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Monitoring of Lubrication Behavior of Metal-Polymer Plain Bearing Based on Triboelectric Principle

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1. Introduction

Metal-polymer plain bearings (MPPB) have found increasing applications in various types of machinery owing to specific favorable characteristics, such as high load-carrying capacity, the possibility of use in dry friction and boundary conditions, damping ability, etc. [1]. The lubrication condition of these bearings can be divided into four types: boundary lubrication, mixed lubrication, hydrodynamic lubrication, and hydrostatic lubrication [2]. Hydrodynamic lubrication and hydrostatic lubrication can be deemed as fluid lubrication because the sliding surfaces are separated by the liquid lubricant. Monitoring lubrication conditions is crucial because the lubricant is critical for their longevity [3]. Traditional monitoring methods of lubrication conditions for these bearings are based on thermal response methods [4].

In this research, the triboelectric principle was applied to a commercial MPPB and a Si-DLC coated shaft, shaping a Si-DLC-based TENG. The TENG can achieve self-sensing, self-diagnosis, and self-maintenance. The mechanism behind the output change trend under boundary and hydrostatic fluid lubrication was revealed for the first time. The triboelectric output signals under different lubrication conditions were applied as an indicator to regulate the oil supply from the pump, which thus achieves self-diagnosis and self-maintenance ability.

2. Experiments and TENG mechanisms

The main structure includes a MPPB and a steel shaft coated with Si-DLC film, which was selected as positive triboelectric material. The commercial MPPB includes a polyether ether ketone (PEEK) resin layer, which is a negative triboelectric layer due to its relatively strong electron-withdrawing capability. A gap on the PEEK layer is fabricated to make the variation of charges, thus shaping a sliding single-electrode mode TENG. The structure and working principle of the T-MPPB is displayed in **Fig. 1**.

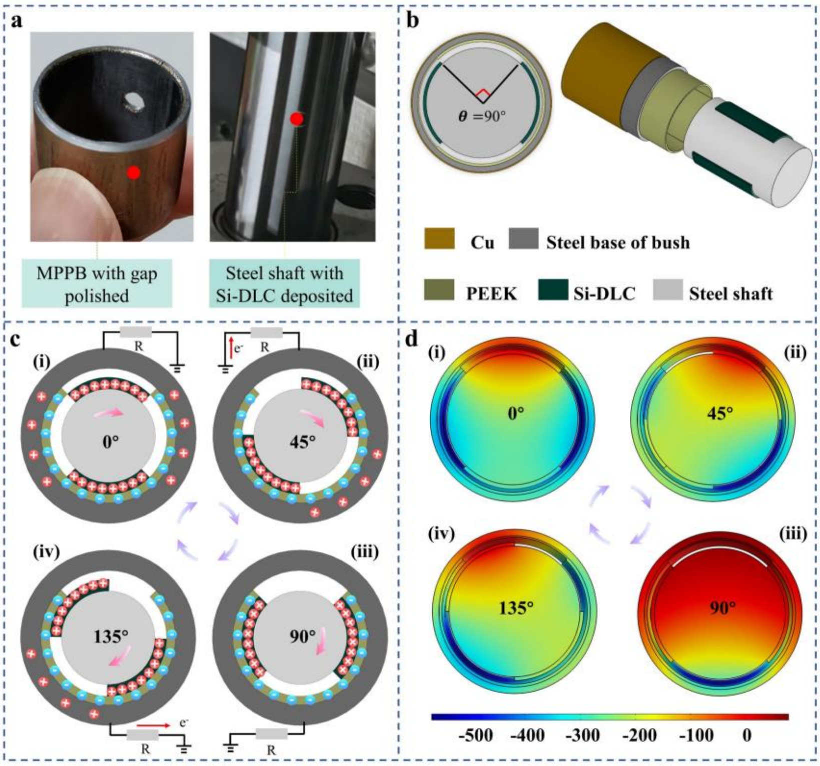

Fig. 1 Structure and working principle of the T-MPPB: (a) Photographic image and (b) detailed components of the T-MPPB. (c) Schematic diagram of four stages of charge transfer under one cycle for T-MPPB. (d) Simulated potential distributions for T-MPPB at four different positions by COMSOL.

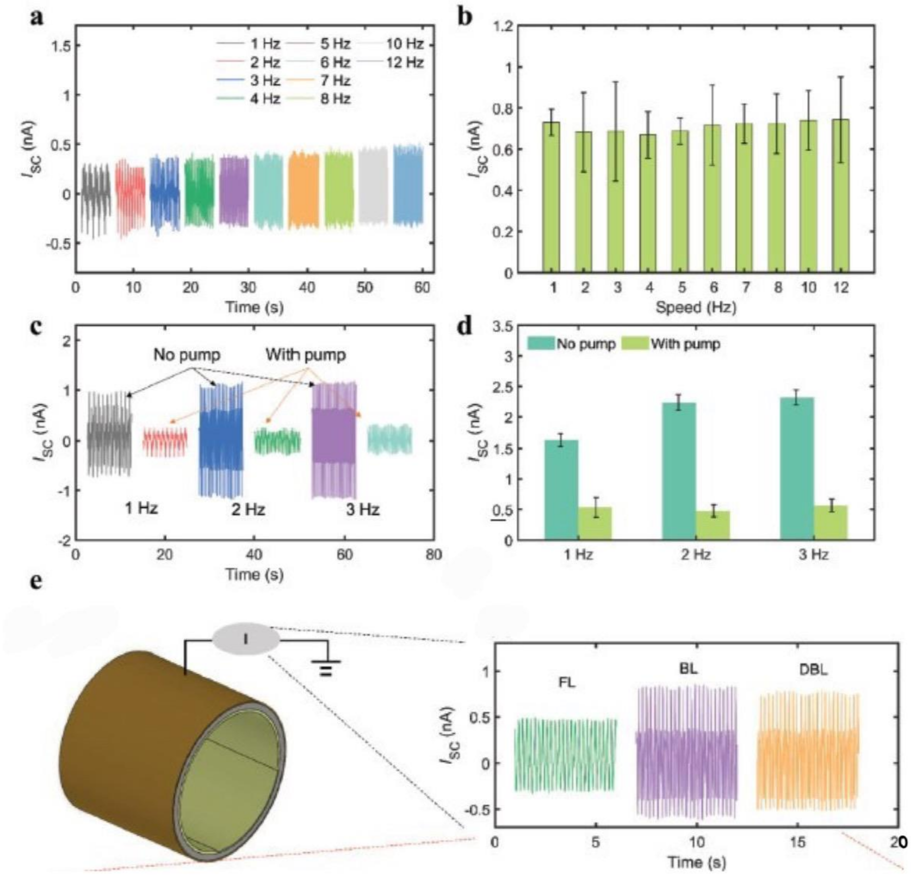

Fig. 2 (a) I_{SC} and (b) the average peak-to-peak I_{SC} change trend of T-MPPB at rotating speeds from 1 Hz to 12 Hz under fluid lubrication. Current comparison for T-MPPB between boundary lubrication and fluid lubrication: (c) waveform signal comparison, (d) average value comparison, and (e) The schematic illustration of T-MPPB to acquire signal

3. Summary

The as-designed structure was tested under three different conditions, fluid lubrication (FL, oil pump on), boundary lubrication (BL, a period of good lubrication condition (1-2 h) after pumping off), and deteriorated boundary lubrication (DBL, e.g. more than 2 h after pumping off). The current signals show a decreasing trend with increasing amount of oil (pump on) as shown in **Fig. 2**, which indicates the ability for self-powered lubrication region monitoring.

References

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