on thermophysical and stability investigation for coolant prepared from hybrid nanofluids so far. The purpose of this study is to prepare and investigate the effect of the synthesis parameters on the viscosity, density, and stability of the hybrid nanofluids.

2. MATERIALS AND METHODS

The nanoparticles materials used in synthesizing hybrid nanoparticles -based coolant are aluminium oxide (Al_2O_3) and Titanium dioxide (TiO_2). Water is chosen as based fluid for coolant. Generally, there are two main techniques used by researchers (Aberoumand & Jafarimoghaddam, 2017; Katpatal et al., 2017; Zawawi et al., 2018) to synthesize nanofluids: the one-step method and the two-step method. In this study, the first step begins with weighing with a high precision electronic balance of ±0.001 g accuracy and dispersing amount of Al_2O_3- TiO_2 into water following nine different mentioned volume fraction (0.2-0.6 wt%), ratio of nanoparticles (70:30-30:70 wt%), stirring time (30-90 min), and sonication time (60-120 min). The magnetic stirrer is used for 45 minutes for direct mixing of the base fluid with the nanoparticles uniformly. The second step is homogenizing process applying a ultrasonicator device (BAKU BK-1200) at the frequency of 40 kHz for 3 hours. The dispersion is undergone to the sonication time with greater stability. The process parameters and levels in synthesizing nanofluids-based coolant are designed using Taguchi approach (Oemar et al., 2023) and depicted in Table 1. The sketch of the two-step method in this study is shown in Figure 1.

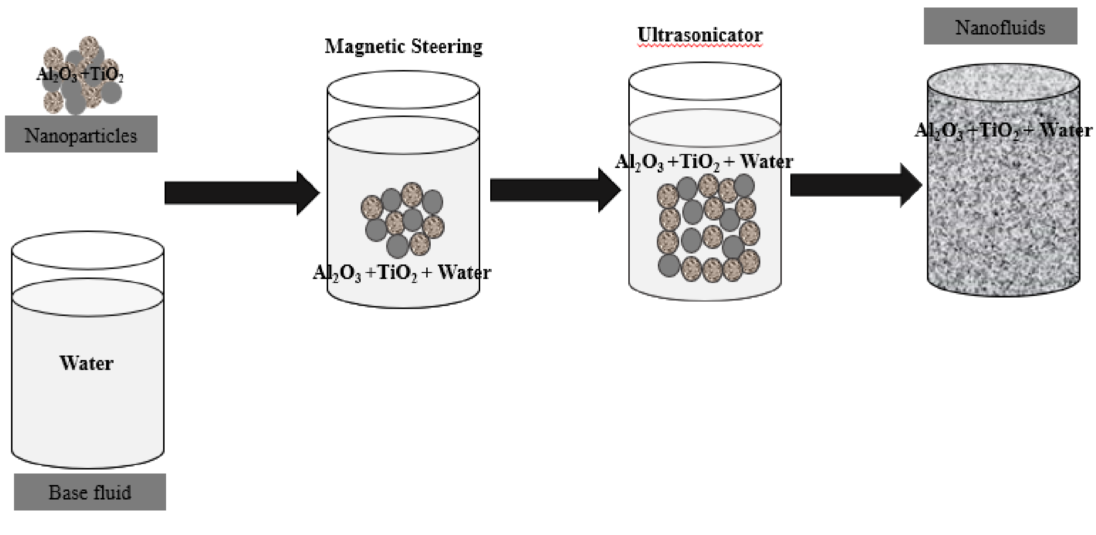

Figure 1. The synthesis process of Al_2O_3- TiO_2/Water hybrid Nanofluid

Table 1. Synthesis process parameters of nanofluids and levels

No.	Parameters	Symbol	Unit	Level 1	Level 2	Level 3
Control factors						
1	Volume fraction	A	%	0,2	0,4	0,6
2	Ratio of nanoparticles	B	%	70:30	50:50	30:70
3	Stirring time	C	min	30	60	90
4	Sonication time	D	min	60	90	120
Response variables						
1	Viscosity	μ	cP	-	-	-
2	Density	ρ	g/cm^3	-	-	-

Table 2. The various combination of Al_2O_3- TiO_2/Water hybrid Nanofluid

Sample No.	Volume fraction, A (%)	Ratio of nanoparticles, B (%)	Stirring time, C (min)	Sonication time, D (min)
S1	0,2	70:30	30	60
S2	0,2	50:50	60	90
S3	0,2	30:70	90	120
S4	0,4	70:30	60	120
S5	0,4	50:50	90	60
S6	0,4	30:70	30	90
S7	0,6	70:30	90	90
S8	0,6	50:50	30	120
S9	0,6	30:70	60	60

3. RESULTS AND DISCUSSION

3.1 Viscosity Al_2O_3- TiO_2/Water hybrid nanofluids

An investigation of the influence of volume fraction, ratio of nanoparticles, stirring time, and sonication time on the viscosity of Al_2O_3- TiO_2/Water hybrid nanofluids was carried out. The viscosity of the hybrid nanofluids under varying temperatures (28, 50, and 93.5 ˚C) is shown in Figure 2. The temperature was observed to enhance the viscosity of hybrid nanofluids. The temperature variable has influenced on the viscosity. A seemingly linear correlation was observed between temperature and viscosity. In addition, the viscosity was noticed to increase as the temperature decreased. The percentage enhancement of the hybrid nanofluids viscosity compared with water and commercially coolant is illustrated in Figure 2.

The temperature and viscosity of nanofluids have an inverse relationship. The higher the temperature of the nanofluid, the lower the dynamic viscosity of the nanofluid. This happens because when the temperature of the nanofluid increases, the particles in the nanofluid will move faster. The conclusions of several previous researchers showed the same results where the viscosity of the nanofluid will decrease as the temperature of the nanofluid increases (Chamsa-ard et al., 2017; Giwa et al., 2021; Huminic et al., 2021; Jose et al., 2015; Kotia et al., 2018).

The viscosity of nanofluids from samples S1 to S9 has a higher value than the viscosity of the base fluid, namely distilled water. This happens because of the addition of nanoparticles which change the viscosity of the base fluid in the form of distilled water. Viscosity data shows that S3 has the highest viscosity at 2.3165 cP when compared to other samples, this happens because in S3 the process of mixing nano particles and base fluid with a magnetic stirrer and a vibration system with an ultrasonic cleaner takes the longest time. namely 90 minutes and 120 minutes. As a comparison, a viscosity test was also carried out on the commercial Coolant. When compared with the nanofluids, commercial coolant has a better ability to maintain its viscosity when tested at higher temperatures.

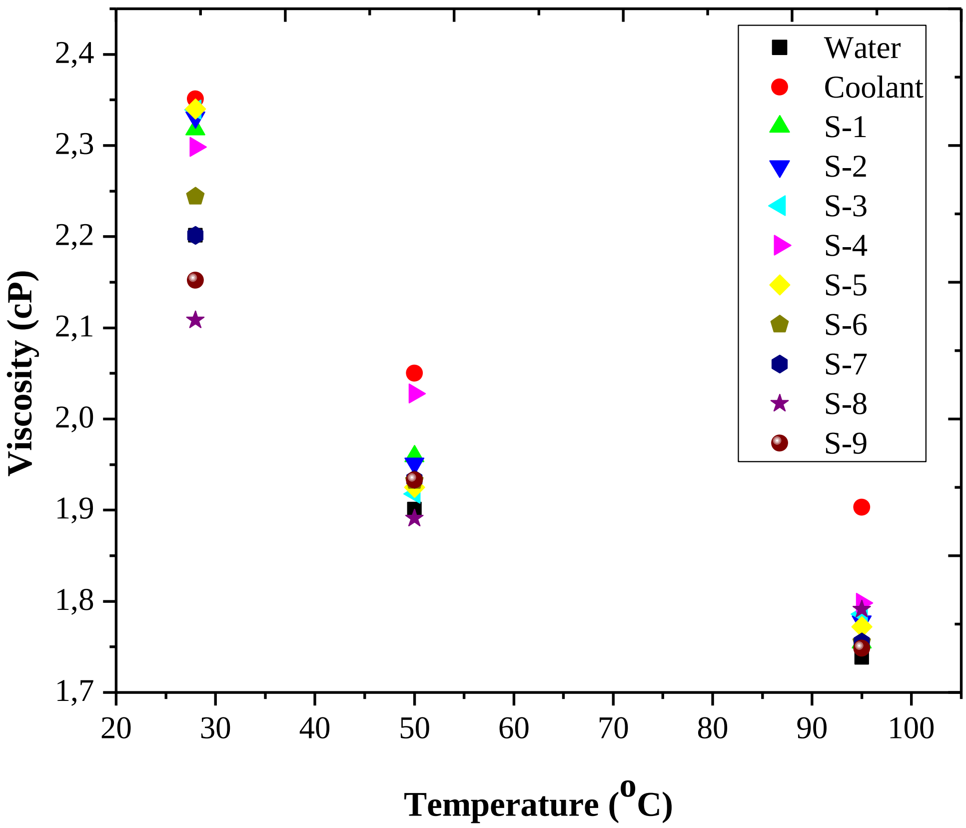

Figure 2. Variation of Al_2O_3-TiO_2/Water hybrid nanofluids viscosity at various temperature

3.2 Density Al_2O_3- TiO_2/Water hybrid nanofluids

Based on the density results in figure 3, sample S8 and S9 have the highest density compared to the other samples. This happens since in sample S8 and S9 the nanofluid uses the highest nanoparticle volume fraction (0.6 %). Meanwhile, sample S3 has the lowest density value (0.996 g/cm^3). This occurs due to the use of a low nanoparticle volume fraction in sample 3 (0.2 %). It can be realized that the density value tends to increase with increasing volume fraction of the nanoparticles (Kedzierski et al., 2016; Kumar et al., 2020).

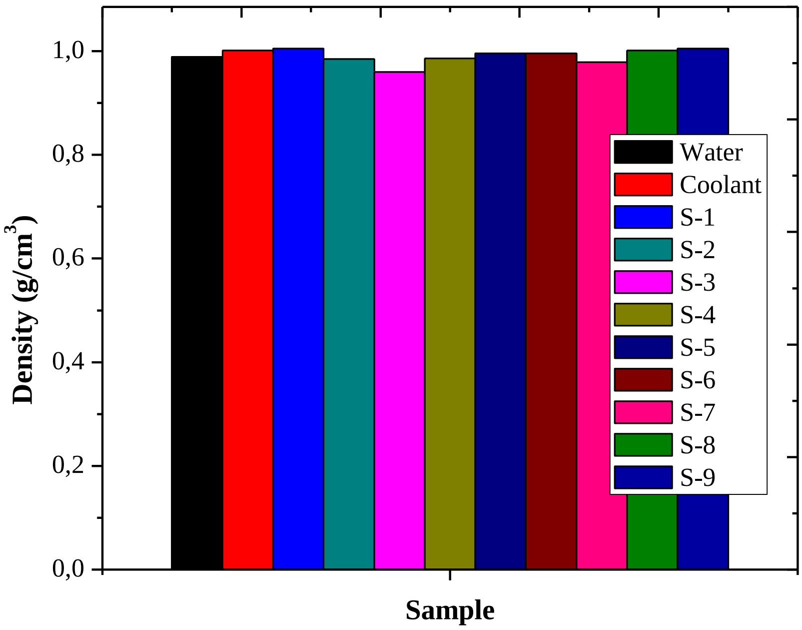

Figure 3. Variation in density of Al_2O_3-TiO_2/Water hybrid nanofluids

3.3 Stability Al_2O_3- TiO_2/Water hybrid nanofluids

The stability of nanofluids was analysed using visual sedimentation observation. Figure 4 shows the stability level of the nanofluid samples i.e., S1 to S9. The photographs were taken shortly after the preparation were carried out. Based on these photographs, it can be seen that the Al_2O_3-TiO_2/water hybrid nanofluids are solid and dark white which indicates that the nanofluids are in a stable state. Based on the visual observation, no deposition was visible for any nanofluids just after preparation. This is indicated by the absence of sedimentation in all samples (Bin Mahfouz et al., 2023; Ma et al., 2021; Yang et al., 2023). While, the sedimentation has occurred after the nanofluid synthesis process (Figure 5). The precipitate of the nanofluid sample is marked with a red dotted line. Based on this line, the amount of sediment from samples 1-9 nanofluids is different. This arises since there are differences in parameters in the preparation process for each sample.

In the first week after preparation, sample S1, S2, and S4 appeared to have the poorest stability because the nanoparticles appeared to be separated from the base fluid. The sediment formed in sample S1, S2, and S4 settles completely to the bottom of the bottle which is used to observe the sedimentation process. Meanwhile, the fluid above the sediment looks clear, like distilled water without a mixture of nanoparticles. This shows that sample S1, S 2, and S4 are not mixed well. Temporarily, sample S5, S6, S8, and S9 appear to have high stability because the nanoparticles and base fluid are mixed and do not quickly form deposits and are able to preserve their stability. At 4 weeks after preparation, the precipitate formed was seen almost evenly in all nanofluid samples, except for sample S6, 8, and 9. In S7, 8, and 9, it can be seen that the fluid above the sediment is more turbid than the other samples, this occurs because the volume fraction used is 0.6% which is higher than S1-6. The volume fraction used and the nanoparticle ratio appear to influence the stability of the nanofluid (Katpatal et al., 2017; Mukesh Kumar et al., 2020) . The sample S9 has the best stability, while the sample S1 has the worst stability. It can be concluded that the use of a volume fraction of 0.6 % and the use of more TiO_2 nanoparticles than Al_2O_3 nanoparticles can increase the stability of the nanofluid.

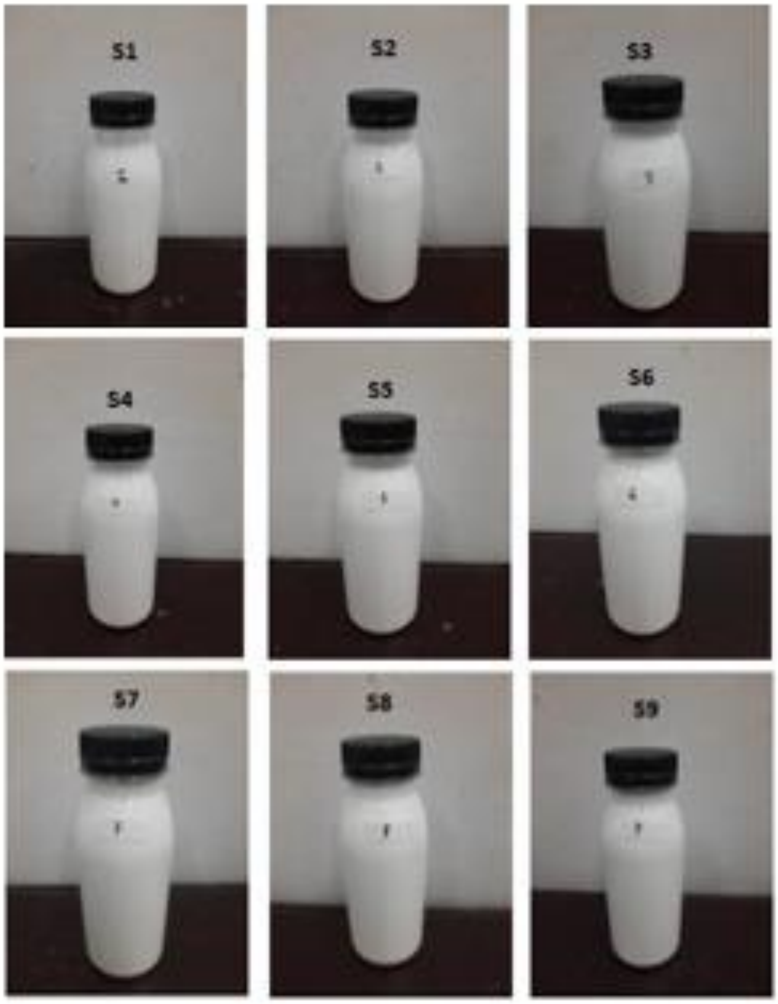

Figure 4. The photographs of Al_2O_3-TiO_2/Water hybrid nanofluids just after preparation

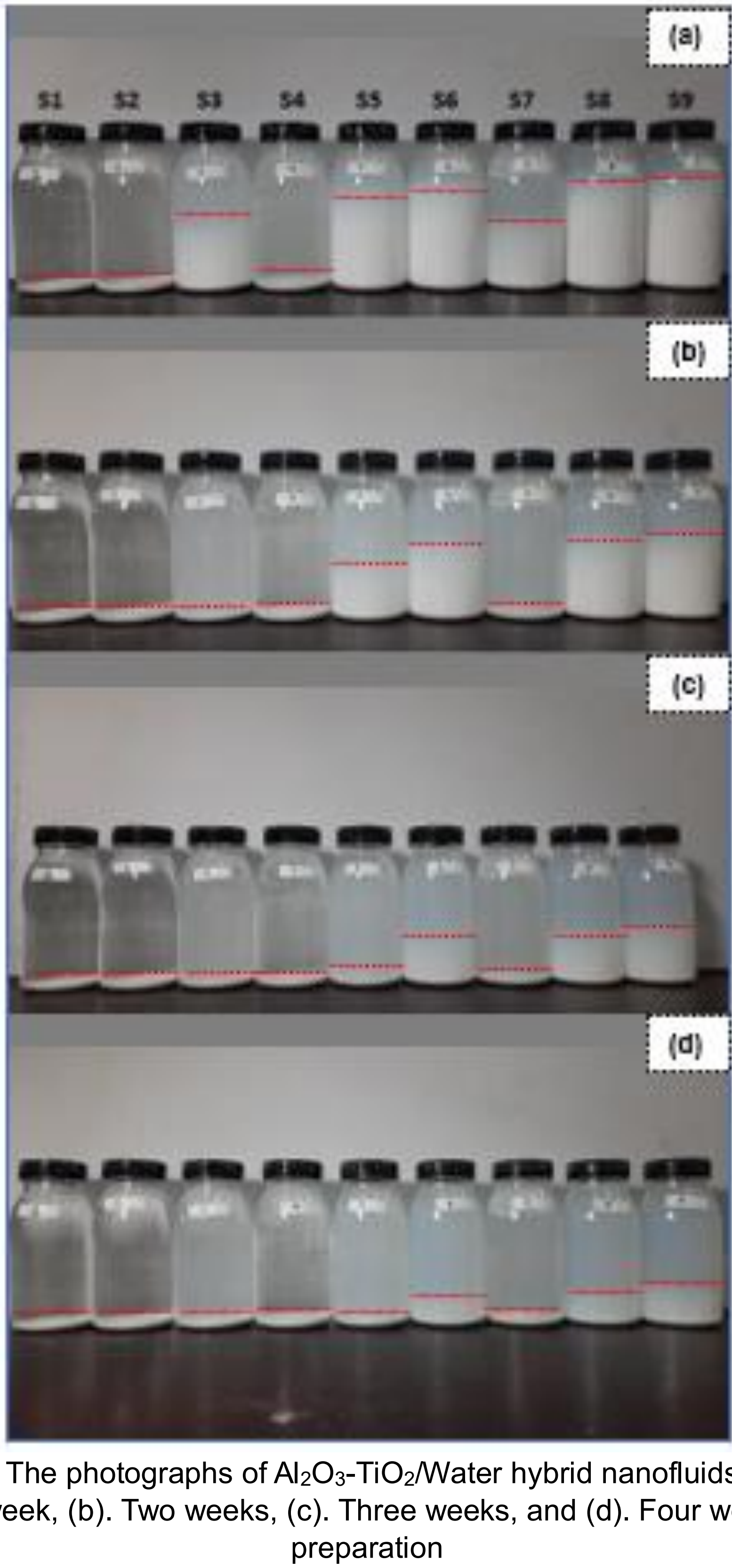

Figure 5. The photographs of Al_2O_3-TiO_2/Water hybrid nanofluids stability; (a) One week, (b). Two weeks, (c). Three weeks, and (d). Four weeks after preparation

4. CONCLUSION

In this study, two thermophysical properties i.e. viscosity and density of Al_2O_3-TiO_2/Water hybrid nanofluids were investigated experimentally for 9 samples with different condition of synthesis parameters such as volume fraction (0.2-0.6 wt%), ratio of nanoparticles (70:30-30:70 wt%), stirring time (30-90 min), and sonication time (60-120 min). The second investigation was stability of nanofluids. Viscosity of hybrid nanofluids was measured in the temperature varied in 28, 50, and 93.5 ˚C of temperature. The viscosity of the nanofluids decrease as the temperature increases, the density tends to increase with increasing volume fraction, and the stability are influenced by the volume fraction and ratio of nanoparticles.

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