Elasticity measurement of Biological tissue using a Probe-Type Instrument

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***Abstract*— In this paper, the elastic properties of chicken and bovine livers were measured using a probe-type instrument. The design of the instrument and the method for calculation the parameters were presented, followed by the experimental validation of the method using artificial material. The validated method was then used to measure the chicken and bovine livers. Good agreements in curve fitting were obtained using the proposed method. Experimental results showed that the chicken liver demonstrated stronger nonlinear behaviors comparing to the bovine liver.**

I. Introduction

Surgical simulation provides an good option for surgical training and optimal surgical planning before actual surgery. To this end, accurate computer model of human organs and tissues are required, which further requires accurate physical properties of these tissues. However, measuring such properties in vivo is a very challenging task due to the complex internal environment and limited space inside body. To take this challenge, in this research, a probe-type device was proposed towards portable measuring system for calibrating tissue properties.

II. Method

Most of human organs and tissues are supposed to be incompressible and the Poisson's ratio γ was considered to be close to 0.5. In this work, we set Poisson's ratio γ as a constant of 0.49 and we are focusing on the calculation of elasticity, *i.e.* the Young's modulus E. According to Hertz contact mechanics, the contact force F between a sphere and a flat elastic surface is given by:

$$F = \frac{4}{3}\frac{E}{1-\gamma^2}R^{\frac{1}{2}}\delta^{\frac{3}{2}}, \tag{1}$$

where R denotes the radius of the sphere and δ denotes the indentation depth. The relationship was further extended to Eq. 2 to cope with relatively thin samples [1]. In this work, we choose Eq. 2 for its generality.

$$F = \frac{4}{3}\frac{E}{1-\gamma^2}R^{\frac{1}{2}}[\delta(1+B\delta)]^{\frac{3}{2}}, \tag{2}$$

where B is a unknown parameter to be determined.

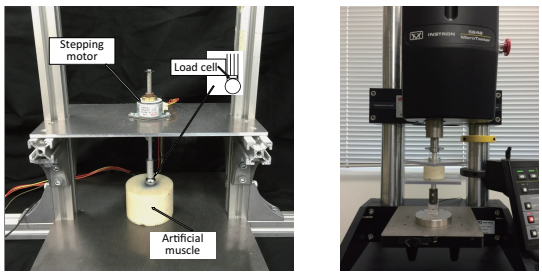

Fig. 1. (a) Developed indentation device, (b) Instron material testing machine.

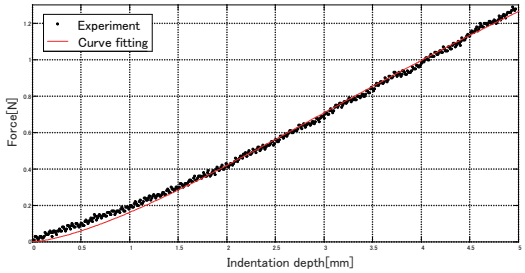

Fig. 2. The curve fitting result.

III. Experimental Setup

The prototype of the developed device, as shown in Fig. 1a, consists of a stepping motor to generate indentation motion, an elongated probe to fit into a trocar, a sphere at the end of the probe to allow us to use Hertz contact mechanics, and a load-cell fixed inside the probe to measure the indentation force. The material sample used in our experiments is made of artificial muscle material and has a size of 35.0 mm in height and 50.0 mm in diameter. In order to obtain a ground truth value of the Young' modulus, the Instron material testing machine, as shown in Fig. 1b, was also employed in our work.

IV. Indentation Experiment and Results

A 5 mm indentation experiment was performed 5 times using the developed device and the indentation forces were measured by the load cell. Matlab curve fitting toolbox was used to fit the measured displacement-force curve based on Eq. 2. The best fitted curve was shown in Fig. 2 and the corresponding calculated parameters are $E = 42.7\,\text{KPa}$ and $B = -0.0495$. For comparison, the Young's modulus calculated by the Instron testing machine is $E = 43.0\,\text{KPa}$. Error is less than 1%. In the future, a portable instrument will be developed based on the idea presented in this paper.

V. Measurement of biological tissue

The developed probe-type instrument was then used to measure the elasticity of biological tissues. A chicken and a bovine liver samples were obtained from a local slaughterhouse,

(a) (b)

Fig. 3. (a) Chicken liver, (b) Bovine liver.

as shown in Fig.3. Same indentation experiments (5mm) were performed using the developed instrument. Curve fitting results using Eq. 2 were shown in Fig.4 and 5 for chicken and bovine liver respectively. Good agreements were achieved.

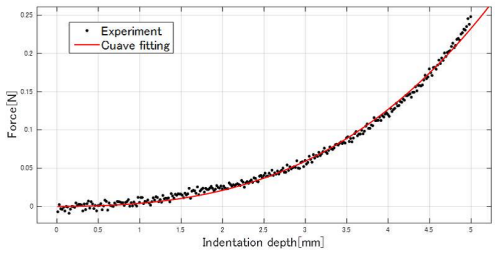

Fig. 4. Chicken's result.

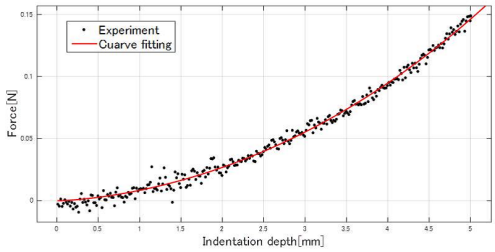

Fig. 5. Bovine's result.

The measured elasticity parameters of chicken and bovine livers were given in Table I. We found that parameter B was quite strong. In the future, we will make our instrument more compact and portable for the convenience of measuring various kinds of biological tissues.

TABLE I

MEASURED ELASTICITY OF CHICKEN AND BOVINE LIVERS

Livers	Young's modulus E (Pa)	Parameter
Chicken	365.1	0.9435
Bovine	1759	0.09423

REFERENCES

[1] Tani, M., Sakuma A.: Applicability Evaluation of Young's Modulus Measurement using Equivalent Indentation Strain in Spherical Indentation Testing for Soft Materials, The Japan Society of Mechanical Engineers, 76(761), pp. 102-108, 2010.