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Measurement of Micro-displacement of Polyvinyl Alcohol Induced by Acoustic Radiation Force – Comparison of Laser-Doppler Velocimetry and High Frequency Ultrasound

音響放射圧による PVA の微小変位の計測　－レーザードップラー法と高周波数超音波法による比較

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1. Introduction

Tissue-mimicking phantoms have important utilities for phenomenon analysis and perfomance evaluation. Silicone and acrilic polymers are often used as biological tissue-mimicking materials.[1,2) However, mechanical properties of their materials are different from those of living tissues and organs. Polyvinyl alcohol (PVA) cryogels are polymers. PVA has been notable for building biological tissue-mimicking phantoms. [3-6)

The physical properties of PVA are influenced with following 5 factors; dehydration process during heating at the initial step, cooling speed, the minimum temperature, volume of the sample, and the number of freeze-thaw cycles.

PVA has shown advantages for biomedical phantoms in magnetic resonance and ultrasound imaging. In these fields the mechanical properties of PVA have been widely investigated. In this paper, we measured micro-displacement of PVA which was induced by acoustic radiation force using laser-Dopper velocimetry in comparson with high frequency ultrasonic measurement.

2. Methods

2.1 High Frequency Ultrasound

The central frequency of ultrasound was 100 MHz and 15 micron resolution was acquired by the frequency. The pulse repetition rate was 3500 Hz. The maximum sampling rate was 2 GS/s with a high-speed digitizer card (Acqiris DP 1400, Geneva, Switzerland).

2.2 Laser-Doppler Velocimetry

Laser-Doppler velocimetry (Graphtec Co.,ltd) was employed to measure the micro displacement of PVA surface generated by acoustic radiation force. The range of frequency response was from DC to 300 kHz, and the measured velocity range was between 0.4 μm/s and 100 mm/s.

2.3 Acoustic Radiation Force

A hemispherical PZT transducer with the central frequency of 1-MHz and the diameter of 5-cm was used as the applicator of acoustic radiation force. Tone-burst pulse was input to the applicator. The range of the duration time was from 5 μs to 80 μs, and that of input voltage was from 15 V to 30 V.

2.4 PVA

PVA powder was dissolved in a mixture of distilled water and dimethyl sulfoxide (DMSO). The PVA power in the mixture solution was stirred for 2 hours at 100 °C until dissolution, and then the solution was poured into an acrylic plastic mold with dimensions of 15 x 7.5 x 4 cm up to 1 cm high. The mold was maintained at -20 °C for 24 hours to promote gelation of the PVA solution.

2.5 PVA of Laser-Doppler Velocimetry

The velocity of PVA surface oscillation induced by acoustic radiation force was measured by laser-Doppler velocimetry in two conditions. One condition was changing the input voltage to 15, 20, 25, 30 and 35 V, respectively with the duration of tone-burst pulse set at 30 μs. Another was changing the duration of tone-burst pulse to 5, 10, 20, 30, 50 and 80 μs with the input voltage set at 20 V, respectively. The displacement was able to be obtained by integrating over time.

2.6 PVA of High Frequency Ultrasound Measurement

In accordance with the result of laser-Doppler velocimetry, input voltage and duration of tone-burst pulse were decided. The center frequency of oscillations of PVA surface was the most important factor for this decision.

3. Results and Discussions

3.1 Measurement of Velocity by Laser-Doppler Velocimetry

Fig. 1(a) shows velocity and displacement when changing the input voltage. From 15 V to 20 V, linear relationships between the velocity and voltage, and the displacement and voltage were shown. From 20 V to 35 V, the relationships were constant. Fig. 1(b) shows the relation between the velocity and displacement when changing the duration of tone-burst pulse. In all ranges, linear relationships between the velocity and voltage and the displacement and voltage were shown.

Fig. 2(a) shows the duration time of oscillation of PVA surface. The duration time of oscillation linearly increased with the increase of the duration time of tone-burst pulse. Fig. 2(b) shows the center frequency of oscillations of PVA surface. The frequency inversely decreased with the increase of the duration time of tone-burst pulse because the time width of tone-burst pulse increased.

3.2 High Frequency Ultrasound Measurement

According to the results of laser-Doppler velocimetry measurement, the input voltage 25 V and the duration of tone-burst pulse 80 μs were chosen for comparative study. Micro-displacement was measured by using high frequency ultrasound,. Max amplitude of measured dispacement was 9 μm, which was equivalent to the results of laser-Doppler velocimetry.

4. Conclusion

Oscillation velocity of PVA surface was measured by varying input voltage and the duration time. Displacement was obtained by integrating the measured velocity. According to the result of laser-Doppler velocimetry, micro-displacement was measured by high frequency ultrasound. The results of the two methods were compared and the measured displacement was almost equivalent. This study showed a relationship between oscillations of PVA's surface and parameters of tone-burst.

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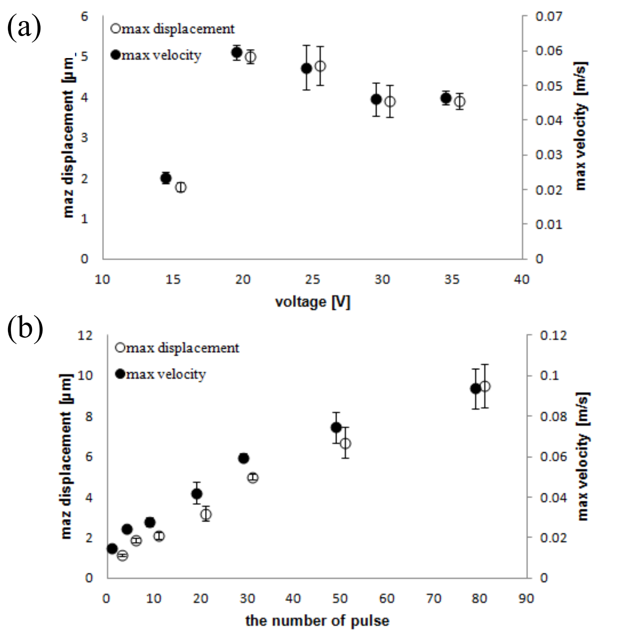

Fig.1 Relation between the pulse number and displacement measured with laser-Doppler velocimetry

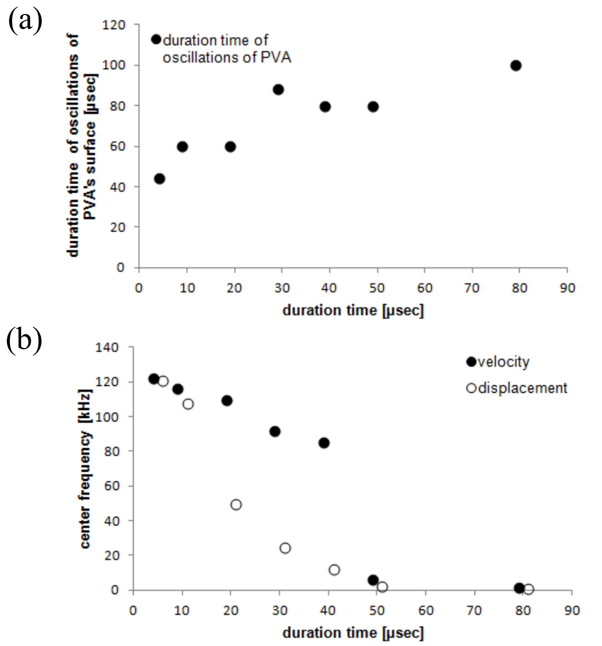

Fig.2 Relation between the pulse duration and oscillation frequency measured with laser-Doppler velocimetry