Improvement of Nanofluid stability using 4-Step UV-Vis Spectral Absorbency Analysis

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ABSTRACT

The most challenging matters for the utilization of nanofluid into a certain system is its stability. The nanofluid with undesirable stability will damage the system due to fouling, and settlement from the base fluid. In addition, unstable nanofluid will have a lower thermal performance enhancement. An improved method, 4-Step UV-Vis spectral absorbency analysis has been suggested to improve the stability of the nanofluid. SiO_2 nanoparticles were dispersed in the PAG lubricant by using the two-step preparation method. The stabilization methods of the SiO_2/PAG were done by using the suggested method. The result indicates that all nanofluid shows good stability in stationary position even after 30 days. The absorbance of every three concentration decreased compared to their respective initial absorbance, but maintained for specific value at over 70 % compared to the initial absorbance even after 30 days.

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Introduction

Nanofluid have been developed by many researchers with the main objective to enhance the performance efficiency of the thermodynamic and mechanical systems. This advanced liquid has been applied in many applications with the aim to provide a more efficient energy system, saving energy supply, reduce the dependency towards fossil fuels and reduce greenhouse gas emissions to the environment. Nanotechnology has actually been employed by many studies in a variety of applications such as engine oil, gear oil, refrigeration system (heating and cooling buildings), cooling of electronic devices, cooling of the boiler exhaust, lubrications, medical applications and nanofluid in transformer oil [1-9]. The nanofluid is a mix of a base fluid (Example: distilled water, ethylene glycol, lubricant) with nano sized particles (1–100 nm) suspended inside which are metal or metal oxide. Among the principal advantages of nanofluid is the enhancement in term of thermal performance, viscosity, tribology, and heat transfer coefficients compared to the base fluid.

Nanofluid can be prepared using two types of method; the one step preparation method and two step preparation method [10]. One-step preparation method is a process in which the nanoparticles are directly developed by physical vapour deposition (PVD) techniques or methods of fluid chemicals for synthetization nanofluid. The most common method to produce nanofluid is the two-step method. Nanofluid can be made on a large scale but with the lower cost of production via the two-step preparation method. In the two step method, the first step is to create the nanomaterials dry powders by thermal decomposition and photochemical routines, salt reduction of transition metal methods metal vapour synthetization and electrochemical synthetization techniques, and ligand reduction [11]. Then, the second steps in two-steps method of preparation; the nanoparticle will be mix and dispersed into the base fluid. Still, due to the high surface area and surface activity, nanoparticles have the tendency to aggregate and agglomerate. The stability of nanofluid was one of the main concerns that affected the properties of nanofluid and their operation in an application system. The agglomeration of nanoparticles in the nanofluid often create problem such as settlement and clogging of in the system, also the thermal conductivity of nanofluid will decrease.

Presently, there are three methods to improve stability of nanofluid. Among the methods to further stabilise the nanofluid are pH control via surface chemical effect, surfactant addition, and ultrasonic sonication vibration. The ultrasonic vibration is the common methods used to stabilize the nanofluid [12-14]. An optimal time for ultrasonic vibration process need to be found in order to attain the best stability for certain nanofluid [15, 16]. Today, there are several techniques to examine the stability of the nanofluid. The techniques are UV Vis spectral absorbency analysis, FESEM and TEM micrograph assessment, visual sedimentation photograph method, pH evaluation, and zeta potential evaluation [17-19]. UV-Vis Spectral absorbency analysis is an effective way to evaluate the stability of nanofluid by quantitatively measure the colloidal stability of the nanofluid dispersions. A comprehensive method by using UV-Vis spectrophotometer to evaluate nanofluid stability has been established by [13, 20-23]. This method consists of three step method [19], by considering the fact that the absorption of energy depending on the intensity of the UV light pass through a fluid. Even so, these three step methods can be further improved; if the most optimum time to produce a more stable dispersion of nanofluid is known. The combination of these method most likely can produce nanofluid with a better dispersion stability and lower sedimentation potential.

Therefore, the purpose of this paper is to establish the 4-Step UV-Vis Spectral Absorbency Analysis to improve current knowledge about the utilization of the UV-Vis spectrophotometer method. The details of each step of the method will be explain briefly in this paper.

Methodology

Sample preparation

The nanofluid preparation method is one of the important aspect and require to be handled properly. A stable and durable nanofluid is an important requisite for the properties enhancement, which is coming from the good preparation method. In this paper, the SiO_2/PAG nanolubricant was prepared by using two-step preparation method. The calculation for the volume concentration for different concentration of nanofluid were done by following previous research [14, 23, 24]. SiO_2/PAG nanolubricant was a lubricant type of nanofluid, which is specifically used in the refrigeration system. SiO_2 nanoparticles (produced by Beijing DK Nanotechnology Co. Ltd company) with 30 nm in diameter were dispersed into PAG lubricant for 1 hour using magnetic stirrer. Figure 1 shows the image of TEM and FESEM of SiO_2 nanoparticle. The figure further confirms that the size of the nanoparticles is 30 mm in average and has spherical shape. The attributes of the SiO_2 nanoparticles are shown in Table 1.

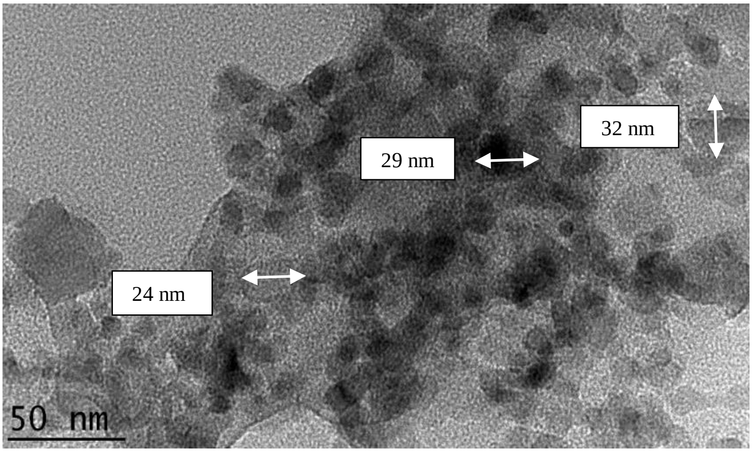

Figure 1 (a): TEM image of SiO_2/PAG nanolubricant at X 88,000 magnifications.

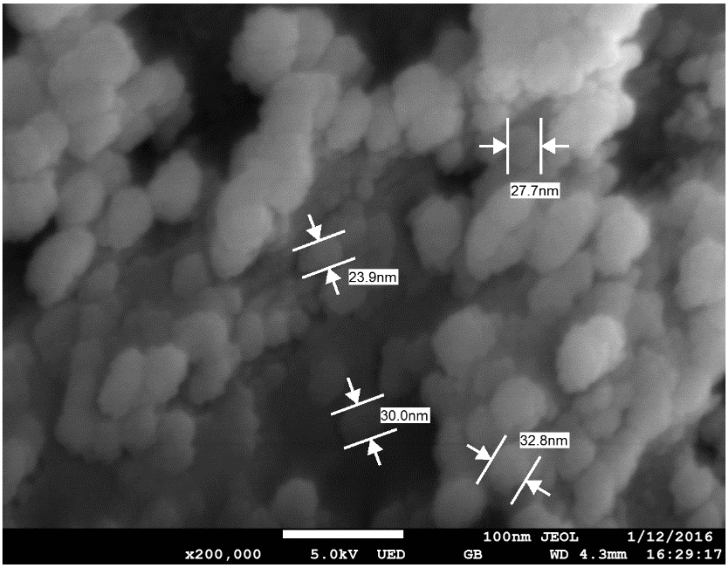

Figure 1(b): FESEM image of SiO_2 nanoparticle powder at X 200,000 magnifications.

Table 1: Properties of SiO_2 nanoparticles.

Property	Value
Molecular mass, g/mol	60.08
Average Particle diameter, nm	30
Density, kg/m^3	2220
Thermal Conductivity, W/m k	1.4
Specific heat, J/kg K 745	745

Then, the ultrasonic vibrator (Fisherbrand FB15051, 320 Watts, and 50 kHz) was applied to further break down the agglomeration between the nanoparticles for a certain period of time. There are debates about how long the sonication process needs to be executed in order to produce nanofluid with the best stability, but with an appropriate amount of time. As concluded from previous study, occasionally after passing the optimized duration of the sonication process, it will cause more serious problems in agglomeration and clogging resulting in faster sedimentation [15, 16], as summarised in the Table 2 below.

Table 2: Summary of the previous experiment of effect of optimum sonication time on stability and properties of nanofluid.

Author	Nanofluid	Optimum sonication time, t (min)	Observation
Buonomo et al. [16]	Al_2O_3/H_2O	80-100	The highest and steady thermal conductivity reading obtained at the optimum sonication time
Sonawane et al. [15]	TiO_2/MO	60	The highest thermal conductivity enhancement obtained at the optimum sonication time
	TiO_2/EG	60	
	TiO_2/H_2O	60	
Garg et al. [25]	CNT/H_2O	40	Optimum ultrasonication time aids in forming better dispersions.

Dispersion stability evaluation

The colloidal stability in term of spectral absorbency of the different concentration of nanofluid was measured by using UV-Vis spectrophotometer (Drawell FDU 8200 UV-Vis) instrument. The UV-Vis spectral absorbency analysis is commonly utilized to determine the stability of the nanofluid because of its applicability for all base fluids, compare to zeta potential analysis which is applicable only for the certain viscosity of fluid. In the UV-Vis spectrophotometer instrument, the UV light passing through the nanofluid dispersion as shown in Figure 2. The intensity of a light passing through the nanofluid decrease exponentially with the increase of concentration of nanofluid.

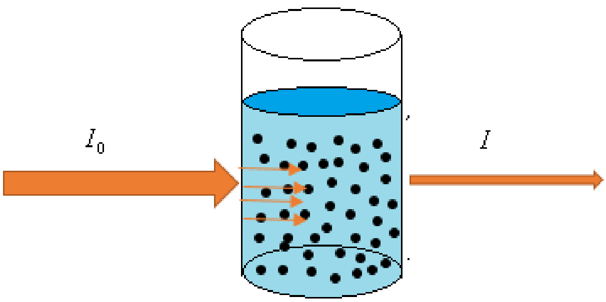

Figure 2: The illustration of UV-Vis spectrophotometer working principle.

Previously, the full analysis of stability using UV-Vis were done in three steps [19]. The four steps of analysis for the spectral absorbency analysis have been proposed in this work. This is due to the fact that different types of nanofluid and nanoparticles, each have their own optimum sonication time to reach stability.

In the first step of the 4-Step UV-Vis Spectral Absorbency Analysis, the peak absorbance of the dispersed nanoparticles need find out from 200 to 900 nm wavelength by scanning. The peak wavelength will show highest numbers of absorbance, and this peak wavelength will act as a reference point for the next step. In the second step of this method, the absorbance for different concentration of nanofluid were measured. The measurement for different concentration of nanofluid were taken at the same wavelength. This is to demonstrate that the nanofluid suspensions will have a linear relationship between the absorbance and the concentration which follow the Beer–Lambert Law [26, 27] which is shown on Equation 1, where A is the absorbance, I_0 is the initial intensity of the light, I is the final intensity of the light, ε is the molar absorptivity , C is the concentration, and L is the path length through the sample.

$$A = \log_2[\frac{I_0}{I}] = \varepsilon CL \tag{1}$$

The third step of this method, the same concentration nanofluid with different sonication time were prepared. Then, the absorbance of the nanofluid will be measured for a certain period of time. Among the different sonication time of the nanofluid, the highest concentration ratio at the end of the experiment indicated that the nanofluid were prepared with the best sonication time. The fourth step of this method, the supernatant particle concentration in base fluid with sediment time was observed for 30 days. This is to demonstrate that with the method proposed in the paper to prepare the nanolubricant; it can achieve better stability for a long period of time.

Results and discussion

The UV-Vis spectrophotometer were used to measure the colloidal stability in term of spectral absorbency of nanofluid. In the first step of the method, the absorbance scanning of the oil based nanofluid from 200 to 400 nm wavelength were shown in Figure 3. As indicated in the figure, it appears that the peak absorbance of SiO_2/PAG oil-based nanofluid suspensions is at 313 nm wavelength. From the graph, it can be understood that the nanofluid have the different absorbance value corresponding to their concentration at the same peak wavelength.

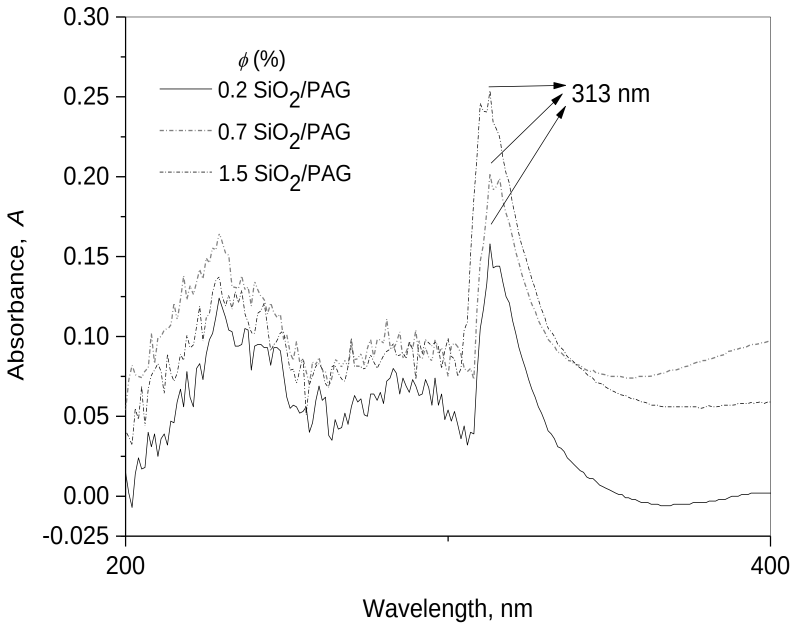

Figure 3**:** UV–Vis spectrum of SiO_2/PAG absorbance scanning from 200 to 400 nm wavelength.

Figure 4 indicates that a linear relationship between the different concentration of the nanofluid and the absorbance at the same wavelength. As shown from the graph, the higher the concentration, the higher the absorbance. From the linear relationship of the graph, the nanofluid concentration can be predicted by measuring the absorbance [28]. This relationship is also useful to predict nanofluid stability, as the absorbance of the nanofluid decreases with time. The comparison of the initial and the current concentration at a certain time will show how good the stability and the sedimentation of the nanofluid.

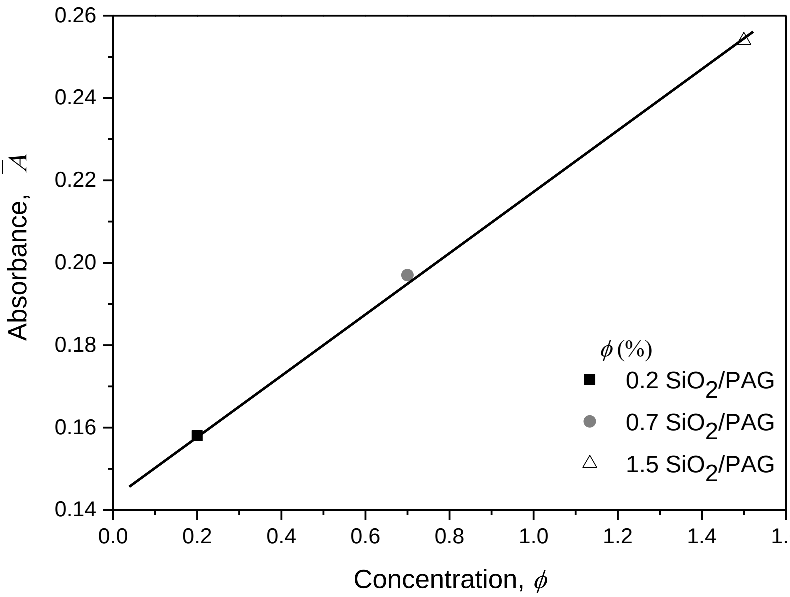

Figure 4**:** UV-Vis spectrophotometer linear relation graph between absorbance and SiO_2/PAG nanolubricant concentration.

Figure 5 shows the UV–Vis spectrum of 0.2 % volume concentration for different ultrasonic sonication times. After two weeks, it is found that the SiO_2/PAG with 2 hours ultrasonic sonication time obtained the best stability compared to other sample. With the increasing of the ultrasonic sonication time, the final absorbance and the initial absorbance ratio still maintained and higher from another sample. Thus, the most optimum time for preparing the SiO_2/PAG oil based nanofluid is 2 hours.

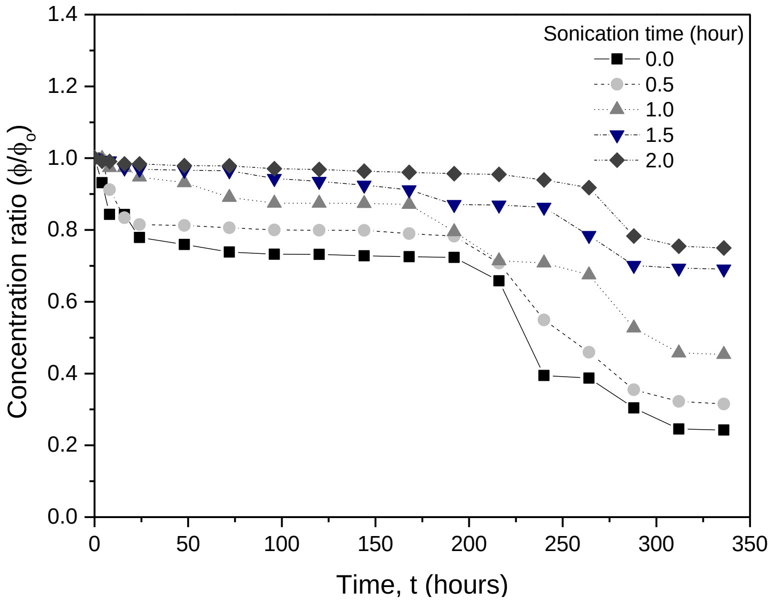

Figure 5**:** Absorbance ratio of SiO_2/PAG nanolubricant for different sonication time as a function of time.

The different concentration of nanofluid was prepared. The ultrasonic vibration process was done for 2 hours as indicated by previous steps to further stabilise the nanofluid. The samples were left for 30 days and the absorbance of the nanofluid were measured for each week. The graph of supernatant particle absorbance against the sedimentation time was shown in Figure 6. It is proven that the higher concentration of nanofluid has a higher absorbance. The higher concentration of nanofluid has higher nanocluster size, thus the chances of the absorbency decrement are also higher [29]. In addition, with the increase of nanocluster size, decrease of absorbency over time were faster due to the settling of nanoclusters. Nevertheless, all nanofluid show good stability even after 30 days. The absorbance of all three concentration decreased compared to their respective initial absorbance, but maintained for specific value at over 70 % compared to the initial absorbance even after 30 days.

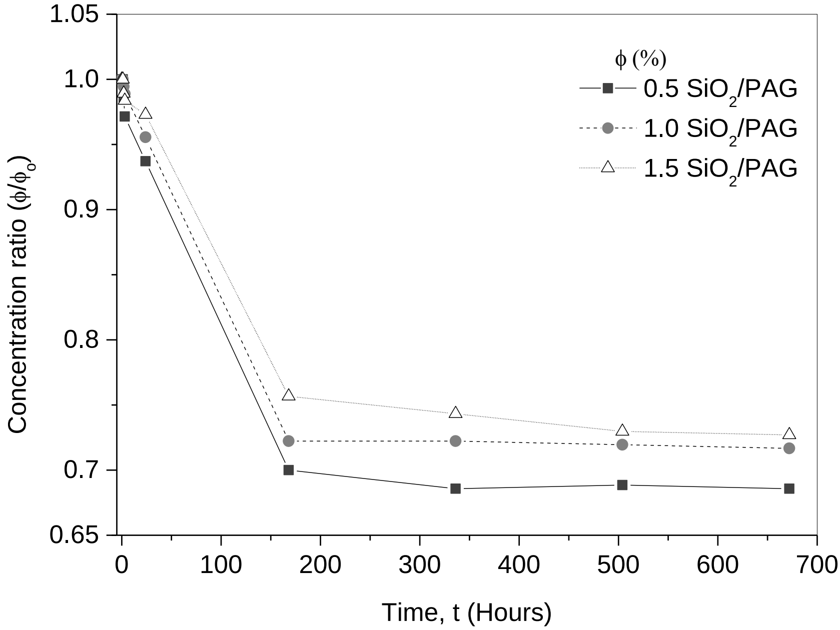

Figure 6: UV-Vis spectrophotometer graph for different concentration nanolubricant for 30 days.

The figure 7 presents the comparison graph of UV-Vis spectrophotometer of the current finding with previous finding from the literature. The concentration ratio, which is obtained from UV-Vis spectrophotometer measurement for 30 days of SiO_2/PAG nanolubricant optimized with 4-Step UV-Vis spectral absorbency analysis was compared with the normal SiO_2/PAG nanolubricant and Al_2O_3/H_2O nanofluid from another experiment [29] at same volume concentration. At the start of the experiment, the optimized SiO_2/PAG nanolubricant show a rapid decrement for the first week, compared to the SiO_2/PAG nanolubricant, and Al_2O_3/H_2O nanofluid. This is probably due to the dissimilar types of base fluid and different sonication time used, which show the different behaviour of the aggregation with nanoparticles. Yet, the optimized SiO_2/PAG nanolubricant show greater long term stability at the fourth week of the experiment compared to other experiment. The optimized SiO_2/PAG nanolubricant which have been prepared via 4-Step UV-Vis spectral absorbency analysis definitely show good long term stability with the concentration ratio still maintained about 70 % from original concentration.

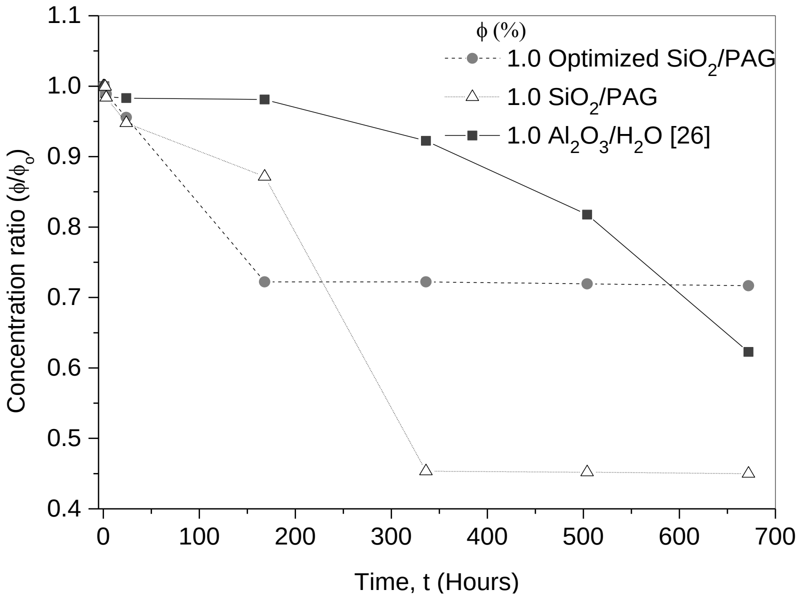

Figure 7: The UV-Vis spectrophotometer comparison graph of previous finding from different researchers with the current finding.

Conclusion

An improved method have been discovered to further improve the stability of the nanofluid. SiO_2/PAG oil based nanofluid have been prepared using two steps preparation method. The stabilization method used in the experiment was ultrasonic vibration process without the addition of pH-stabilizer and surfactant. The peak absorbance of the nanofluid, linear relation of concentration and absorbance, optimum sonication time, and time dependant sedimentation observation were done in a 4-stage method of UV-Vis spectral absorbency analysis. This method have been introduced as an improvement from the previous method. The final result show that all nanofluid show good stability even after 30 days. The absorbance of all three concentration decreased compared to their respective initial absorbance, but maintained for specific value at over 70 % compared to the initial absorbance even after 30 days.

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