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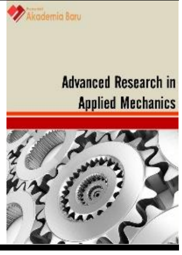


# Comparison of Preparation Methods Effect on the Stability of Compressor oil-based Nanolubricant

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**ABSTRACT**

The stability evaluation for a nanolubricant is important before any application to a system. The production of nanolubricant can be done using the various method. This study aims to compare the effect of nanolubricant stability on the different preparation methods. The TiO2 nanolubricant with compressor oil base was prepared using a high-speed homogenizer (HSH) and ultrasonic bath. The HSH speed was varies between 5000 and 15000 rpm while the sonication period was varied from one hour to 5-hours. Visual observation and UV-Vis spectrophotometer method were used to evaluate the nanolubricant stability. Results reveal that the UV-Vis method produces better stability for TiO2 nanolubricant than HSH. The 5-hours ultrasonic shows the best result with a 0.9 concentration ratio after 15 days of preparation. The HSH shows that the 15000 rpm nanolubricant have better stability than the lower speed. The stability of nanolubricant increase by the increment of HSH speed as well as ultrasonication periods. The ultrasonic bath with a 5-hours sonication time is recommended for TiO2 as it provides the best stability.

***Keywords:***
Compressor; nanolubricant; stability; high speed homogenizer

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## 1. Introduction

Stability is one of the crucial milestones that require attention after a nanolubricant preparation. Unstable nanolubricant reduce the benefits that shall be gained from the fluid thus returning those fluid properties to their original condition. Nanolubricant is one of the innovations that expand from a relatively new technology called nanofluids. Generally, it is a suspension of solid particles in a base fluid that can enhance the properties of the original fluid [1]. Nanolubricant has been applied in many systems such as refrigerators [2], air conditioning [3], automobile engines [4], and hydraulic systems [5].

There are two well known nanofluid preparation methods namely one-step and two-step methods. The one-step method simultaneously made and dispersed the nanoparticles in the base fluid. On the other hand, in the two-step method, the nanoparticles were manufactured in powder form in the factory and then dispersed afterwards in selected base fluid [6]. The two-step method is

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preferable as the nanoparticles are easier to manufacture on a factory scale and give high flexibility for the user to prepare the nanolubricant in a different base.

Preparation of nanolubricant can be done using several methods including dissolver, probe sonicator, ultrasonic homogenizer, and bath sonicator [7]. Each of the methods has its advantages and limitations. Whatever method is used to prepare the nanolubricant, the aim is the same is to get stable and homogenous nanolubricant. Redhwan *et al.* [8] prepare the Al2O3 nanolubricant in poly alkylene glycol (PAG) oil using ultrasonic bath method. The prepared nanolubricants has excellent stability and can increase automotive air conditioning performance. Hamisa *et al.* [9] study the stability of $TiO_2$ nanolubricant using polyol ester (POE) oil to be used in hybrid electric vehicle air conditioning. The Ultrasonication period was varies between one and seven hours to determine the most stable method.

High-speed homogenizer (HSH) was commonly used in food processing as well as cosmetic industries. It was not found in the literature this method was used for homogenizing nanolubricants with compressor oil-based. Although, this method can produce homogenous liquid and may have the potential to produce excellent stability nanolubricant. Therefore, the current study aims to compare the preparation method between HSH and ultrasonic bath methods. The stability will be evaluated qualitatively and quantitatively to identify the effect of the different preparation methods of nanolubricant.

## 2. Methodology

The nanolubricants in this paper were prepared using a two-step method. The $TiO_2$ nanoparticles were weighted using high accuracy balanced scale and stirred in synthetic compressor oil for half an hour. The concentration of nanoparticles was calculated using Eq. 1

$$\phi(\%) = \frac{V_{np}}{V_{np} + V_{oil}} \times 100\% \quad (1)$$

Where $V_{np}$ is the volume of nanoparticles converted to weight by multiplying with $TiO_2$ density, $V_{oil}$ is volume if base fluid. The concentration of nanolubricant used in this study is 0.01%. Six nanolubricant samples were prepared where three of them was homogenized using HSH and the other samples using an ultrasonic bath. Three different speeds were used to differentiate the effect of nanolubricant stability which is 5000, 10000, and 15000 rpm. The ultrasonication was conducted at the same power with different time lengths (1, 3, and 5 hours).

The stability evaluation was conducted using three different methods. Transmission electron microscopy (TEM) was performed on one of the samples to confirm the size and distribution of nanoparticles inside the prepared fluids. Qualitative evaluation was conducted by visual using sedimentation photograph capturing method. A quantitative measurement using an ultraviolet-visible (UV-Vis) spectrophotometer was also performed to verify the visual observation results.

All the samples for visual observation were kept in a test tube in stagnant condition and appropriately locate to avoid any movement or disturbance. The samples for UV-Vis measurement were poured in a glass cuvette and measured hourly for the first day after preparation. The measurements were continued on daily basis from the second day until the end of the experiments. The UV-Vis results were presented in terms of concentration ratio by dividing the measured absorbance value with the initial measured value just after preparation.

## 3. Results

The result for TEM captured at a magnification of ×88,000 is depicted in Figure 1. In this figure, the $TiO_2$ nanoparticles were observed to have good distribution inside the respective compressor oil. The size of nanoparticles is within the size declared by the manufacturer (30 to 50 nm). The TEM results show that the prepared nanolubricant shall have good stability since the nanoparticles were able to disperse evenly in the lubricant.

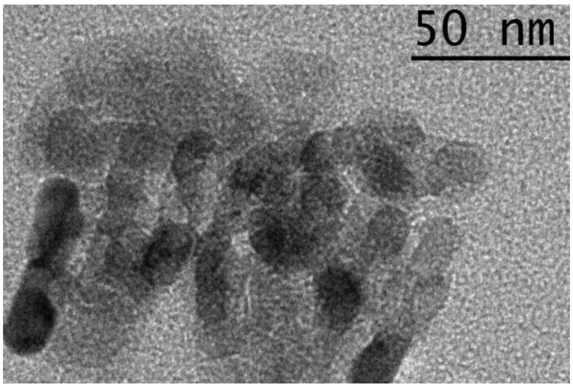
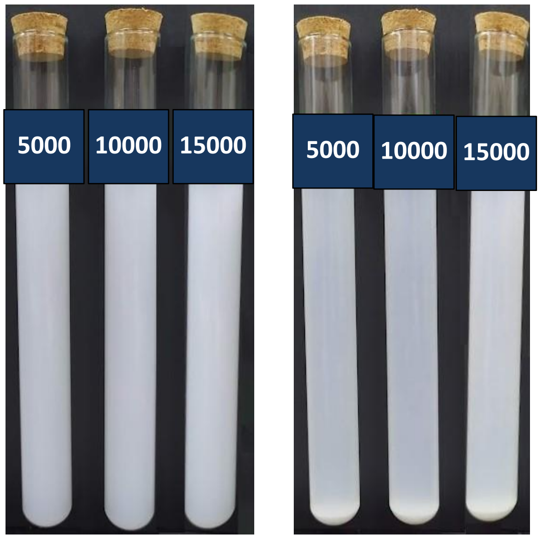



**Fig. 1.** TEM image of $TiO_2$ nanoparticles in PVE lubricant

Figure 2 shows a comparison of nanolubricant observation from zero-day to 15 days after preparation. The $TiO_2$ nanolubricant at 0.01% concentration was prepared using HSH at a different speed. The intensity of nanolubricants at zero-day is the same for all samples. 15 days after that, there are some differences between samples. The white intensity of 15000 rpm is greater than 5000 and 10000 rpm. Small sedimentation of nanoparticles was observed at the bottom of the test tube for all samples after 15 days.




(a) 0 day (b) 15 days

**Fig. 2.** Visual observation for HSH preparation at different speeds (rpm)

The visual observation photos for nanolubricants were prepared using the ultrasonic bath method as depicted in Figure 3. The nanolubricants were prepared at different sonication periods between one to five hours. The murky white nanolubricants does not show significant changes after 15 days of preparation. The only difference observed with naked eyes is a thin line appearing at the top layer of nanolubricants for all samples after 15 days. This layer indicates that a separation between nanoparticles and base fluid has started to happen. Some sedimentation occurred indicated by this line but cannot be captured using naked eyes. The difference in colour intensity between samples also is not significant.

Overall, the visual observation on the nanolubricant does not show significant changes in the stability of nanolubricants even after 15 days of observation. The difference between preparation methods is too small but can be differentiated by the colour intensity. The ultrasonication method shows a better effect on stability where the nanolubricant intensity remains almost the same after 15 days of observation.

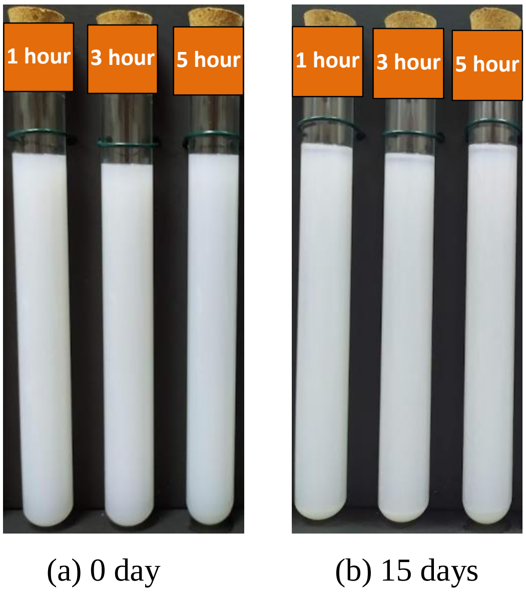



**Fig. 3.** Visual observation for ultrasonication bath preparation at different sonication times

The quantitative stability evaluation using the UV-Vis method is shown in Figure 4 for nanolubricants prepared using the HSH method. For the first two days after preparation, all nanolubricants shows excellent stability where the concentration ratio remains above 0.95. After that, the concentration ratio started to decrease. From day five onwards, separation concentration between samples started to appear. The decrement rate of concentration for nanolubricant with 5000 and 10000 rpm was faster than 15000 rpm. From day eight onwards, the concentration decrement started to be consistent at a linear rate until the end of observation. After 15 days, the concentration ratio value for 15000 rpm is about 0.4 while the 10000 and 5000 rpm have concentration values around 0.3 and 0.2, respectively. The concentration ratio value shows that the nanolubricant stability for samples prepared using the HSH method has dropped more than 60% than the initial value. Higher HSH speed provides better nanolubricant stability.

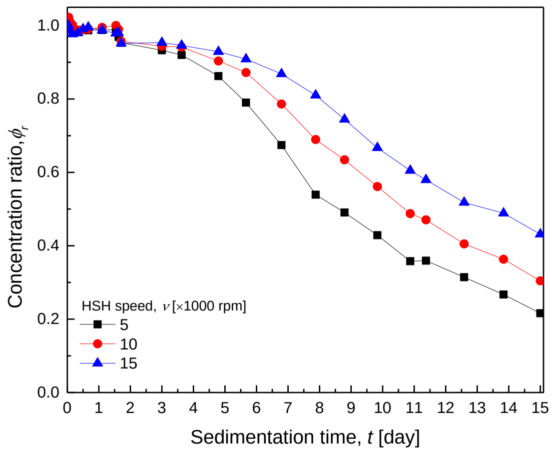



**Fig. 4.** Concentration ratio UV-Vis evaluation for HSH at different homogenizing speeds

Figure 5 shows the UV-Vis results for nanolubricants prepared using the ultrasonic bath method at different sonication times. Overall observation on the results is that the concentration ratio was above 0.8 for all samples after 15 days. The concentration ratio remains above 0.9 from the first day until the seventh day. Separation of line observed on day five onwards where the 5-hour sonication sample maintains at concentration ratio above 0.9. The other samples decrease gradually over time.

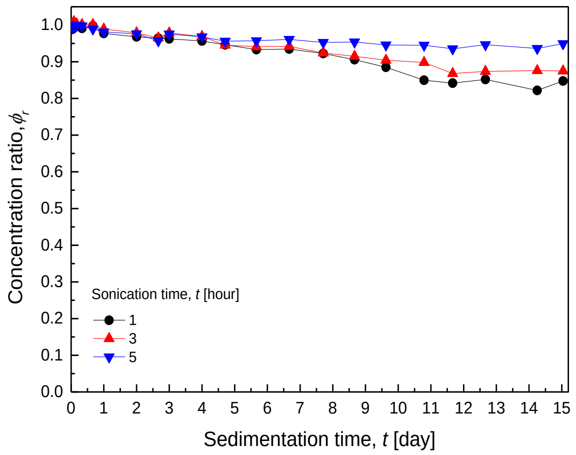



**Fig. 5.** Concentration ratio of UV-Vis evaluation at different sonication times

Comparison can be made between results for nanolubricant preparation with different methods. The nanolubricant prepared using an ultrasonic bath shows better stability than HSH when the visual and UV-Vis results consistently show better results. The nanolubricants prepared using 5-hours sonication time shows the best stability among other samples. Even though the nanolubricant with one-hour sonication does not show better results than 3-hours and 5-hours, the UV-Vis result for this sample is still better than the nanolubricant prepared using the HSH method.

## Conclusions

The current study aims to compare the stability of nanolubricant prepared using two different methods. $TiO_2$ nanolubricant was prepared using a high-speed homogenizer and ultrasonic bath methods. The visual observation on the prepared samples shows that the ultrasonic bath method produced better stability when the nanolubricant intensity remain longer than the HSH method. The visual results were confirmed with UV-vis results where the concentration ratio remained above 0.8 for all samples. Meanwhile, the HSH method produced a concentration ratio between 0.2 and 0.4 after 15 days of preparation. Comparison between the two preparation method can be concluded as the ultrasonic bath provide a better stability effect on $TiO_2$ nanolubricant than HSH. For a short period of fewer than 2 days, the HSH also provide excellent nanolubricant stability. Further investigation is recommended to find better stability for the ultrasonic bath as the trend showing longer ultrasonic time produce better stability.

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