Friction Reduction by DLC Coating in Combination with Aqueous Xylitol Solution and Effect on Surface Properties

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1. Back ground

In recent years, environmental problems have been considered in various fields. It is assumed that lubricants will be needed to replace the mineral oil-based lubricants with poor biodegradability that are currently widely used in internal combustion engines and for EVs. Therefore, research using aqueous alcohol-based solutions as lubricants without the use of petroleum is attracting attention[1]. In addition, low-friction properties of Diamond-Like Carbon (DLC) coatings in combination with lubricants containing glycerol monooleate (GMO) have been reported compared to DLC alone, and this is reported to be due to the hydroxyl groups (OH groups) in the GMO[2]. This suggests that the combination of aqueous alcohol-based solutions and DLC may provide better low-friction properties than aqueous alcohol-based solutions alone.

2. Test conditions

For the block-on-ring test, The SUJ2 blocks with a size of 6.33 x 16.6 x 9.65 mm and a surface roughness of Ra 0.015 µm were used. Three types of blocks were tested: uncoated and with ta-C and a-C:H DLC coated on the sliding parts and the steel rings with an outer diameter of Φ34.99 mm and a surface roughness of Ra 0.2 µm. The lubricants used were xylitol solution and general-purpose gear oil for e-Axle, with the xylitol solution at a saturating concentration of 60 wt%. The lubricant temperature was 25 °C and the pressing load on the block was 5 N (31 MPa). The test method was to increase the rotational speed every 30 sec from 1 rpm after the load was applied, and the friction coefficient was obtained up to a maximum of 5000 rpm

3. Test resuits

Fig.1 shows the test results. As the test is a speed increase test, the lubrication conditions shift from boundary lubrication on the left side of Fig.1, through mixed lubrication, to EHL and fluid lubrication. It was confirmed that the friction coefficient decreased in xylitol solutions compared to gear oil in the areas considered to be boundary and mixed lubrication. Compared to the results for uncoated SUJ2 material in xylitol solution, friction was reduced in all regions for ta-C and a-C:H. Fig. 2 shows the surface properties of the blocks after testing, measured using Atomic Force Microscopy. The uncoated block under gear oil lubrication showed 140 nm of wear, compared to the uncoated block under xylitol solution lubrication, which showed no wear. In addition, the a-C:H coating of the xylitol solution, which had a significant friction-reducing effect, resulted in more smoothing compared to the uncoated gear oil specification.

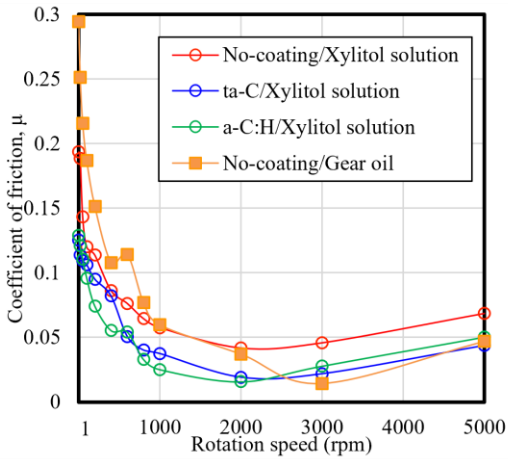

Fig.1 Comparison of friction reducing effects in aqueous xylitol solution and gear oil.

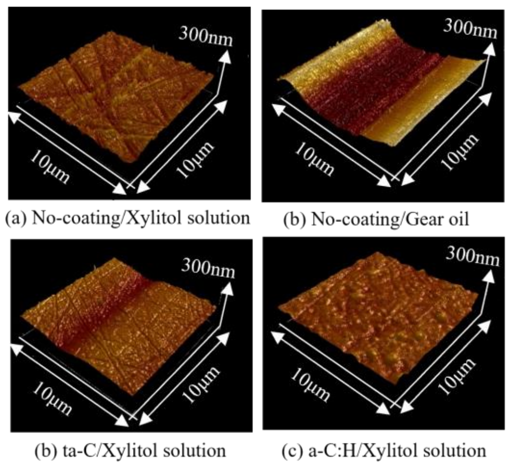

Fig.2 Surface measurement results of blocks after testing

References

1) Tobias Amann, et al., "Macroscale superlubricity of diamond-like carbon coatings and ceramics using different lubricants From model test to application", World Tribology Congress2022, WTC2022 July 10-15, 2022, Lyon, France.

2) Makoto Kano, "Diamond-Like Carbon Coating Applied to Automotive Engine Components", Tribology online, Vol.9, No.3(2014), 135-142