Dispersion Stability of hBN Nanoparticle in Liquid Phase with Different Dispersion Agents

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ABSTRACT

Solid nanoparticles nowadays became a new solution to advance additive in lubricant technologies due to its ability to perform without jeopardies the lubricant formulation, but it tends to sediment due to gravitational force. The aim of this study is to investigate the effect of difference surfactant agent for better dispersion of solid nanoparticles inside the liquid phase. A set of nano-oil was prepared according to L_9 Taguchi array by using ultrasonic homogenizer. Three types of surfactant agent were used which are sodium cholate, oleic acid and Sodium Benzene Dodecyl Sulphonate (SDBS). The absorbance values of the nano-oils were measured using UV-spectrometer as quantitative results. The sample image of the sedimentation process was recorded as a qualitative result. The result shows that suspension of conventional engine oil SAE 15W-40 with the addition of hBN nanoparticles and surfactant agent of SDBS manage stable over the period of 58 days.

Keywords: DOE, Stability, Nano-oil, Surfactant agent, UV-Spectrometer.

Introduction

Today, a lubricant is the most important things for any machinery parts that appearing in this world. The main features of lubricant are to controls resistance and friction between surfaces through supplying a durable film. According to Ludema [1], to prolong the life of any equipment, it is

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necessary to put lubricant on that particular equipment. A lubricant can perform a critical number of functions such as lubrication, cooling, cleaning, suspending, protecting metal surfaces against corrosive damage and also overheating. Lubricants are usually characterized into three basic classes which are a solid lubricant, semi-solid lubricant, and liquid lubricant. Even though lubricant can help reduce the friction and wear, lubricant still have their disadvantageous which are degraded and deteriorate very rapidly in some operating conditions. According to recent numerous studies, the nanotechnology can indeed improve the oil lubricating properties. By mixing lubricant with nanoparticles (additives) it can maximize the performance of the lubricant. Somehow, by adding the additives into the lubricant, an issue regarding sedimentation problem occurred. The nanoparticles do not dissolve with oil molecules in the lubricant. As reported by Yu and Xie [2], the agglomeration of nanoparticles results are not only to the settlement and clogging of micro-channels but also effect on the decreasing of thermal conductivity of nano-lubricant and as solution, adding dispersant agents inside the oils with mixed of nanoparticles is an easy and economic method to enhance the stability of nano-oils. Moreover, a study conducted by Paramashivaiah and Rajashekhar [3] stated that the use of the surfactant agent is to provide an effective and efficient coating to induce electrostatic or steric repulsions that can counterbalance van der Waals attractions and also give better dispersion on the nanoparticles additive inside the oil. So, investigation regarding on the stability is needed as it influences the properties of nano-lubricant for application, thus, the influencing factors to the dispersion stability of nano-lubricant can be studied and analyzed.

The objectives of this study are to optimize the nanoparticle suspension inside the liquid phase condition and to investigate the effect of different surfactant agent and suspension agent for better dispersion of solid nanoparticle inside the liquid phase condition.

Research Methodology

Design of Experiment (DOE) Taguchi L_9

Taguchi method with consisting of L_9 orthogonal arrays was used in this study which consists of nine rows corresponding to the number of testing, with three columns at three levels. This array has eight degrees of freedom (DOF), in which six were assigned to three factors (each one 2 DOF) and 2 DOF was assigned to the error. As for observation on the degree of significance on the design parameters in vol. % contribution, three factors with three levels were taken into account. The design of experiment, DOE were shown in Table 1 and Table 2. Three samples of nanoparticles which are hBN, Al_2O_3 and graphite were used in this study to analyse more data which help to discuss more on the hBN nanoparticles performance. In

addition, hBN nanoparticle has been claimed as a good friction additive for conventional engine oil.

Table 1: DOE with $L_9(3^3)$ orthogonal arrays

Level	Factor		
	Surfactant	Nanoparticle	Homogenize time
1	Oleic acid	hBN	10 minutes
2	Sodium cholate	Al_2O_3	20 minutes
3	SDBS	Graphite	30 minutes

Table 2: Overall sample preparation

Test No.	Factor		
	Surfactant	Nanoparticle	Homogenize time
1	Oleic acid	hBN	10 minutes
2	Oleic acid	Al_2O_3	20 minutes
3	Oleic acid	Graphite	30 minutes
4	Sodium cholate	hBN	20 minutes
5	Sodium cholate	Al_2O_3	30 minutes
6	Sodium cholate	Graphite	10 minutes
7	SDBS	hBN	30 minutes
8	SDBS	Al_2O_3	10 minutes
9	SDBS	Graphite	20 minutes

Ultrasonification setting parameter

Nano-oil used in this study was prepared by dispersing an optimal composition of 0.5 vol.% nanoparticles of hBN, Al_2O_3, Graphite in SAE 15W-40 conventional engine oil with addition 0.3 vol.% surfactant agents by using ultrasonic homogenizer [4]. The mixtures were homogenized in three different times which are in 10 minutes, 20 minutes and 30 minutes. The samples were mixed using ultrasonic homogenizer (Sartorius Labsonic P) with 50% amplitude and 0.5 active time interval as shown in Figure 1. During the homogenizing process, the sample temperature was controlled not to exceed 70°C.

UV-Spectrometer

The stability of nano-oil samples was measured by using UV-spectrometer as quantitatively result. UV–spectrometer can provide a measurable data on the stability by evaluating the light absorbance transmitted to the sample. UV-spectrometer can imply the conditions of measurement such as sample path length, sample concentration, and wavelength. This testing normally covers the estimation of the ultraviolet absorption of a variety of petroleum products. UV-spectrometers manage to cover the absorbance of fluids or the

absorptivity of fluids and solids, or both, at wavelengths in the district from 220 to 400 nm of the range.

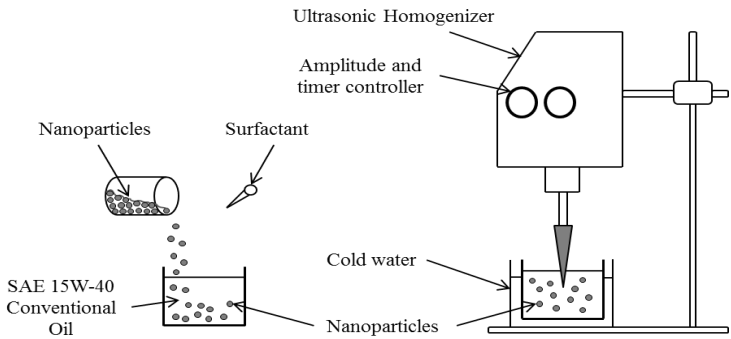

Figure 1: Schematic diagram sample preparation by using ultrasonic method

Result & Discussions

S/N Ratio analysis

Figure 2 shows the result of the Taguchi analysis for S/N ratio, the optimal value obtained for nanoparticles stability was by the combination of oleic acid, hBN nanoparticles and 30 minutes of homogenizing time. Oleic acid has normally been used as surfactant agent and gives a lot of advantages especially when it was used in liquid mixtures due to it oily properties. Even though oleic acid contributed much in the S/N ratio compared to SDBS and Sodium Cholate, the sedimentation of hBN nanoparticles was too obvious according to data obtained for two months observation which is shown in Table 5. The occurrence of oily properties of oleic acid seem not contributed much in this experiment due the conventional engine oil SAE 15W-40 still in fresh condition.

Effect of SDBS agent on the sedimentation of Nanoparticle

Table 3 shows the picture of SAE 15W-40 on SDBS agent with three different nanoparticles that had been taken after the nano-oil was kept at room temperature for two months (56 days). Based on the image observation on hBN nanoparticles, it clearly shows no significant changes from the first day until the fourth day. The changes can be seen in a week time which the sample colour brighter compare to the image on the previous day. This scenario happened was believe due to attractive magnetic forces, where the rate of aggregation is significantly higher, whereas the repulsive electrostatic

forces are almost negligible [5]. From this process, it causes on occurring a sedimentation process. The changes of the image kept occurring until in day 56th whereby the image on that days show more bright compared to the other day.

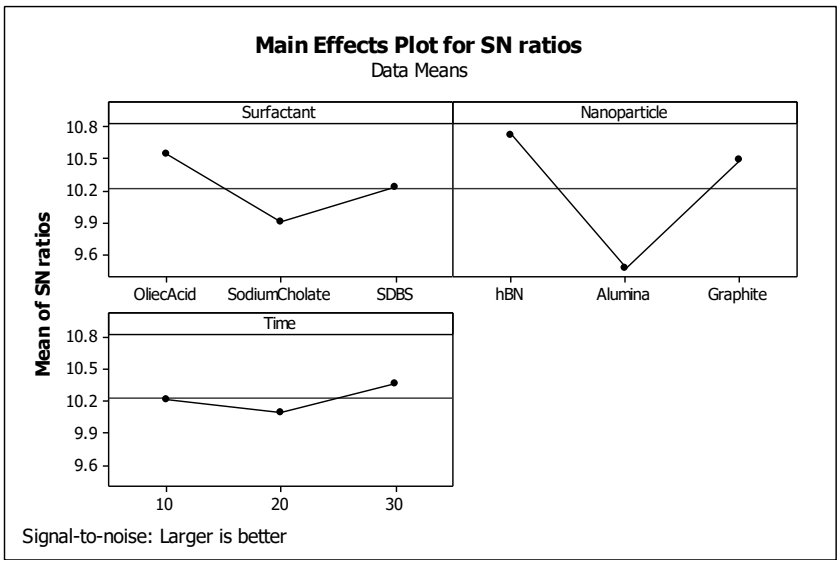

Figure 2: S/N ratio result plotted by Main Effect

Effect of Sodium Cholate agent on the sedimentation of Nanoparticle

Table 4 shows the picture of SAE 15W-40 on Sodium Cholate agents with differences of nanoparticles. This picture was taken after the nano-oil was kept at room temperature within two months. The result of the images showed no changes happened to the nanoparticles on the first day. Changes in the nanoparticles stability can be seen on the second day whereby hBN nanoparticles showed significant changes compared with Al_2O_3 and Graphite nanoparticles. This change clearly is shown by sedimentation and agglomeration of nanoparticles on the bottom of the bottle, while on the upper surface of nano-oil appear the dark colour of the yellowish oil. According to Stachowiak [6] nanoparticles size cause them to aggregate, cluster or coagulate once found in most liquids phase. This may be caused by the diffusion of nanoparticles in the nano-oil was unstable causing sedimentation process occurs at the bottom of the bottle. Compared the result obtained by SDBS surfactant, Sodium Cholate agent cannot maintain the stability of hBN nanoparticles while the result for Al_2O_3 and Graphite showed almost same pattern. The sedimentation of hBN nanoparticles occur

as an early second day of sample preparation and kept sediment until day 56th.

Table 3: Picture of SAE 15W 40 on SDBS agents with three different nanoparticles

Picture of SAE 15W 40 + Additive + SDBS Agent						
Days	abs	hBN (30 min)	abs	Alumina (10 min)	abs	Graphite (20 min)
1	3.9849		3.1201		3.9850	
2	3.9813		3.0599		3.6881	
3	3.7849		2.9931		3.6726	
4	3.7056		2.9317		3.5840	
7	3.6896		2.8655		3.3327	
8 (Week 1)	3.6818		2.8747		3.2169	
15 (Week 2)	3.5369		2.8517		3.0736	
22 (Week 3)	3.5159		2.7192		3.0402	
28 (1 Month)	3.4611		2.6804		3.0229	
56 (2 Month)	3.1953		2.5216		2.9991	

Table 4: Picture of SAE 15W 40 on Sodium Cholate agents with three different nanoparticles

Picture of SAE 15W 40 + Additive + Sodium Cholate Agent						
Days	abs	hBN (20 min)	abs	Alumina (30 min)	abs	Graphite (10 min)
1	3.3851		3.2912		3.6461	
2	3.3258		3.1540		3.6309	
3	3.3209		3.0523		3.5490	
4	3.2890		2.9729		3.4407	
7	3.2823		2.9410		3.3993	
8 (Week 1)	3.0990		2.9384		3.3573	
15 (Week 2)	3.0111		2.9004		3.2800	
22 (Week 3)	2.9864		2.8645		3.1871	
28 (1 Month)	2.9597		2.7760		3.1496	
56 (2 Month)	2.7613		2.6083		2.9969	

Effect of Oleic Acid agent on the sedimentation of Nanoparticle

In two months, the changes sample colour phases have been recorded at room temperature condition shown in Table 5. Based on the observation, no changes appeared for all samples on the first day. The second day of observation, the colour of sample changes to brighter colour. The surface of the samples can be seen bright and the bottom layer of samples is still the same colour, which is cloudy. This is because sedimentation process and agglomeration of particle occur on the bottom of the bottle. According to Amiruddin [7], since oleic acid obtained the oily properties and tend to weaker the repulsive van der Waals forces between the particles it causes unstable molecules on the pigment surface which resulting in attractive van der Waals force to cause agglomeration. In addition, since the nanoparticles

used are solid particles, the gravitational force also is a factor of the sedimentation of nanoparticle occur.

Table 5: Picture of SAE 15W 40 on Oleic Acid agents with three different nanoparticles.

Picture of SAE 15W 40 + Additive + Oleic acid Agent						
Days	abs	hBN (10 min)	abs	Alumina (20 min)	abs	Graphite (30 min)
1	3.9999		3.6515		3.9897	
2	3.9897		3.5944		3.6333	
3	3.8928		3.3772		3.5293	
4	3.7890		3.1445		3.3608	
7	3.6902		3.1226		3.3434	
8 (Week 1)	3.6442		3.1078		3.3417	
15 (Week 2)	3.5878		3.0362		-	
22 (Week 3)	3.2370		3.0127		-	
28 (1 Month)	3.2069		2.9913		3.1605	
56 (2 Month)	3.1104		2.8614		3.0683	

Stability of nanoparticle hBN with SDBS, Sodium Cholate and Oleic Acid agent

The agglomerations of nanoparticles can be prevented either by decreasing the van der Waals forces by refractive index matching or by introducing repulsive forces (steric, electrostatic, or electrosteric forces) [8]. This action gives enhancement to repulsive force over an attractive force that can avoid particles agglomeration and ensure the stability of nanoparticles inside the oil. Uses of the surfactant agent also can improve wetting of particles or adhesion characteristic and reduce the tendency to agglomerate in the continuous phase solvent [9]. The function of this surfactant agent is to

provide an effective and efficient coating to induce electrostatic or steric repulsions that can counterbalance van der Waals attractions.

Figure 3 show of images and the line graph of hBN nanoparticles mixing with three different surfactant agents which are SDBS, Sodium Cholate and Oleic acid. Based on the image result, hBN nanoparticles with mixtures of SDBS agent give long time period to become cloudy compared to others images. This condition shows the nanoparticles inside the oil are taking a time to agglomerate with each other and it is indicated that the nanoparticles inside the nano-oil are more stable compared to other samples. According to Warheit [10] stated that sedimentation and agglomeration can be prevented whereby by doing an alteration towards surface properties of nanoparticles.

Moreover, its show that reading of absorbance for hBN nanoparticles with SDBS agent on days 56th is higher than reading on days 56th for Sodium Cholate and Oleic Acid agent. Besides that, to prove the results is better, the gradients for each graph was been determine. The result shows the gradient graph hBN with SDBS agent is higher compared to the others graphs.

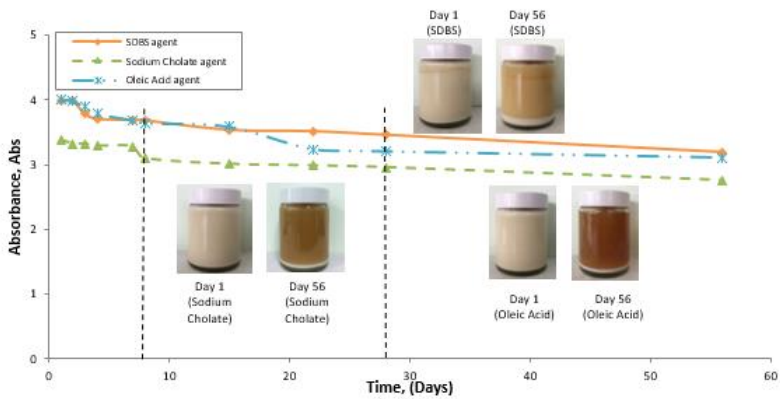

Figure 3: Picture and Graph of SAE 15W 40 for stability on nanoparticle hBN with SDBS, Sodium Cholate and Oleic Acid agent

Conclusion

In conclusion, the result shows that the effect of SDBS agent towards hBN nanoparticles is more stable compare to others samples. The result from the qualitative analysis show, the sedimentation process on the hBN nanoparticles with SDBS agent is taking a longer time compares to others oil sample. The forming of sedimentation process clearly can be seen in day 7th

compared to others oil sample that produces sedimentation process at the early stage on day 4th. This shows that sample with the addition of SDBS agent gives more stability dispersion through the hBN nanoparticles inside the oil. This is due to the electrostatic mechanism which increases the repulsive force and results in thickening the electrical double-layer that provides stability. Stability of this sample also is affected by the homogenizer time whereby the homogenizer time for this sample is 30 minutes.

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