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EFFECT OF SOOT PARTICLE SIZE ON FOUR BALL METALLIC WEAR USING ELECTRON MICROSCOPY IMAGE ANALYSIS

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ABSTRACT−The impact of soot primary nanoparticles affecting metal wear was investigated. The commercial Carbon Black (CB) with different primary particle sizes were mixed with the engine oil for simulating soot contamination. The physical properties of carbon black including density and hardness were calculated using Transmission Electron Microscopy (TEM) image analysis. The metallic wear test was evaluated by using a Four-ball wear tester. After the tests, the ball surfaces were inspected by utilizing High-Resolution Optical Microscope (OM), Scanning Electron Microscope (SEM) and Energy Dispersive X-ray spectroscopy (EDX) analysis. Based on a Four-ball wear test, the 1 % by weight of carbon black contamination shows a bit higher average wear scar diameter (WSD), but the surface roughness is reduced. SEM micrograph of metallic wear scar for the engine oil without soot shows the area of grooves, plastic deformation and subsurface crack. On the other hand, when carbon black is added to the oil, it can be seen that there are many deep grooves along with the sliding direction. The relationship of calculated oil film thickness, primary nanoparticle size distribution, carbon atom density of soot and hardness is clearly explained metallic wear mechanisms.

KEY WORDS : Soot, Engine oil, Metallic wear, Electron microscopy, Nanostructure, Carbon black

1. INTRODUCTION

Diesel engine is a compression ignition engine which converts chemical energy within the molecule of diesel liquid fuel into heat of combustion during chemical reaction of fuel and air molecules and mechanical energy using engine mechanisms. Diesel fuel is injected under high pressure into the combustion chamber where the combustion process occurs. Soot, which is the remain of incomplete combustion process, consists mostly of carbon, and unburnt hydrocarbon. The primary and agglomerated soot particles sizes observed by Transmission Electron Microscopy (TEM) are in the range of 20 ~ 80 nm and 100 ~ 300 nm, respectively (Daido *et al*., 2000). Soot can be entered into the engine oil through the piston ring clearance during the combustion process (Needelman and Madhavan, 1988). The used oils were characterized by collecting the engine oil from the commercial small diesel engine vehicles. The results showed that the percentage of soot, fuel and metallic wear contamination increased as the engine mileage increased.

The average of soot contamination is about 0.69 percent by weight (Kamsrisuk *et al.*, 2016). The results of soot contamination on engine oil viscosity were also investigated by increasing the proportion of soot contamination. The engine oil viscosity increases with the rise of soot contamination (George *et al*., 2007). The engine testing for evaluated soot tribological properties is challenging, because of the uncontrolled test parameter and the difficulty of wear measurement. The specimen bench test, which is easy to control test parameter and good repeatable results, is used. Carbon black is a synthesis soot, the physical properties, of which is similar to the engine soot. It can be used as the soot representative. The metallic wear tests are performed in order to compare the worn surfaces of the engine oil containing carbon black, alumina and silica. The results showed that the balls worn surfaces were similar in three different kinds of the samples (Ryason *et al*., 1990). The impact of carbon black on metallic wear is studied by using a Four-ball wear tester is studied. The wear scar diameter of the ball with in the oil containing carbon black is significantly larger than that of the engine oil alone (Karin *et al*., 2016). The impact of carbon black and oil additive by comparing the based engine oil with formulated lubricant is also reported. The results showed that wear scar diameter of the formulated lubricant is lower than that of the pure base oil. The wear scar diameter is higher as carbon black levels increases. The metallic wear mechanism of soot-contaminated lubricant might be abrasion (Green and Lewis, 2008).

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