The hBN Nanoparticles as an Effective Engine Oil Additive to Enhance the Durability and Performance of a Small Diesel Engine

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ABSTRACT

The aim of this study is to investigate the effectiveness of the hexagonal boron nitride (hBN) nanoparticles as additive to enhance the durability and performance of a small diesel engine. The optimum volume fraction of 70 nm hBN nanoparticles was homogeneously dispersed together with SAE 15W40 diesel engine oil. The engine performance test was performed using a single cylinder diesel engine which coupled with 20 Hp eddy current dynamometer. The results of the experimental studies demonstrated the potential of hBN as an additive for improving the engine performances, emission characteristics, fuel consumption and wear of the engine components.

Keywords: *Friction Modifiers, Anti-wear, Mechanisms, Automotive*

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Introduction

Most of small engine nowadays won’t last for long especially diesel type of engine [1-3]. Meanwhile, the cost of manufacture raises prominently year by year due to high cost of raw material and machining tool required [4-5]. Even though, combustion engine continually improved in term of their durability, mechanical losses due to the friction in engine elements such as piston, piston rod, camshaft, crankshaft and also transmission system still occur [6]. Reducing this friction and wear to a minimum level which can promising to a better efficiency and performance of the engines become a challenging part to all engine related party. This why, lubricant been the alternative in solving this problem. The basic principle of lubricant is to keep oil film between separated surfaces of the moving part relative to each other which can minimize the occurring wear [7-9]. According to Bartels et al. [10] to provide new desirable properties, improve existing features, and eliminate undesirable features or at least reduce it to a minimum level, some additives are added to the lubricant.

Previous studies have reported that using nanoparticles as an oil additive can improve the anti-wear, load-carrying, and friction-reduction performance of lubricant [11-17]. The hexagonal boron nitride (hBN) nanoparticles or some other name call as white graphite which is in lamellar structure has become an interesting additive in lubricant technologies. The potential of this nano size particle in maintaining the heat stabilizing and reduce wear between the engine component has dominantly suitable as friction modifier which can booth the performance and increases the engine efficiency [14]. With optimized mixture and stabilized homogeneous method, these hBN nanoparticles can sustain homogeneously between the lubricant molecules.

With the increase in the number of vehicles, the problems with fuel consumption and environmental pollution are becoming more prominent [18-19]. 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, such an additive would need to enhance, or at least maintain the key lubrication properties. Thus, in this work, the potential of hBN nanoparticles as an effective additive in SAE 15W40 diesel engine oil to enhance the engine performances, reduce emission, and simultaneously reduce fuel consumption and frictional wear on the contact surfaces was studied.

Experimental Method

The nano-oil was prepared by dispersing an optimal composition of hBN nanoparticles (0.5 vol. %) in SAE 15W40 conventional diesel engine oil using ultrasonic homogenizer. The detailed preparation, optimum composition value, lubrication properties, tribological properties and stability of nano-oil have been discussed extensively in previous publications [14, 20-23]. The AIRMAN YANMAH YX2500CXA single cylinder diesel engine was used for performance test. This single cylinder engine was attached with 20 Hp eddy current dynamometer (air cooled type) and equipped with DAQ data collector board. The torque and power were recorded by DynoMite 2010 software. The emission and fuel consumption were measured parallel with the engine performance test, where fuel consumption measurable fuel tank were fitted to the fuel intake and the gas emission analyser SV50 were coupled to the exhaust chamber. The overall testing setup was shown in Figure 1. The test was repeated three times with a new piston ring for each test to ensure the results are more precise and reliable. The wear of piston ring was evaluated by measuring the mass before and after the test. Furthermore, the morphology of the worn surfaces was observed and analysed using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX).

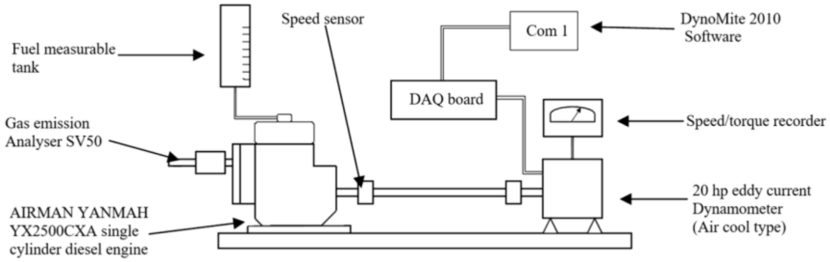
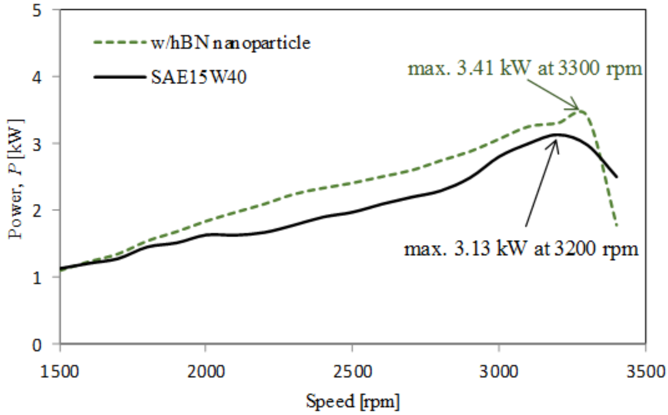


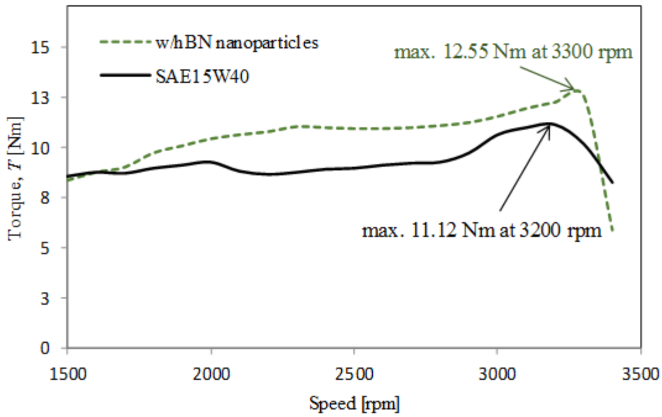
Figure 1: Schematic diagram for engine performance testing setup

Results and Discussion

From Figure 2, the average maximum power improves approximately 9.1% and average maximum torque increases about 12.86% at 3300 rpm when tested using SAE 15W40 with hBN nanoparticles compared to conventional engine oil without hBN nanoparticles. This improvement is believed due to increases of the engine efficiency cause by the smoothness of engine operation. This was coherent with the reduction of brake specific fuel consumption (BSFC) and emission which is shown in Figure 3 and Figure 4. According to the results, the BSFC for conventional engine oil containing hBN nanoparticle shown linearly decreasing trend with increasing of speed while for conventional engine oil, the trend is more quadratic with the initial value is less at the lower speed (1500 rpm) compared to conventional engine oil with hBN nanoparticles. The average BSFC for conventional engine oil containing hBN nanoparticles is reduced approximately 13~32% compared than conventional engine oil. This is shown that the conventional engine oil with hBN nanoparticle improved the fuel efficiency compared to conventional engine oil. The results of CO_2 gas emission composition of conventional engine oil with hBN nanoparticle show average reduction almost 27.5% compared to original conventional engine oil. The hydrocarbon content also shows reduction approximately 5.27%. This improvement condition is due to better combustion inside the engine which cause of improved of BSFC.



(a)



(b)

Figure 2: SAE 15W40 with hBN nanoparticles effectively improve both maximum (a) power and (b) torque of a small diesel engine

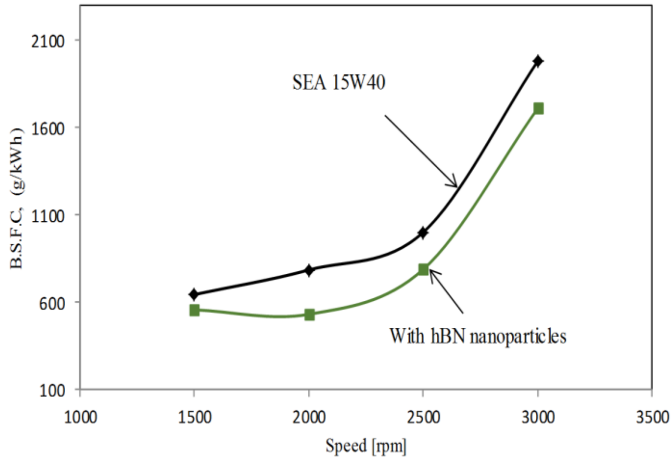


Figure 3: Trend of BSFC over speed for SAE 15w40 with and without hBN nanoparticles

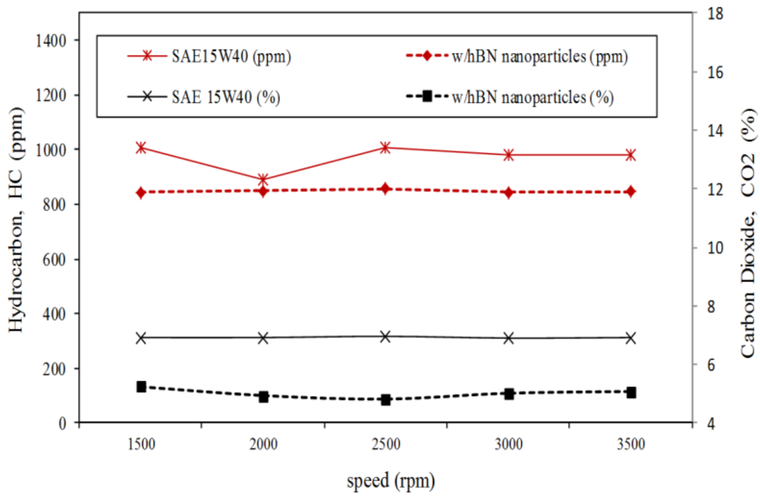


Figure 4: Comparison gas emissions between SAE15W40 with and without hBN nanoparticles on composition of carbon dioxide and hydrocarbon

Besides, less frictional wear has occurred on the contact surfaces between the piston ring and engine cylinder wall, as shown in Figure 5. The damage of the material due to adhesive wear type with intensive plastic deformation was less pronounced than for conventional diesel engine oil containing hBN nanoparticles (Figure 6 (c)) compared with conventional engine oil (Figure 6 (b)). As shown in Figure 7, boron (B) element has been entrapped and deposited in the worn contact areas of piston ring. This boron element created a mending effect which could reduce friction coefficient and consequently gain a better engine performance.

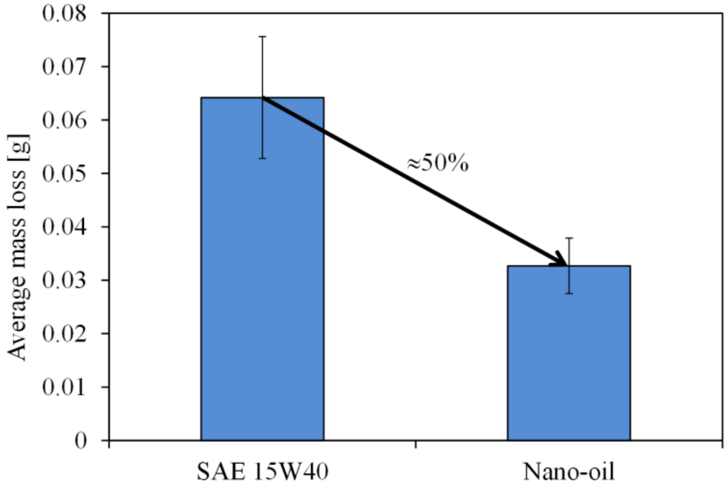


Figure 5: Comparison of average mass loss of piston ring lubricated with SAE 15W40 diesel engine oil and nano-oil

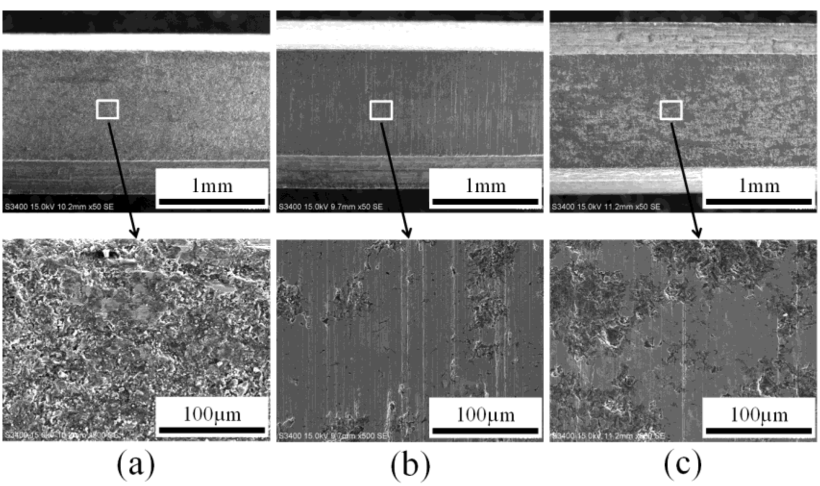


Figure 6: SEM micrograph of piston ring surfaces (a) new piston ring, (b) lubricated with 15W40 diesel engine oil and, (c) lubricated with 15W40 containing hBN nanoparticles

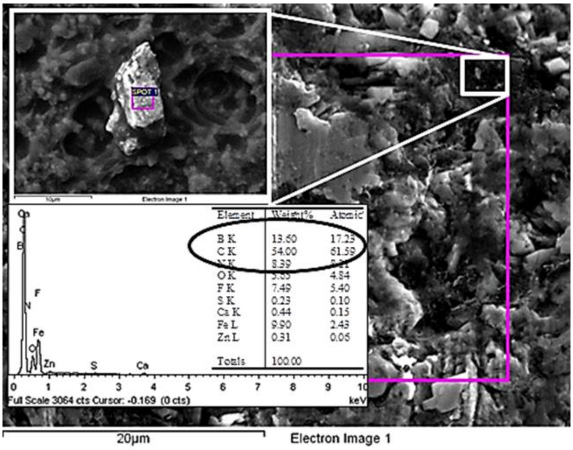


Figure 7: SEM micrograph and EDX spectrum shows that the boron element entrapped and deposited in the contact areas of piston ring when lubricated with 15W40 containing hBN nanoparticles.

Conclusions

1. The average power gain after engine performance testing has shown that, the conventional engine oil with hBN nanoparticle give a positive increment approximately 9.1%.
2. The average torque obtains after engine performance testing has shown that, the conventional engine oil with hBN nanoparticle increase the torque approximately 12.86%.
3. The BSFC for conventional engine oil containing hBN nanoparticle improved approximately 13~32% compared with engine oil without hBN nanoparticles.
4. The CO_2 and HC gas emission also improved by reduction approximately 27.55 for CO_2 and 5.27% for conventional engine oil with hBN nanoparticles.
5. Presence of hBN nanoparticles additive in conventional diesel engine oil could reduce the wear of piston rings with less adhesive and plastic deformation on the contact surfaces.

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