Evaluations of piston ring wear using nano hexagonal boron nitride lubricant additives in small diesel engine

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ABSTRACT – The aim of this study is to evaluate the piston ring wear using 0.5 vol.% 70nm hexagonal boron nitride (hBN) nanoparticles additive, where homogeneously dispersed in SAE 15W40 diesel engine oil. The single cylinder diesel engine test was conducted using 20hp eddy current dynamometer (air cooled type). The wear of piston ring was evaluated by measuring the mass changes. Surface characterization was observed using Scanning Electron Microscopy (SEM), and Energy-Dispersive X-ray spectroscopy (EDX). It was found that the wear of piston ring reduces approximately 50% when lubricated with nano-oil. Besides, surface damage of the piston ring due to adhesive wear type with intensive plastic deformation was less pronounced than for SAE 15W40 diesel engine oil.

1. INTRODUCTION

Most of small engine nowadays easy to fail even though in normal operating condition causes of mechanical losses due to the friction in engine elements such as piston, piston rod, camshaft, crankshaft and also transmission system especially diesel type of engine. Reducing this friction and wear to a minimum level, which can promise to a better efficiency and performance of the engines become a challenging part to all engine related party. Thus, lubricant has been the alternative in solving this problem. The basic principle of lubricant is to keep the oil film between separated surfaces of the moving part relative to each other which can minimize the occurring wear. The addition of additives in lubricant could provide new desirable properties, improve existing features, and eliminate undesirable features or at least reduce it to a minimum level [1-5].

The boron nanoparticle has become an interesting additive in lubricant technologies. This is due to the fact that low-cost, environmental friendly and good lubrication properties of boron nanoparticles, dispersed in conventional oil, could potentially reduce the friction coefficient and wear [3-5]. However, most of current wear tests are limited to lab scale test which is not reflected in the real world applications. Thus, in this work, the potential of hBN nanoparticles as an effective additive in SAE 15W40 diesel engine oil to reduce wear of piston ring in small diesel engine was studied.

2. METHODOLOGY

The nano-oil was prepared by dispersing optimal composition of 0.5 vol.% 70nm hBN nanoparticles in SAE 15W40 diesel engine oil using ultrasonic homogenizer. The optimal value of hBN nanoparticles was determined from the previous study [5]. The Nippon Piston Ring (NPR) with a diameter of 70mm was used in AIRMAN YANMAH YX2500CXA single cylinder diesel engine. Prior to test, the piston was cleaned using acetone in an ultrasonic bath. The engine test was performed using air cooled type 20hp eddy current dynamometer as 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. The Surface morphology of the piston ring was observed using SEM and EDX.

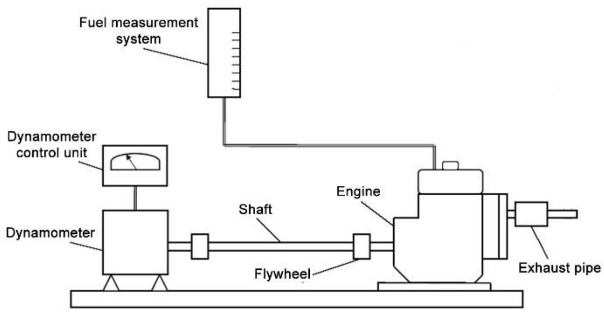


Figure 1 Schematic diagram of the engine test setup.

3. RESULTS AND DISCUSSION

The average value and percentage of piston ring mass loss is shown in Table 1 and Figure 2. The average mass loss of the piston ring lubricated with engine oil with and without hBN nanoparticles additive is 0.0052g and 0.0114g, respectively. This contributes to the 50% reduction of piston ring wear when lubricated with nano-oil.

Figure 3 shows the SEM micrograph of worn piston ring surfaces before and after the engine test. It can be observed that piston ring wear mechanism is dominated by the adhesive wear type with intensive plastic deformation of asperities. This wear type mechanism is slightly small in piston ring lubricated with nano-oil. This might be due to the mending effect, where boron (B) element has been detected entrapped and deposited in the worn contact areas of piston ring, as shown in Figure 4. This phenomenon could reduce friction coefficient and consequently reduce wear [6].

Table 1 Average value of mass loss of tested piston rings.

Test Run	SAE 15W40			Nano-oil		
	Before [g]	After [g]	Mass loss [g]	Before [g]	After [g]	Mass loss [g]
1	6.3715	6.3129	0.0586	6.3716	6.3422	0.0294
2	6.3714	6.2941	0.0773	6.3715	6.3328	0.0387
3	6.3715	6.3148	0.0567	6.3714	6.3413	0.0301
Ave	6.3715	6.3073	0.0642	6.3715	6.3388	0.0327
*σ	0.0001	0.0114	0.0114	0.0001	0.0052	0.0052

*σ = standard deviation

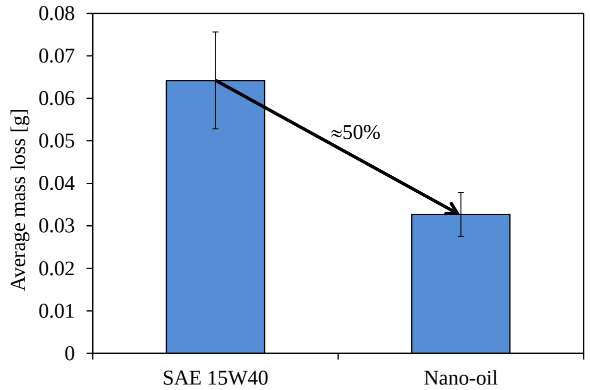
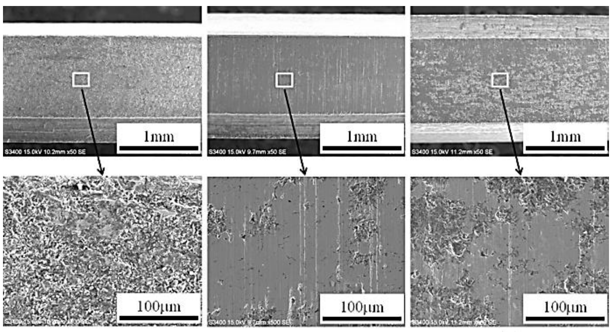


Figure 2 Comparison of average mass loss of piston ring lubricated with SAE 15W40 diesel engine oil and nano-oil.



(a) (b) (c)

Figure 3 SEM micrograph of worn piston ring surfaces: (a) before test, (b) after tested with 15W40 diesel engine oil and, (c) after tested with nano-oil.

4. CONCLUSIONS

In conclusions, wear on the piston ring reduces approximately 50% when lubricated with nano-oil. This might be due to the hBN nanoparticles entrapped and deposited in the worn contact areas of piston ring resulting in low friction and preventing contact between sliding components. Besides, an adhesive wear with intensive plastic deformation of asperities was observed on the worn surfaces of piston ring. This wear type mechanism is slightly small in piston ring lubricated with nano-oil.

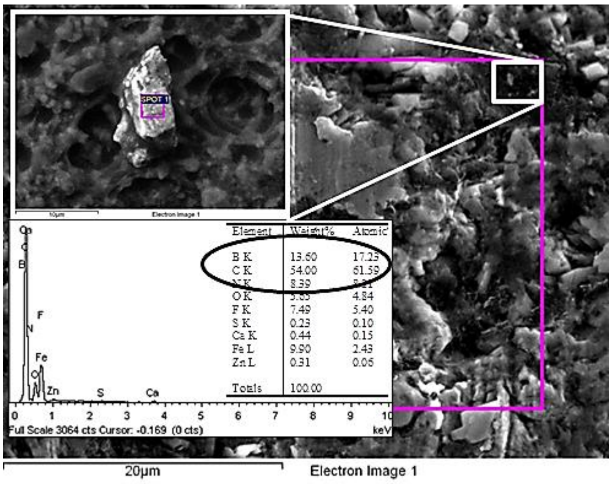


Figure 4 SEM micrograph and EDX spectrum of entrapped particles in the worn contact areas of piston ring lubricated with nano-oil.

5. ACKNOWLEDGEMENTS

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