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主論文の要旨

論文題目　**Effect of applied load, sliding distance, mating materials and nano-particles on tribological properties of diamond-like carbon coatings in the base oil lubrication condition**
(DLC膜の油中摩擦摩耗特性に及ぼす荷重、すべり距離、相手材料及び異物粒子の影響)

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論文内容の要旨

Diamond-Like Carbon (DLC) coatings have been widely used as protective surface film to mechanical components due to their excellent tribological performance under various mild sliding contact conditions. For automobile engine industry, urgent demands have been focused on the wear and seizure resistance of DLC coatings under high contact pressure conditions under oil lubrication conditions.

Firstly, this thesis investigated the seizure resistance of amorphous hydrogenated carbon (a-C:H) and hydrogen-free tetrahedral amorphous carbon (ta-C) under oil boundary lubrication condition and the effects of load and sliding distance on the wear and friction behavior of each coating were tested in poly-alpha-olefin base oil. The coated and non-coated SUJ2 steel cylindrical specimens were slid with their central axes parallel to the sliding direction against a rotating steel counterface. Both DLC coatings resist seizure much better than the non-coated specimens. Under a relatively low applied load, ta-C shows much lower specific wear rate than the a-C:H. When the load is raised above a critical value, the specific wear rate of ta-C increases rapidly and became 3~5 times higher than that of a-C:H. While in the case of a-C:H, the specific wear rate decreases significantly when the load exceeds a critical value and maintains that lower wear rate even the load increases. By contrast, ta-C shows a rapid increase in specific wear rate as sliding distance increases. While the specific wear rate of a-C:H decreases slightly and shows much lower specific wear rate than ta-C. Based on the results of Raman Spectroscopy, Atomic Force Microscope and Scanning Electron Microscopy, it is concluded that ta-C and a-C:H coatings are influenced by different sets of wear mechanisms when it slid under boundary lubrication conditions in pure base oil.

Then a comparative study on the wear behavior of a-C:H and ta-C when they rubbed against various selected mating materials is conducted to find out the optimal tribopair which could prolong the lifespan of DLC coating in high contact pressure conditions. In this thesis, a-C:H and ta-C coating were slid against various mating materials under boundary lubrication condition in base oil to clarify the wear mechanisms of a-C:H and ta-C coating. It is expected that such findings could be used as a guideline to select the optimal combinations of DLC/mating material. Tribological tests were performed in a cylinder-on-disc tribotester, Field Emission Scanning Electron Microscopy (FESEM) and Raman Spectroscopy were used for the characterization of worn surface of ta-C and a-C:H coatings. The results show that the specific wear rate of ta-C coating increases along with the increase of the hardness and roughness of mating material, while the specific wear rate of a-C:H coating increases together with an increment in the I_D/I_G ratio. It is concluded that for ta-C coating, local stress concentration-induced microfracture is the main wear mechanism in relative high wear condition, along with minor graphitization-induced wear which prevails in low wear condition. On the other hand, a-C:H coating shows that simultaneous generation and the removal of the graphitized layer on the contact surface is the predominant wear mechanism.

Moreover, under high sliding contact pressure condition, the effect of various nanoparticles with distinct size on the wear of ta-C and a-C:H under oil boundary lubrication condition was clarified. When the friction components are exposed to some severe operation circumstances where containing large amounts of foreign particles, such as dust or grains of sand, the friction and wear could be enhanced by introducing foreign particles. However, such particles may inversely behave as protective additives to reduce the friction and wear of the whole tribo-system due to the unique mechanical or chemical properties of those foreign particles. Based on the obtained results, we proposed a potential replacement of the current chemical-based lubrication additives with a novel environmental friendly ZrO_2 nanoparticles to further improve the wear resistance of ta-C coating in base oil boundary lubrication conditions. The results show that by adding ZrO_2 nanoparticles, the wear of ta-C coating could be reduced about 40% compared to non-additive base oil condition.