A Tribological Test Method for PVA Hydrogels and Articular Cartilage

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Hydrogels are considered promising replacement materials for articular cartilage. Friction conditions in biological systems such as joints are complex and their simulation requires tribological tests that closely model the real life conditions. The current work presents a methodology for manufacturing and tribological characterization of polyvinyl alcohol (PVA) hydrogels and porcine articular cartilage using a special setup of a commercial rheometer. Measurements of elastic modulus and zeta potential of the PVA hydrogel allowed for a deeper understanding of the tribosystem's behavior. The results showed that the presented setup can be used for evaluation of the tribological performance of a PVA hydrogel compared to real cartilage.

Keywords: biotribology, PVA hydrogel, extended Stribeck curve, elastic modulus, zeta potential

1. Introduction

In a total knee or hip arthroplasty the whole joint is replaced by an artificial implant. Choosing the right material is a challenge since two or more parts of the joint are in relative motion in the daily life and, hence, may experience different frictional behavior and even wear [1, 2]. In order to recover the full functionality of the joint and to relieve the patient's pain, the implants should have the same frictional properties as the joint. Understanding the tribology of a joint replacement is therefore crucial for development of new implant materials. Polyvinyl alcohol (PVA) hydrogels are considered as one of the most suitable candidates for joint cartilage replacement because they are biocompatible and have mechanical properties similar to the joint cartilage [3]

2. Methods

The PVA hydrogels (61,000 g/mol.) were prepared from freeze-thaw technique through 5 temperature cycles from -20 °C to 8 °C directly in the tribological cell of a MCR rheometer. The tribological measurements were performed using the same MCR Tribometer with pin-on-disc setup (see Figure 1) and with special clamping adapters to accommodate the in-situ produced PVA hydrogel specimen. Oscillatory tests along with sliding velocity ramps were carried out over several orders of sliding speed and results are shown in the form of extended Stribeck curves [4].

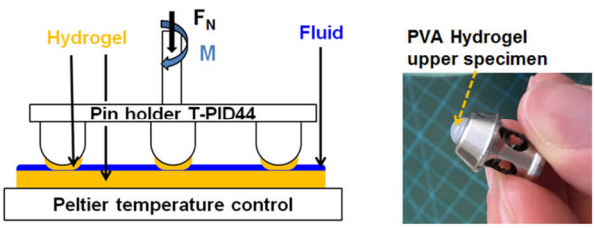

Figure 1: Schematic of the pin-on-disc setup (left) and adapter for soft specimen (right).

Zeta potential was measured with an electrokinetic analyzer for solid surfaces with one of its proprietary measuring cells. The elastic modulus was measured using instrumented indentation technique by applying a 100 µN load on a spherical indenter.

3. Results and Discussion

The work demonstrates how a combination of complementary measurement techniques can be used for characterization of tribological, chemical and mechanical properties of PVA hydrogel. The tribological measurements with PVA on PVA configuration as well as PVA on porcine knee cartilage configuration provided information about the friction coefficient at various sliding speeds occurring during daily motion. The friction factor trend observed on the PVA gel with different artificial synovial fluids was similar to that observed on porcine cartilage specimen. This indicates that the PVA gel corresponds well to the real friction behavior in the joint. The surface charge measurements corroborated the tribological result while the indentation results confirmed that the elastic modulus of the PVA hydrogel is similar to that of the outer surface of the joint cartilage. The methodology and analysis used in this study will further be expanded to understand the long-term friction and wear behavior of these materials.

4. References

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