An Intelligent electret thrust ball bearing with self-powering and self-sensing capabilities

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Abstract

As the core component of rotating machinery, thrust bearing a location where mechanical failures frequently occur. With the rapid development of the Internet of Things (IoT) and big-data technology, the higher requirement for the intelligence of bearings has been put forward. At present, intelligent bearings mainly realize self-sensing by adding micro sensors inside them, which increases the complexity of the structure and requires an external power supply at the same time, thus limiting practical applications. This paper reports a novel type of intelligent thrust ball bearing, called electret thrust ball bearing (ITBB), which has both self-powering and self-sensing capabilities. Through measuring the electrical output characteristics of the ETBB at different rotating speeds, it is found that the rotating speed of the ETBB can be characterized by the two values of output voltage and frequency, which has extremely high sensitivity and stability. This work has widespread application prospects in the development of IoT and Intelligent machinery.

Device conceptualization

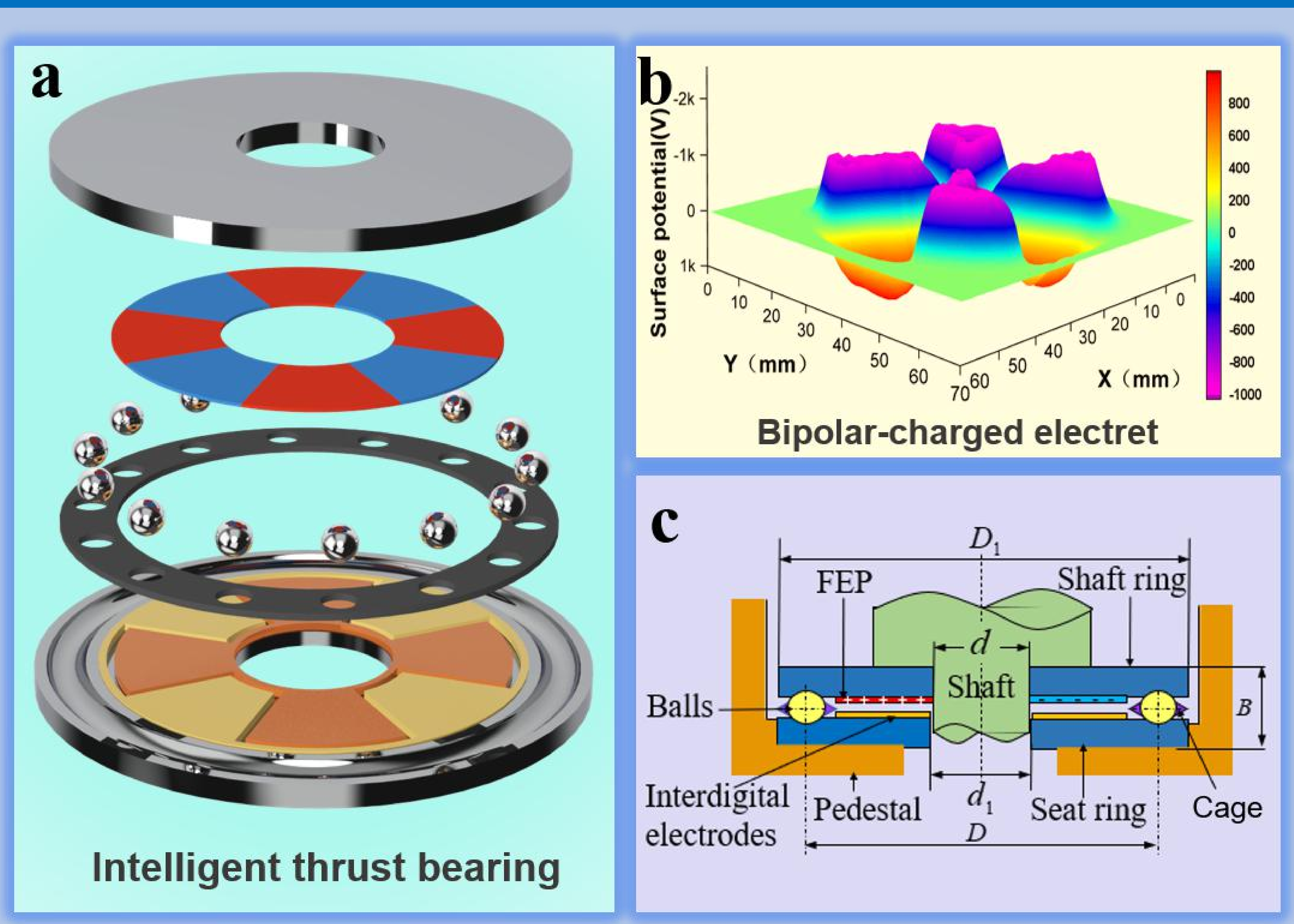

Figure 1: : Structural design of the ITBB based on the free-standing mode (a)Structural explosion diagram of the ITBB(b) Measured 3D potential distribution of the ITBB: Blue color depicts the negatively charged area and red color depicts the positively charged area. (c) Installation diagram of the ITBB with the rotor shaft and the bearing seat hole.

Fig.1(a) shows that the ETBB is composed of six parts from top to bottom, which are shaft ring, electret, cage, rolling balls, interdigitated electrodes and seat ring, respectively. Due to the typical characteristics of non-contact and relative rotational movement, the proposed e-REH can be readily embedded into the ITBB to achieve self-powered and self-sensing capabilities. Generally, the shaft ring of the ETBB rotates with the rotating shaft and the seat ring is fixedly connected with the bearing housing hole, as shown in Fig.1(c). Electret patterned bipolar charging is based on corona localized charging system , which realizes the bipolar distribution of positive and negative charges by changing the electrostatic shielding pattern and the polarity of the injected charge. The measured 3D potential distribution of the fan-shaped rotational energy harvester is shown in Fig.1(b).

Experimental Results

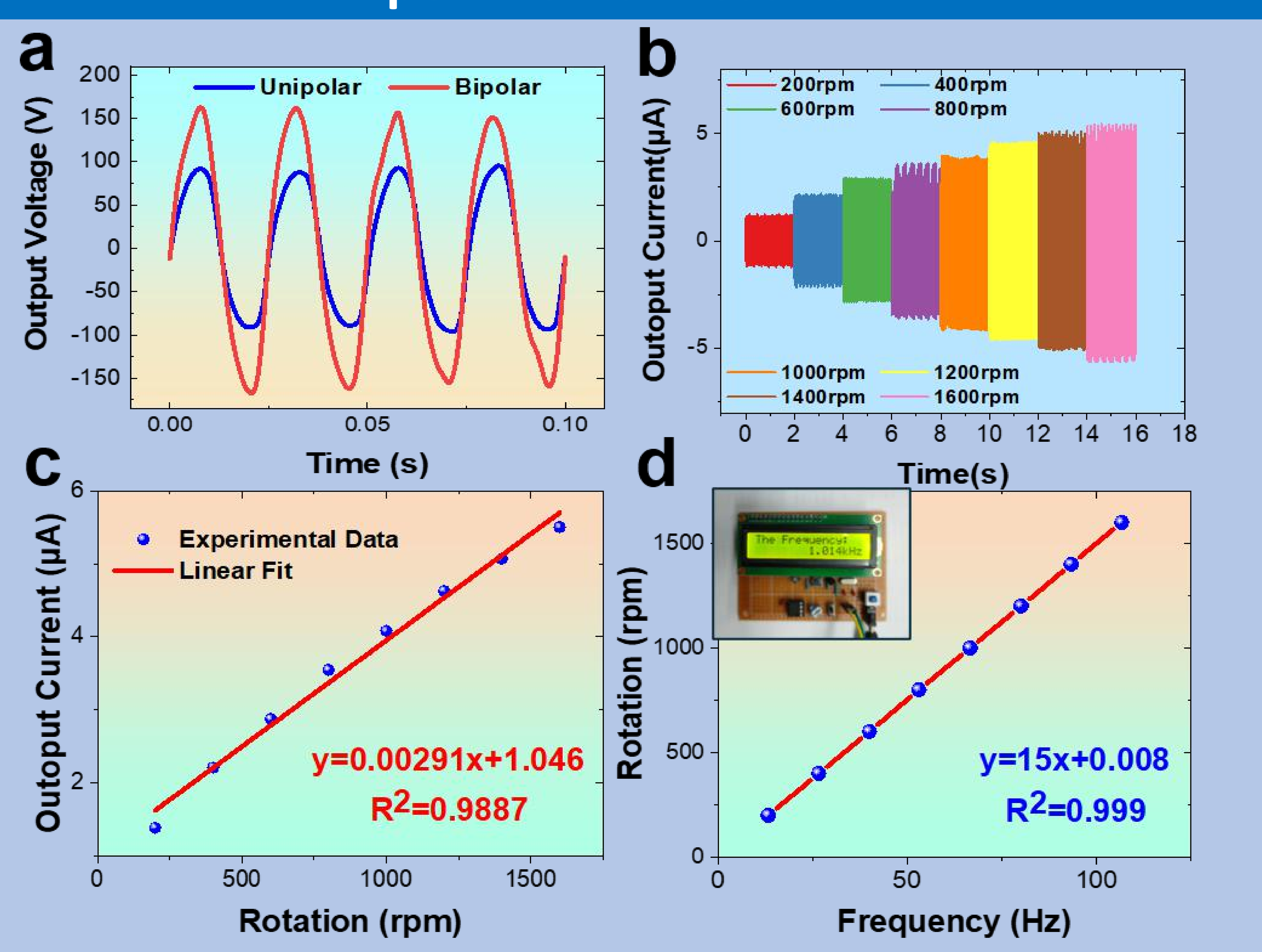

Figure 2: Experimental measurement results of the ETBB (a)Comparison of unipolar and bipolar output voltage at 600 rpm (b) Comparison of output current at different rotating speed (c) The relationship between bearing output current and speed based on linear fitting of experimental data (d) Derive the relationship between output current and frequency based on experimental data.

The comparisons of unipolar and bipolar output voltage at 600 rpm are shown in Fig.2(a).Experimental results show that the output voltage of bipolar charging is about twice that of unipolar charging. The output current comparison of the ITBB at different rotating speeds is shown in fig.2(b), which indicates that the output current of the ITBB keeps increasing with the increase of the speed. For this reason, through further research on the peak output current of the ITBB at different rotating speeds, the research results are shown in Fig.2(c), which illustrates that the rotating speed and the output current of the ITBB have a superior linear relationship. Therefore, it is highly sensitive to indicate the rotating speed through the output current of the ITBB, which can realize the self-sensing of the rotating speed. The frequency of the output current can also be used as an indicator to monitor the rotating speed of the ETBB, which also has high sensitivity ,as shown in fig.2(d).

Conclusions

In summary, a novel intelligent thrust bearing (ETBB) based on the electret rotary power generator is proposed, which has self-powering and self-sensing capabilities. In terms of structure, by taking advantage of the non-contact and relative rotation characteristics of the shaft ring and the seat ring, the electret rotary power generator based on the free-standing mode with the same characteristics is embedded into the thrust ball bearing, which not only ensures the integrity of the thrust ball bearing mechanical structure ,but also turns it into an intelligent thrust bearing with self-powering and self-sensing. The output power of the ETBB is theoretically increased by four times by bipolar charging, which greatly improves its ability to collect rotating mechanical energy and provides the application prospect of supplying energy for other sensors. Through measuring the electrical output characteristics of the ETBB at different rotating speeds, it is found that the rotating speed of the ETBB can be characterized by the two values of output voltage and frequency, which has extremely high sensitivity and stability. This work proposes an electrostatic intelligent bearing with self-powering and self-sensing, which has widespread application prospects in the development of IoT and Intelligent machinery.