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主　論　文　の　要　旨

論文題目　**Effects of Oil Additives on Friction and Wear Characteristics of DLC Coatings**
(DLC コーティングの摩擦特性および摩耗特性に及ぼす油添加剤の影響)

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One of the solutions to reduce friction between two sliding surfaces in automobile engine is by applying DLC coating to engine components. However, it is critical that the effect of lubricant additives to DLC coating to be clarified before hands as to avoid components failure. At the beginning, tribological friction test between SUJ2 balls and as-deposited plus UV irradiated a-C:H coatings was conducted to clarify the effect of ultraviolet irradiation to DLC coating in four different additives added lubricant oils. Atomic force microscopy (AFM, Nanopics 1000), nano-indentation hardness tester with Berkovich indenter (Elionix ENT-1100a), spectroscopic ellipsometery, non-contact three-dimensional scanning white light interferometry (Zygo, Newview), and energy dispersive spectroscopy-scanning electron microscopy (EDS-SEM, JEOL, JCM-5700NU) were used to investigate the effect of UV irradiation to a-C:H DLC before and after friction test. Prior the friction test, the results showed that UV irradiation presented no significant change in terms of hardness and roughness but the irradiation did penetrate into topmost surface of the a-C:H coating to several degree and could create dangling bonds to interact with lubricant additives elements. Friction test results showed that

UV irradiated a-C:H coatings presented lower friction coefficient than as deposited a-C:H coatings. Worn surface analysis revealed that UV irradiated a-C:H coatings attracted more lubricant additives element to attach on its surface thus created thicker tribofilm on its own surface and its counter materials, resulted in lower friction coefficient than the as-deposited a-C:H coatings.

Subsequently, friction and wear behaviour of amorphous hydrogenated carbon (a-C:H) DLC coating slide against high carbon steel SUJ2, titanium carbide (TiC) and titanium nitride (TiN) mating material disks in Base and ZnDTP+MoDTC oils boundary lubrication is comparatively investigated to determine the most favourable DLC/mating material/lubricant and interrelated tribofilm formation mechanism on each mating materials. Tribological tests were executed by utilizing roller on disk friction tester, nano-indentation hardness test, 3D optical surface profiler, and EDS-SEM were used to characterize the tribofilm formed on both worn roller and disk surfaces. The results showed that the wear volume of a-C:H/TiC tribo-pair in ZnDTP+MoDTC marked a tremendous wear volume reduction compared to than that of in Base oil. EDS investigation on tribofilm element investigation revealed that SUJ2 and TiN mating material disk attracted high concentration of Molybdenum at% on its surface that later caused high wear volume on both roller and disk sliding surfaces. TiC mating material disk however, formed a low at% yet helpful tribofilm consisting of a fraction of Zn (zinc) and P (phosphorus) from ZnDTP attached on both roller and disk which assisted the reduction of wear volume.

Furthermore, friction and wear properties of amorphous hydrogenated carbon (a-C:H) DLC coated bearing slide against alloy steel SAE4620, TiC and TiN mating material rings in Base and ZnDTP+MoDTC oils boundary lubrication was evaluated to identify the most suitable DLC/mating material/lubricant combinations by

investigating the tribo-layers formation and compositions on each mating materials. Tribological tests were conducted by using the bearing on ring friction tester, 3D non-contact scanning white light interferometry, and EDS-SEM to characterize the tribofilm formed on the wear track of both bearing and ring surfaces. The results reveal that the a-C:H/TiC tribo-pair in ZnDTP+MoDTC gives the lowest friction and wear by providing the best lubrication mode for all three types mating material compared to than that of in Base oil. EDS analysis on tribo-layers element disclosed that SAE4620 and TiN mating material rings attract high concentration of Mo at% on its surface which reflected on the higher friction and wear results. Although traces of Molybdenum can also be detected on TiC mating material ring, significantly higher at% of Calcium from detergent on both bearing and ring helps to protect both the a-C:H and TiC coating thus further lower the friction and wear of the a-C:H/TiC tribo-pair.