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Effect of hBN/Al_2O_3 nanoparticles on engine oil properties

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Abstract

This paper provides oil properties study of conventional diesel engine oil enriched with hBN/Al_2O_3 nanoparticles. In this study, an optimal composition (0.5 vol.%) of 70nm hBN and Al_2O_3 nanoparticles separately dispersed in SAE 15W40 diesel engine oil by sonication technique. The oil properties were studied by measuring the Viscosity Index (VI), Total Acid Number (TAN), Total Base Number (TBN) and flash point temperature. In addition, the stability of nanoparticles in oil was also observed by measuring the absorption value over time using ultraviolet (UV) spectrometer. The results reveal that the nano-oil with hBN nanoparticles could improves or at least maintain the key lubrication properties, though the TAN value is slightly increased. In addition, the dispersion of nano-oil was stable up to 168 hours before the sedimentation occurs. The dispersion of nano-oil with hBN nanoparticles is better than that of nano-oil with Al_2O_3 nanoparticles. The results presented here may facilitate improvements in the conventional diesel engine oil properties performance.

Keyword: hBN nanoparticles; Al_2O_3 nanoparticles; Oil properties

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1. Introduction

Nowadays, there are a great variety of advanced lubrication technologies includes thin film coatings [1-4], nanolubricants [5-6] and gas lubricant [7-8]. The technology involved in lubrication by nanoparticles is a rapidly developing scientific area and one that has been watched with interest for the past ten years. Nanolubrication offers a solution to many problems associated with traditional lubricants. With the increase in the number of vehicles, the problems with fuel consumption and environmental pollution are becoming more prominent. The use of an energy-conserving and emission-reducing automotive engine oil additive would have a great impact on energy conservation and environment protection. However, some additives such as Zinc dialkyldithiophosphates (ZDDP), containing phosphorus and sulfur substance, can poison the catalytic converter which results to the failure of the emission system. Therefore, researchers and scientists are now looking for environmental friendly additives that have an ability to enhance, or at least maintain the key lubrication properties.

Recently, nanoparticles is the most promising additives, where a low concentration of nanoparticles between 0.2% and 3% vol. into lubricating oil is sufficient to improve tribological properties [9-15]. Qiu et al. [14] found that the concentration of Ni nanoparticles between 0.2 and 0.5% provides the best anti-wear behavior and friction reduction. Tao et al. [15] demonstrated that 1% is considered the optimum concentration for the diamond nanoparticles in paraffin oil. In addition, friction-reduction and anti-wear behaviors are dependent on the characteristics of nanoparticles, such as size, shape, and concentration. The size of nanoparticles is mostly in the range of 2 to 120 nm [16-18]. The mechanisms of friction-reduction and anti-wear of nanoparticles in lubricant have been reported as colloidal effect, rolling effect, protective film, and third body. Chiñas-Castillo and Spikes [19] investigated the action mechanism of colloidal solid nanoparticles in lubricant oils. Their study showed that in thin film contacts, colloid nanoparticles penetrate elastohydrodynamic (EHD) contacts, mainly by a mechanism of mechanical entrapment.

In general, as observed from prior studies, a lot of studies were investigated on the tribological properties of lubricating oil with addition of nanoparticles. However, there are a limited number of studies to investigate the oil properties of conventional diesel engine oil enriched with nanoparticles. Hence, the goal of this paper is to investigate the oil properties of conventional diesel engine oil by dispersing hBN/Al_2O_3 nanoparticles.

The uniqueness of this study exists in the fact that low-cost and environmental friendly hBN/Al_2O_3 nanoparticles, dispersed in conventional diesel engine oil, could potentially enhance the oil properties performance. This promising technology has an even greater impact on fuel consumption and engine durability for a greener future. Besides, good lubrication and thermal conductivity properties, which can simultaneously improve oil properties, performance and boost heat transfer in engines [20], were the key factors for using hBN/Al_2O_3 nanoparticles.

2. Methods

Nano-oil was prepared by dispersing separately an optimal composition (0.5 vol.%) of 70nm hBN and Al_2O_3 nanoparticles in SAE 15W40 diesel engine oil by sonication technique, using ultrasonic homogenizer for 20 minutes. Samples were stabilized using a surfactant (oleic acid) to prevent sedimentation of nanoparticles. The optimal composition was determined from the previous work [6]. The hBN and Al_2O_3 nanoparticles were observed using Scanning Electron Microscopy (SEM). The oil properties were investigated in terms of Viscosity Index (VI), Total Acid Number (TAN), Total Base Number (TBN) and flash point temperature. The VI was calculated from kinematic viscosity at 40^{o}C and 100^{o}C, using a viscometer, according ASTM D2270-04 standard practice. The TAN, TBN and flash point temperature were measured using 716 DMS Methrohm machine and flash point meter, respectively. Besides, the stability of nano-oil was also observed by measuring the absorption value over time using UV spectrometer in which the conventional diesel engine oil was set as a background.

3. Results and discussions

Figure 1 shows the SEM image of hBN and Al_2O_3 nanoparticles. As shown in Figure 1(b), Al_2O_3 nanoparticles agglomerated. However, the hBN nanoparticles were well dispersed and their sizes were rather uniform. The physical properties of the nanoparticles are shown in Table 1.

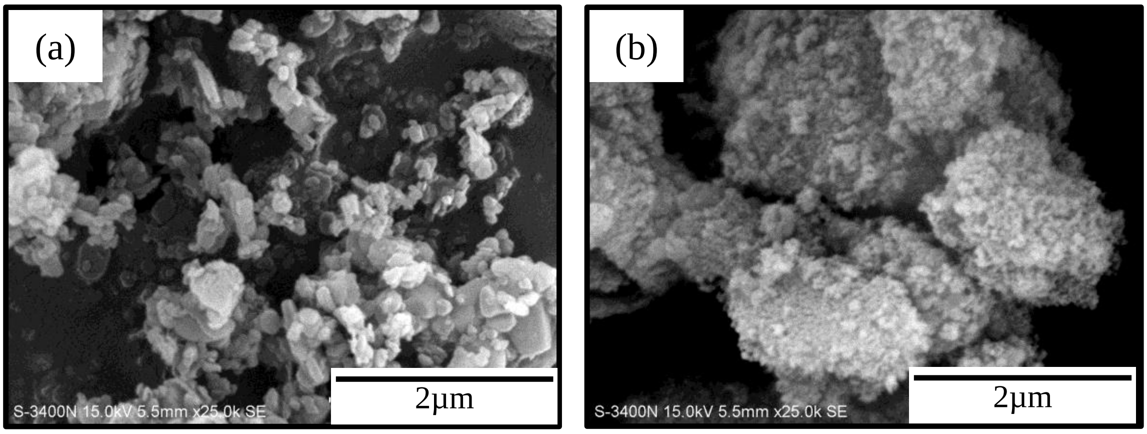

Fig. 1. SEM micrograph of (a) hBN nanoparticles and (b) Al_2O_3 nanoparticles.

The kinematic viscosity of nano-oil at 40^{o}C and 100^{o}C is slightly increased, as compared with conventional diesel engine oil, as shown in Figure 2. From the view point of boundary lubrication, these results may be due to the higher film thickness ratio.

From Figure 3, the finding provides evidence that nano-oil with hBN nanoparticles improves the VI value approximately 3%, as compared with conventional diesel engine oil and with Al_2O_3 nanoparticles additives. This circumstance may be due to lower thermal expansion coefficient of hBN nanoparticles (1 x 10^{-6}/^{o}C), so it has a good effect on thermal stability properties and directly give a significant impact on the viscosity index characterization.

As for TAN value, nano-oil shows a negative results in which the value is increased gradually, as compared with conventional diesel engine oil. Increment approximately 20% for nano-oil with hBN nanoparticles and 27% for nano-oil with Al_2O_3 nanoparticles is not preferable because the TAN value indicates the existence of naphthenic acid corrosion problem. This corrosion might create a failure inside the engine component and can cause hazards emission to the environment.

The higher the TBN, the more effective it is in suspending wear-causing contaminants and reducing the corrosive effects of acids over an extended period of time. Therefore, the higher value of TBN could eliminate the negative effect of the TAN value.

The flash point of lubricant can be defined as lowest temperature at which it can vaporize to form an ignitable mixture in air. Although the flash point temperature of nano-oil with Al_2O_3 nanoparticles is slightly decreased, there is no significant difference in flash point temperature between the conventional diesel engine oil and with hBN nanoparticles additives.

Table 1. Physical properties of hBN and Al_2O_3 nanoparticles

Properties [a]	hBN	Al_2O_3
Appearance	White powder	White powder
Average particle size (nm)	70	70
Density (kgm^{-3})	2.3	3.97
Maximum use temperature in air (°C)	1800	1750
Thermal conductivity ($Wm^{-1}K^{-1}$)	27	30
Thermal Expansion Coefficient @25°C-1000°C	1×10^{-6}/°C (parallel to press dir.)	2×10^{-3}/°C (parallel to press dir.)

a. From manufacturer.

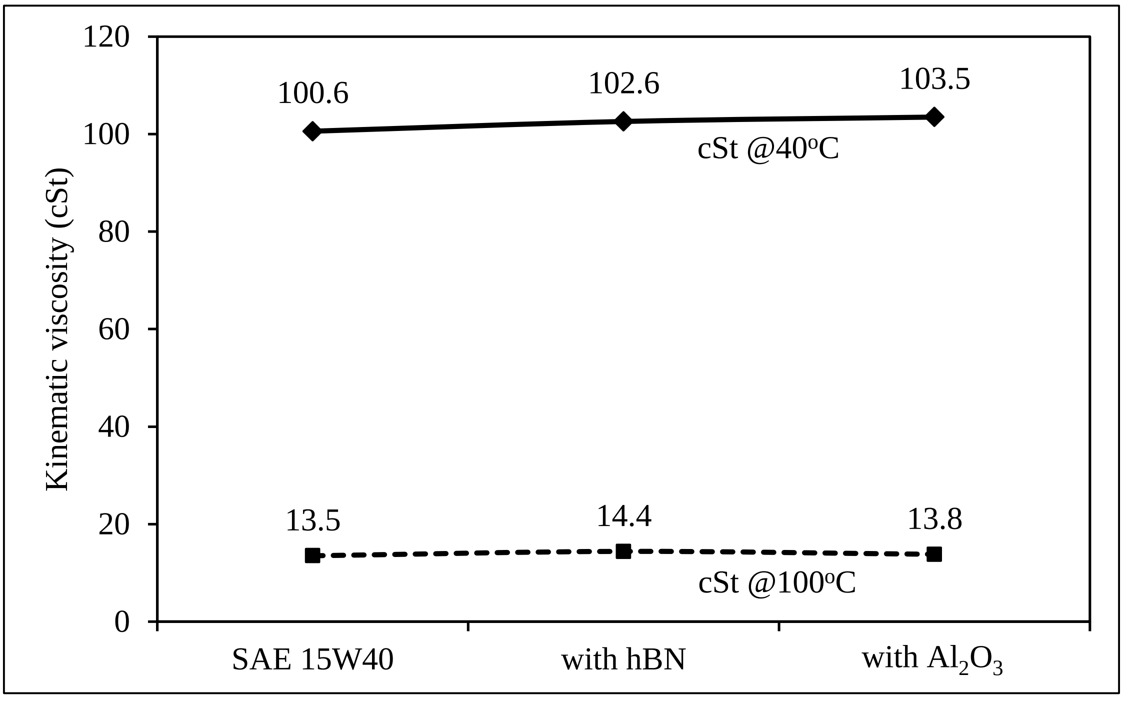

Fig. 2. Kinematic viscosity measured at 40°C and 100°C.

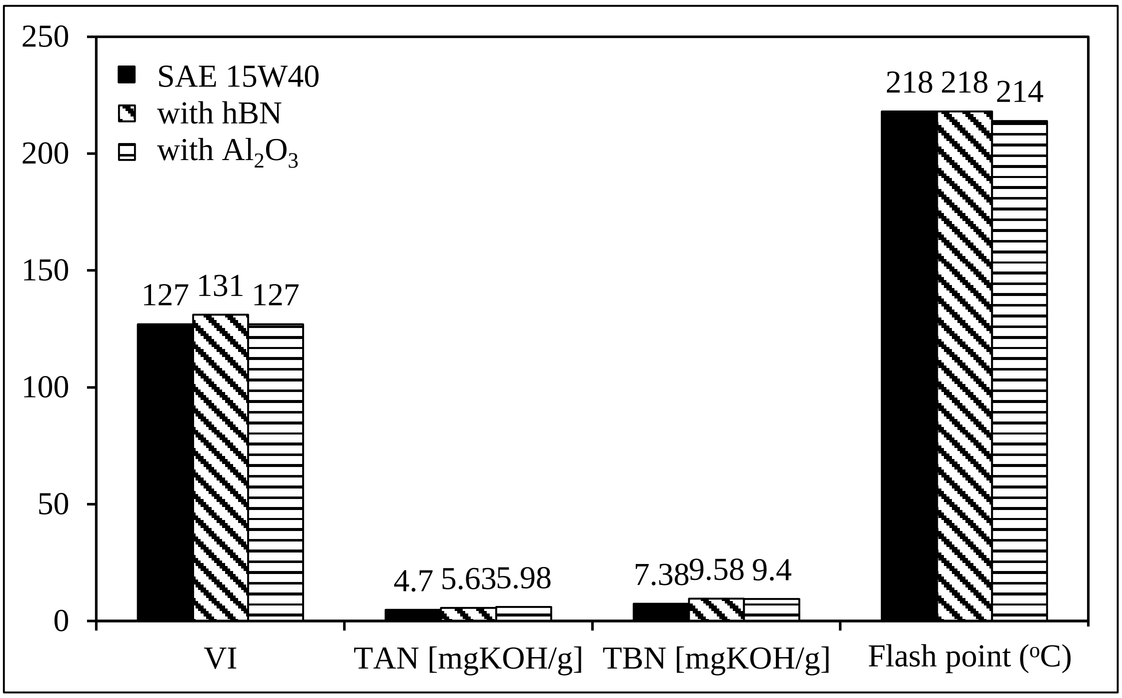

Fig. 3. The oil properties comparisons between SAE 15W40, with hBN and Al_2O_3 nanoparticles.

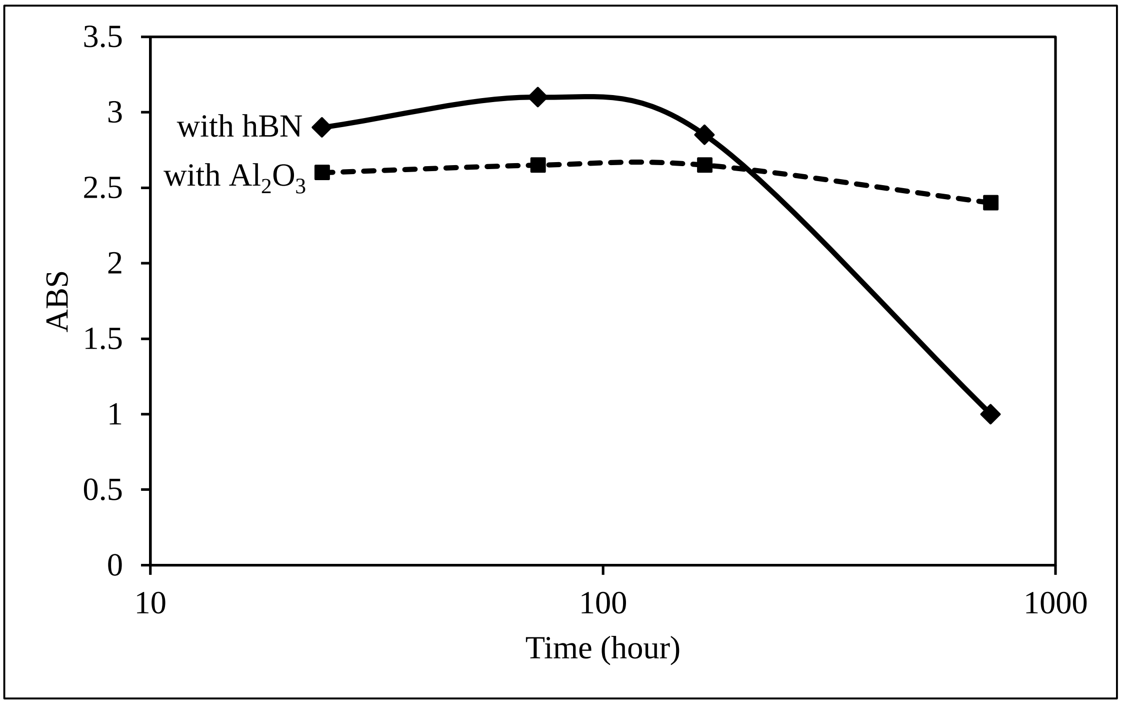

Fig. 4. The absorbency curve of nano-oil with time.

From Figure 4, the higher absorbency indicates that the dispersion of nano-oil with hBN nanoparticles is better than that of nano-oil with Al_2O_3 nanoparticles. The dispersion for both nano-oil was stable up to 168 hours. However, the stability of nano-oil with hBN nanoparticles decreased sharply with the 63% reduction in absorbency value at 720 hours.

The photographs shown in Figure 5 were taken after the nano-oil was kept at room temperature for 24 hours, 72 hours, 168 hours and 720 hours. As can be seen from Figure 5(c), the nano-oil with hBN nanoparticles precipitated more at the bottom of the bottle, which correlates well to a smaller value of absorbency at 720 hours. This phenomena may be due to the adsorption of oleic acid as a surfactant in nano-oil is unable to sustain and not suitable for prolonged stability. Further investigation will be required to address the sedimentation problem of nano-oil.

From the above analyses it is quite evident that the nano-oil with hBN nanoparticles has better oil properties compared than the nano-oil with Al_2O_3 nanoparticles.

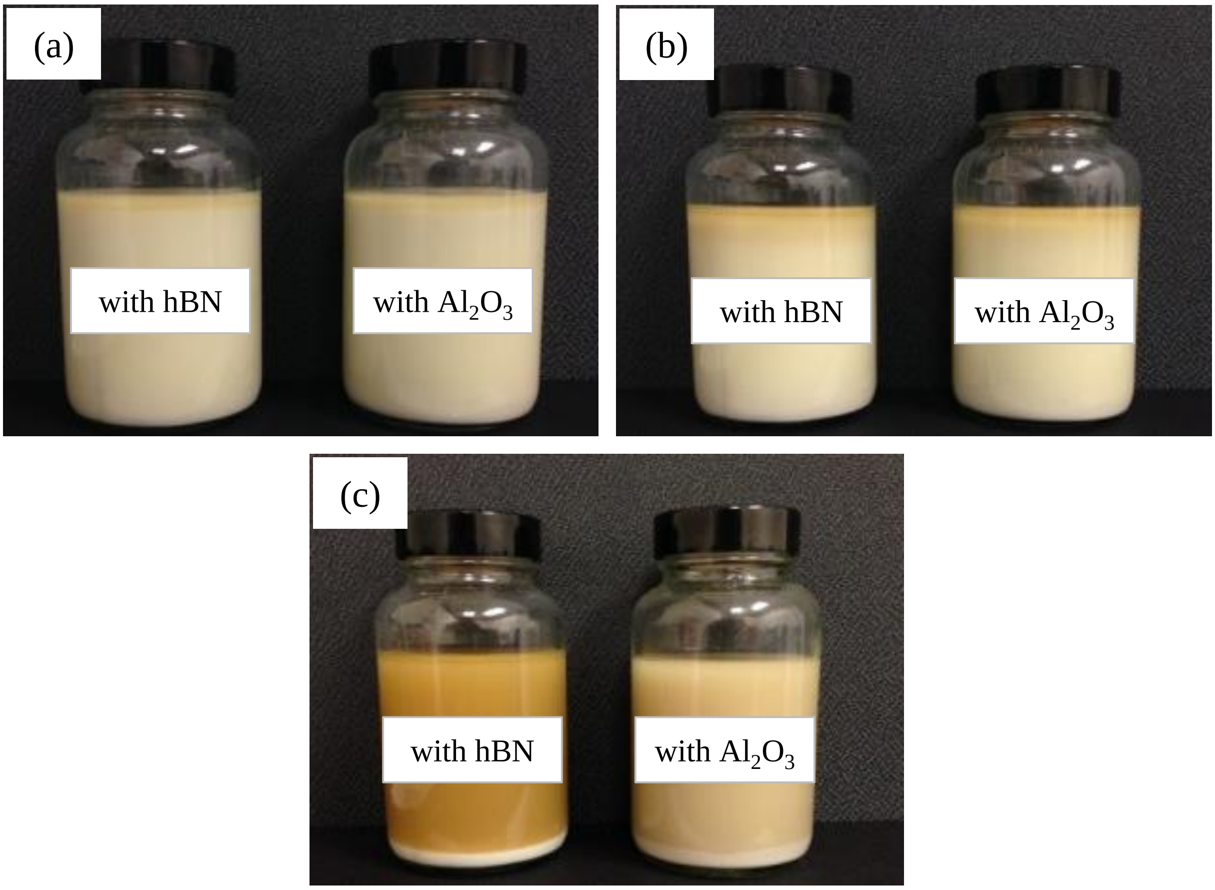

Fig. 5. Photograph of oil solution with different nanoparticles after (a) 24 hours, (b) 168 hours and (c) 720 hours.

4. Conclusion

This paper presented results of hBN/Al_2O_3 nanoparticles as additives for improving conventional diesel engine oil properties. In summary, as compared with conventional diesel engine oil with and without Al_2O_3 nanoparticles, the current study proves that the hBN nanoparticles dispersed in SAE 15W40 diesel engine oil could improves or at least maintain the key lubrication properties of VI, TBN and flash point temperature, though the TAN value is slightly increased. However, the higher value of TBN could eliminate the negative effect of the TAN value, which makes the nano-oil with hBN nanoparticles is much better than the nano-oil with Al_2O_3 nanoparticles. Besides, the dispersion of nano-oil was stable up to 168 hours before the sedimentation occurs. The higher absorbency indicates that the dispersion of nano-oil with hBN nanoparticles is better than that of nano-oil with Al_2O_3 nanoparticles. Overall, this study has contributed to our knowledge about the effectiveness of hBN nanoparticles as compared with Al_2O_3 nanoparticles for improving oil properties. In particular, further investigation for addressing sedimentation problem of nano-oil will be necessary and will be taken into consideration for future work.

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