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Energy Harvesting Using Torsional Deformation of Permanent Magnet Elastomers

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Permanent magnet elastomers (PMEs) are magnetic composite materials composed of magnetically-hard magnetic particles dispersed in a viscoelastic matrix and magnetized to behave as permanent magnets. Owing to their viscoelastic properties, PMEs can undergo large three-dimensional deformations and generate changes in magnetic flux solely through material deformation. By placing a coil around the PME, electric power can be generated based on Faraday's law of electromagnetic induction, making PMEs promising for energy harvesting applications. In studies on string-shaped PMEs, it has been reported that applying string vibration yields a remarkably high power output of approximately 120 mW. This suggests that torsional vibration enhances power generation compared to purely lateral input due to increased magnetic flux variation. However, large torsional inputs are not common in practical environments, and the underlying mechanism remains unclear. This study focuses on the significant enhancement of power generation induced by torsional vibration in string vibration and aims to clarify its mechanism. The relationship between the rotational behavior of magnetic particles and magnetic flux variation under torsional deformation was investigated using X-ray computed tomography (CT). The results showed that the particles rotate following matrix deformation, and the rotation angle depends on the axial position (see Fig. 1). Particles near the rotating end exhibited larger rotation angles, consistent with magnetic flux density measurements, confirming particle-scale changes in magnetization. Furthermore, the effects of material properties and specimen geometry on torque and power generation were investigated. String-shaped PME samples with varying particle volume fraction, Young's modulus, and aspect ratio were tested under controlled twist angles. The results showed that torque increased moderately (approximately 3–3.7 times), whereas generated power increased significantly (approximately 21–23 times). These results indicate that generated power is more sensitive to these parameters than torque, contributing to improved energy harvesting performance.

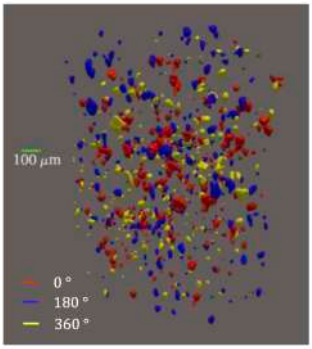

Figure 1: X-ray Visualization of Magnetic Particles (Position Changes under Torsional Deformation)

Type:

Poster