RHEOLOGICAL PROPERTIES OF THIN-FILM PERMANENT MAGNET ELASTOMERS IN STRETCH DEFORMATION

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Abstract. Permanent magnet elastomers are three-dimensional deformable permanent magnets, which are novel functional materials in which the magnetic field around the elastomer changes during deformation. The detection of the magnetic field variation enables the realization of tactile sensors. Considering the application of tactile sensors, it is important to understand their viscoelastic properties. In the present study, the rheological properties of permanent magnet elastomers in stretch deformation were investigated. The results show that the viscoelasticity changes due to magnetization. Additionally, this variation due to magnetization was discussed by fitting it into a four-element mechanical model.

1. Introduction

Recently, flexible tactile sensors have gained attention in applications such as artificial skin and soft actuators for robots. One such sensor is the magnetic-type tactile sensor that utilizes a film-shaped magnetic elastomer [1]. Magnetic elastomer is a functional material that exhibits the combined properties of viscoelasticity and magnetism. The elastomer is prepared by stably dispersing magnetic particles like iron powder in a viscoelastic material such as silicone gel. By applying an external magnetic field, the deformation and viscoelasticity can be controlled [2].

A recent development is the permanent magnet elastomer, which displays residual magnetization. The elastomer is prepared by dispersing magnetically-hard magnetic particles such as NdFeB in a viscoelastic material and then magnetizing it [3]. This magnet is highly deformable and has high coercivity and residual magnetization. When deformed, the PME shows a dramatic change in the surrounding magnetic field. This has potential applications in tactile sensors.

In the present study, film-shaped PMEs are prepared, and dynamic viscoelastic measurements in stretch deformation are performed considering the application of the tactile sensors. The rheological changes before and after magnetization were evaluated and discussed by fitting the mechanical models.

2. Experimental Procedure

The permanent magnet elastomers were prepared by dispersing neodymium particles (MQFP14-12-20000-089, Magnequench) in silicone polymer matrices (Sylgard18, The Dow Chemical Company) and then magnetized. The average diameter of the neodymium particles is 5 μm. The silicone gel and neodymium particles were mixed, vacuum-degassed, and then heated at 343 K and cured to shape a film of 2x5x20 mm. The volume fraction of neodymium particles is 20 vol.%. The mixing ratio of Sylgard184 main agent to curing agent was 40:1. The cured sample was magnetized by a pulse-uniform magnetic field of 6T. The magnetization direction was set to the thickness direction of the samples. Their rheological properties in stretch deformation were measured using a viscoelastic measurement device (DMS6100, Hitachi High-Tech Science Corporation).

3. Results and Discussion

The results of the experiment at an initial strain of 10% are shown in Fig.1. It was confirmed that both the storage modulus and the loss modulus increase with an increase in the excitation frequency. The enhancement of the loss modulus is larger than that of the storage modulus with increasing in the excitation frequency. The storage and loss moduli of the permanent magnet elastomer are larger than those of the magnetic elastomer. Here, we call the magnetized elastomer a permanent magnet elastomer and the non-magnetized elastomer a magnetic elastomer.

The influence of magnetization in the storage and loss modulus was discussed by fitting the experimental results into a four-element mechanical model (Fig. 2). The identified values of each mechanical element are shown in Table 1. All four parameters increased after magnetization compared to before magnetization. When the magnetic elastomer was magnetized, it is thought that the dispersed magnetic particles within it were

oriented in the direction of magnetization. Thus, the alignment of magnetic particles inside the elastomer may have formed a three-dimensional structure, leading to increases in both the elastic modulus and viscous modulus.

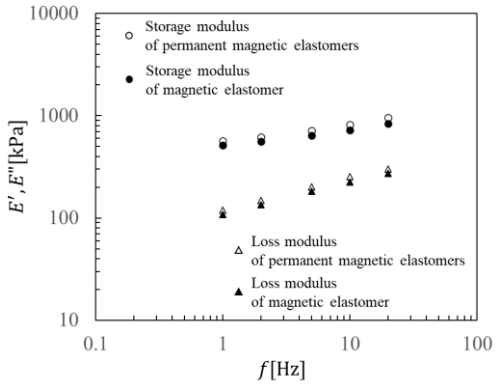

Fig. 1 Storage and loss modulus before magnetized (magnetic elastomer) and after magnetized samples (permanet magnet elastomer) at initial strain of 10%

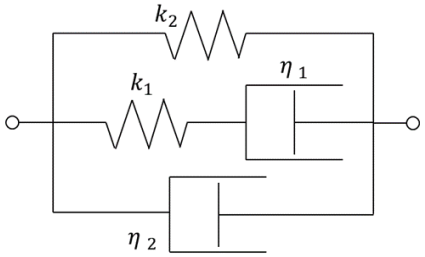

Fig. 2 Four-element mechanical model

Table 1. Value of each mechanical element in the four-element mechanical model

	Magnetic elastomer	Permanent magnet elastomer
k_1 [Pa]	272283	300520
k_2 [Pa]	480913	536196
η_1 [Pa-s]	14848	16368
η_2 [Pa-s]	2009	2225

Conclusions:

The dynamic viscoelastic measurements in stretch deformation were performed to investigate the rheological properties of the thin-film permanent magnet elastomers. As a result, it was confirmed that both storage modulus and loss modulus increase by magnetization. This change is thought to be influenced by the orientation of internal particles due to magnetization and the formation of a three-dimensional structure.

Acknowledgement:

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