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Study on Excitation for Quantitative Transmission of Transient Shear Wave across Living Tissue
生体内における定量的横波発生を可能とする励振法の検討

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1. Introduction

Recent years, static parameters such as strain in living tissue, young's modulus, shear elasticity modulus and dynamic parameters such as strain velocity, standing wave by fluctuation, velocity of transmission pulse are used in real-time for medical ultrasonics. Studys for acquisition and visualization of these functional and pathological information in living tissue have been developed.

We have devised real-time elastgraphy [1-4]. This can be expected to contribute to diagnosis or treatment through visualization of dynamic pathological information in tissue. Systematic prediction of temporal and spatial changes of tissue condition intended by these methods must be pursued. Therefore, to solve this problem, quantitative generation of shear waves is needed.

In this study, we consider an efficient excitation method for quantitatively generating shear wave, which can be used effectively to develop various techniques including real-time elastgraphy.

2. Methods

When pressure is applied perpendicular to tissue surface, shear waves are emitted toward two skew directions with a lobe shape. We supply the pair pressures phases of which are inverse each other to make the effect of overlapping of both. By this technique, we expect that the shear waves can be emitted toward one straight direction.

In this study, using the PZFlex, which is a standard FEM simulator for ultrasound propagation, and modeling uniform medium with soft biological tissue, we simulate the generated pattern and the propagation direction of traveling shear waves with 20 Hz frequency.

In the simulations, the density of the soft biological tissue is set as 1020 kgm^{-3}, the sound speed of longitudinal wave is 1520 m/s, the sound speed of transverse wave is 0.5 m/s, and the longitudinal wave damping is 900 times larger than that of the liver.

Figure 1 shows the spatial distributions of the pressure used in the simulations. Each distribution is a pair of two pressure patterns with inverse phase each other, and has a different spatial gap between two pressure patterns respectively.

3. Results

We selected the position of 75 mm inner from the center of the excitation aperture to evaluate the strength of the shear waves. **Figure 2** shows the temporally maximum values of the square root of the second invariant of the deviatoric stress tensor at this position by each distribution of pressures pair. This figure indicates that the emitted shear wave is strongest for the excitation of Fig. 1(d). **Figures 3-7** show the sequence of the shear wave propagation by the excitation of Fig. 1(d). From these figures, we confirmed that the relatively strong shear wave can be emitted toward the direction perpendicular to the excitation aperture.

4. Discussions and Conclusions

In this study, these results indicate that adjusting width of aperture by changing the gap between two pressure patterns enable us to make the effect of overlapping.

We are going to propose more effective methods including inclining acoustic field by the various devices, for example, the number of pressures, positions of excitations, spatio-tempral excitation phase. It is desirable to investigate properties of the shear wave and simulation techniques.

Acknowledgment

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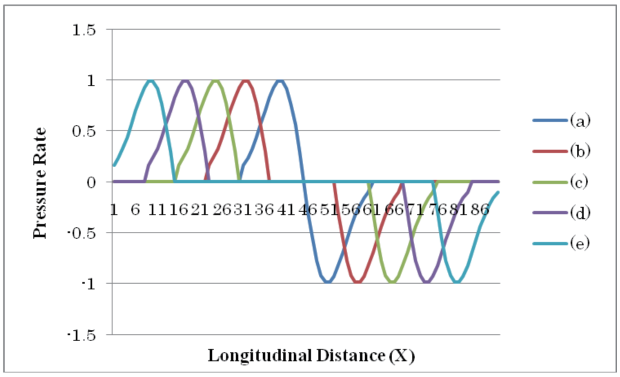

Fig. 1 Outline of spatial distributions of pair pressures. Gap is (a) 0 mm (b) 15 mm (c) 30 mm (d) 45 mm (e) 60 mm

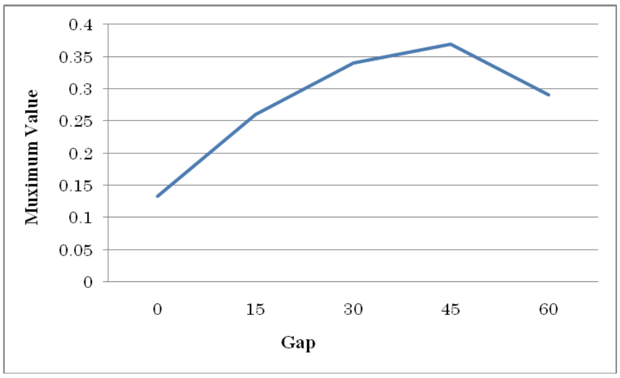

Fig. 2 Temporally maximum values of square root of the second invariant of the deviatoric stress tensor by each distribution of pair pressures

Fig. 3 Distribution of shear waves caused by distribution of pair pressures of Fig. 1 (d) from the bottom boundary at 1 ms

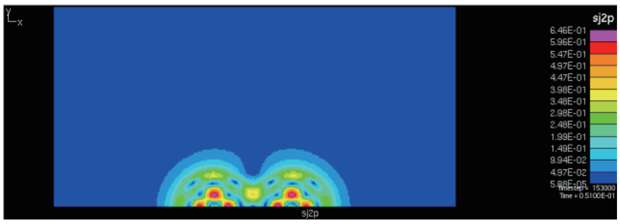

Fig.4 Distribution of shear wave caused by distribution of pressure of (d) from the bottom boundary at 50 ms

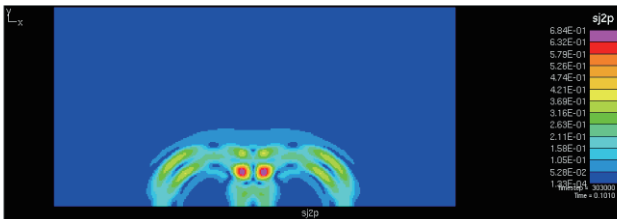

Fig.5 Distribution of shear wave caused by distribution of pressure of (d) from the bottom boundary at 100 ms

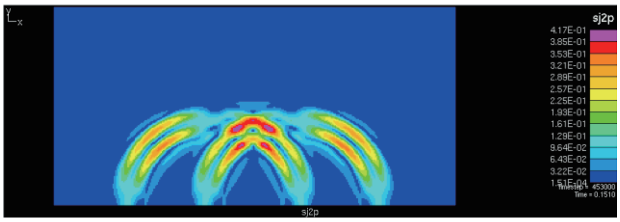

Fig.6 Distribution of shear wave caused by distribution of pressure of (d) from the bottom boundary at 150 ms

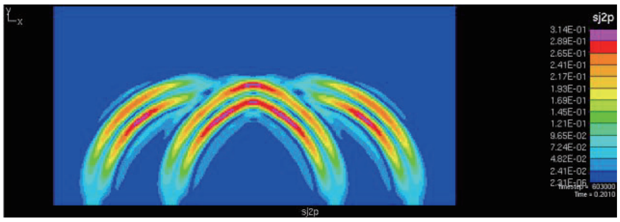

Fig.7 Distribution of shear wave caused by distribution of pressure of (d) from the bottom boundary at 200 ms