PDMS의 물성치 측정 및 비선형 모델

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Measurement of Mechanical Property of PDMS and its Nonlinear Model

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Abstract - This paper presents the measurement of the mechanical property of PDMS (Polydimethylsiloxane) elastomer depending on volumetric mixing ratios of base polymer and curing agent and their hyperelastic material models.

1. Introduction

A PDMS (Polysdimethylsiloxane, from Dow Corning, Sylgard 184) has been widely used for fabrication of micro structures by using a soft-lithography technology because it is cheap, optically transparent, biocompatible, and etc.. Its outstanding mechanical property enables to realize active micro actuators for the peristaltic liquid-pumping [1] and micro balloon actuators for VR (Virtual Reality)-based micro hand [2] with large out-of-plane motion.

Prof. Quake proposed interesting method for the bonding of PDMS-to-PDMS. If the volume ratios of base polymer and curing agent are changed, an excess of vinyl group or one of silicon hydride group exists in PDMS film [3]. A 20:1 mixture of PDMS shows strong peaks of vinyl groups while 5:1 one have one of silicon hydride group which form a covalent bond each other through the sequential heating process. Obtained results in Ref.[4] can back up the previous reports [3] dealing with qualitative understanding on the bonding process of PDMS mixed with different volume ratio.

Another interesting point is about the controllability of the mechanical property of PDMS films mixed by changing mixing ratios of the base polymer and curing agent. However, the measured isotropic mechanical property of PDMS could not be acceptable for the structural analysis in the large strain region. Thus, it is very hard to predict, estimate, and evaluate the incompressible mechanical behavior of PDMS structure in the large strain region. Thus, a study on the nonlinear material model of PDMS is necessary in order to understand the mechanical behaviour of PDMS structure.

2. Mechanical Property of PDMS

2.1 Tensile test

The uniaxial tension tests of the prepared samples are performed with Micro-Tensile Tester (AMETEK LPX-PLUS). The loading speed is 1 mm/min and a 10 kN of load cell is used. In order to investigate the mechanical property of PDMS depending on its volumetric mixing ratios, four types of PDMS samples with different mixing ratios are prepared.

Figure 1 shows the recorded raw data of four samples. The engineering strain-stress curves of PDMS samples is calculated from the recorded raw data. Either when the base polymer decreases or when the curing agent increases, its Young's modulus increases. In the case of the bonded sample of 5:1 PDMS film and 20:1 one, its tensile strength is much larger than other cases. This phenomenon enables to realize all PDMS pneumatic micro hand [2] working under the extremely high pressure of the external compressed air. The structural (or sealing) failure of the bonded structure is occurred at the interface of the bonded layers of the balloon actuator chamber since the interface has the largest strain density. It is confirmed that the mechanical property of PDMS is controllable by using its volumetric mixing ratios. The tensile strength of PDMS structure could be improved through the layer-to-layer bonding process of PDMS. As not shown here, isotropic mechanical properties of samples are estimated from Fig. 1. Considered that tensile strength and Young's modulus in Ref. [4-5], the measured result on 10:1 PDMS are comparable to them

2.2 Material Model

Fig. 3 shows the nonlinear-fitting of the experimental raw data in Fig. 1. The material modelling is performed using the commercially available software package, MSC. Marc-Mentat. The positive constants and the bulk modulus for an Ogden model and a Mooney-Rivlin model are obtained through 200 iterations since the negative constant does not have any physical meanings. An Ogden model can describe the mechanical behaviour of PDMS. However, in the case of a Mooney-Rivlin model, it is too stiff or flexible in the measurement range in the full measurement range. It is concluded that the two-term Ogden model is preferable for the analysis of PDMS structure.

3. Conclusion

In this paper, the mechanical properties of PDMS depending on volumetric mixing ratios are measured and discused.

[Reference]

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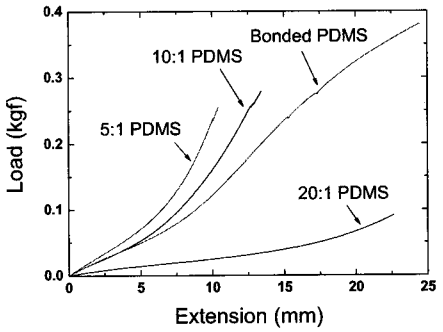
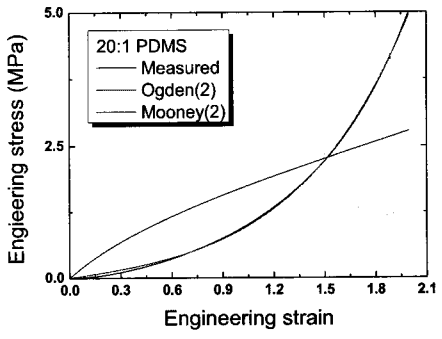


<Fig. 1> Raw data of four PDMS samples.



<Fig. 2> Example of material model of 20:1 PDMS.