Understanding of lubrication mechanisms on articular cartilage for bio-inspired tribological system with super lubricity

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Mechanisms of super-lubricity of articular joints have received much attention over the years. Sliding surface of articular joints are covered with soft, porous, and highly hydrated articular cartilage and lubricated with synovial fluid that contains biomolecules including proteins, phospholipids and hyaluronan (HA). Many studies have been conducted to clarify the detailed lubrication mechanism of articular cartilage, and some recent studies are focusing on the importance of the boundary lubrication mechanism with biomolecules. In this study, highly hydrated hydrogel is used as a simulated material of the articular cartilage and the lubrication effect of water-based lubricants with synovial fluid constituents is evaluated to explore the feasibility of the bio-inspired tribological system consists of biomolecules and a highly hydrated hydrogel.

Poly(vinyl alcohol) (PVA) hydrogel was prepared by the repeated freezing-thawing method and the spherical glass lens was used as a counterface material. Phosphate buffered saline (PBS) was used as the solvent and proteins (albumin, γ-globulin), phospholipid (DPPC), and HA were added to it. The sliding pair of glass lens and PVA hydrogel was lubricated with prepared test lubricants and the friction coefficient exerted between sliding surfaces were evaluated by using reciprocating friction tester.

Representative results of the reciprocating friction tests are shown in Fig.1. Friction coefficients were plotted against the sliding speed. Compared with the friction coefficient in water, the HA solution reduced friction remarkably. HA increased the viscosity of the lubricant and reduced friction by increasing the fluid film thickness under high sliding speed condition. In addition, it could reduce friction even under the low sliding speed condition, probably because large HA molecules were trapped between porous hydrogel surface and the glass counterface and reduce the interaction between frictional surfaces. Effects of protein and DPPC were depended on the sliding speed. Proteins increased friction under low sliding speed condition by forming denatured protein film on the hydrogel surface, while DPPC might formed adsorbed bilayer as the effective boundary lubrication film. The synergistic lubrication effect of HA and DPPC appeared and the excellent low friction with the friction coefficient less than 0.01 could be achieved under low sliding speed condition. It is a promising result indicating the good potential of the bio-inspired tribological system with the combination of HA/DPPC mixture solution and the highly hydrated hydrogel.

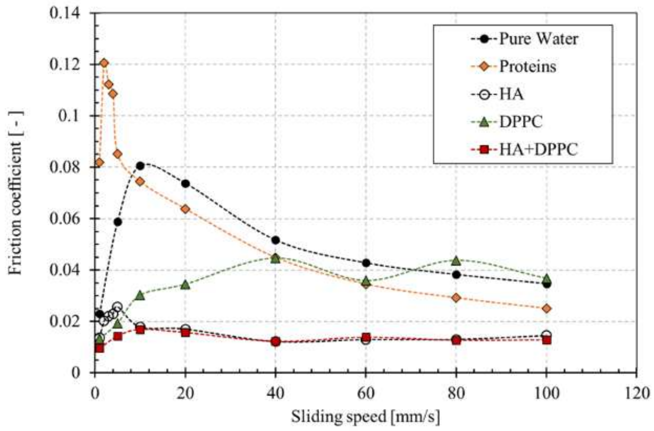

Fig.1 Sliding speed dependency of friction coefficient in lubricants with biomolecules