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Standard materials for the measurement of acoustic attenuation coefficients
超音波減衰定数測定のための標準物質

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1. Introduction

For a better estimation of diagnostic ultrasound images, phantoms have been used. Ultrasonic properties of tissue mimicking materials such as velocity, attenuation, and scattering must be known to make the phantoms. A variety of methods have been used for measuring attenuation coefficient of biological tissues and tissue mimicking materials. Substitution technique is an appropriate method for measuring the attenuation coefficient. The method involves a comparison between the detected waves after it propagates through the sample and after it propagates through a reference medium. This technique may be applied to small test samples of tissue mimicking material, such as samples obtained during pouring of complete phantoms.

For a accurate measurement reference the reference medium should have the same acoustic velocity and density as biological tissues or tissue mimicking materials have. This study deals with methods for preparing standard materials as the reference medium.

2. System configuration for the measurement

The system arrangement used for measuring acoustic attenuation coefficients is shown in Figure1.

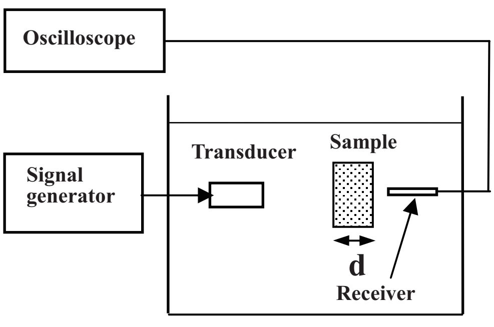

Fig.1 The system arrangement.

This technique[1)] may be applied to small test sample of tissue mimicking materials. The technique uses a non-focused source transducer.

A small receiving transducer is employed as a detector. Both source and receive transducers are immersed in a water bath, whose temperature is known to within ±0.1 degree C. The receiver should be placed in the far field of the source transducer, that is, at an axial distance of at least a^2/λ ,where a is the source transducer radius and λ is the ultrasound wavelength in water. Means should be provided to position the receiver along the central axis of the source transducer beam and to align the sensitive face of the receiver so that the sound beam is transmitted, should be parallel; the sample should be oriented with those faces perpendicular to the sound beam axis.

The amplitude of the received ultrasound signal is measured for transmission through water only and compared to the amplitude obtained when the sample is placed in the source beam. The attenuation coefficient, α (f), is calculated directly from the sample thickness and the ratio of the two transmitted signals, accounting for transmission losses at the water-sample interfaces, Thus, the attenuation coefficient in dB/cm is given by

$$\alpha(f) = \frac{20}{d}\log_{10}\frac{A_0(f)T(f)}{A_i(f)} \qquad (1)$$

where $A_0(f)$ is the amplitude with the sample out,
$A_i(f)$ is the amplitude with the sample in the beam,
d is the thickness of the sample, measured in cm,
T(f) is the amplitude transmission coefficient given by the transmission efficiency originating the acoustic impedance miss-matching at the boundaries between the sample and water, and the signal loss due to refraction,

f is the ultrasound frequency.

The attenuation coefficient of the reference sample, $\alpha_0(f)$, is given by

$$\alpha_0(f) = \frac{20}{d_{ref}}\log_{10}\frac{A_{0ref}(f)T_{ref}(f)}{A_{iref}(f)}, \qquad (2)$$

where $A_{0ref}(f)$ is the amplitude with the reference medium out,

$A_{iref}(f)$ is the amplitude with the reference media in the beam,

T_{ref} is the amplitude transmission coefficient in the reference medium,

d_{ref} is the thickness of the reference media.

T(f) and T_{ref} are completely same, if the sample is identical with the reference media in acoustic impedance and velocity. And d and d_{ref} is set in the same value.

In the case the following equation is given from Equations (1) and (2).

$$\alpha(f) = \alpha_0(f) + \frac{20}{d}\log_{10}\frac{A_0(f)}{A_{0ref}(f)} \qquad (3)$$

Accurate direct experimental determination of $\alpha_0(f)$ of the reference medium may be made by Lerch's method[2], if large amount of liquid as the reference is supplied in the experimental.

3. On the standard materials

In this study the main aim is to develop the new standard materials with the same acoustic velocity and impedance as the samples

We have planed adoption of NaCl and $MgSO_4$ aqueous solutions to the standard materials for the measurement at acoustic attenuation coefficient.

Densities and acoustic velocities of NaCl and $MgSO_4$ aqueous solutions were measured at various temperatures and concentrations on high precision measring[3), 4)].

From those data relationships between the density and the acoustic velocity of NaCl and $MgSO_4$ aqueous solutions have been calculated. The obtained results are shown in figures 2 and 3, where temperature of the solutions is 22C degrees C. This temperature is specified in IEC satandard[5)].

The results shown in figures 2 and 3 indicate that NaCl aqueous solution with the density 1.04 (10^3 k/m^3) is higher in acoustic velocity than typical human tissue and $MgSO_4$ aqueous with the density 1.04 (10^3 k/m^3) is lower. The acoustic velocity and the density of typical human tissue are defined in IEC standard.[5)] From the results it is indicated that the aqueous solution with appropriate mixing ratio of NaCl and $MgSO_4$ can achieve same ultrasonic properties as human tissue.

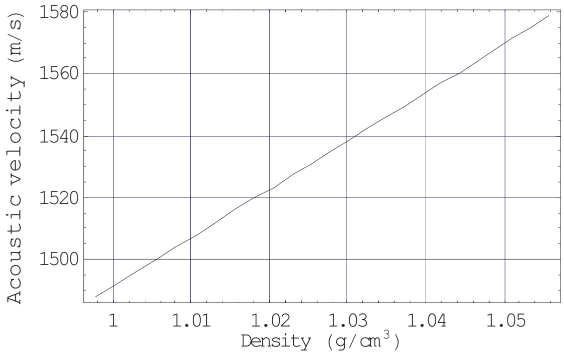

Fig.2 The calculated result for NaCl aqueous solution.

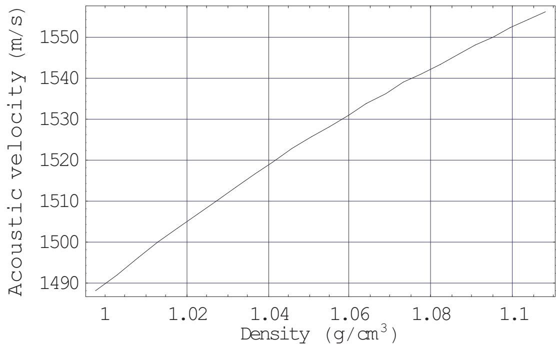

Fig.3 The calculated result for $MgSO_4$ aqueous solution.

3. Result

Optimum mixture strength area of aqueous mixture of NaCl and $MgSO_4$ for the standard material is shown by a ternary contour plot in figure 4.

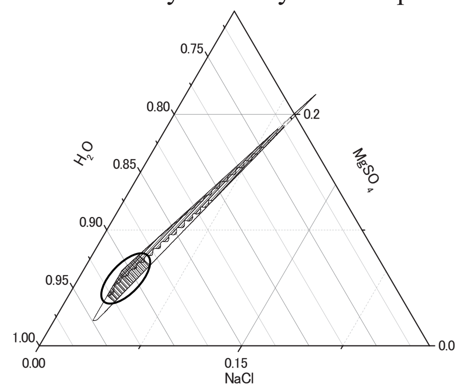

Fig.4 Correct mixture strength area of the mixture.

4 Conclusion

Optimum data for the standard materials for the measurement of acoustic attenuation coefficients given and they were conformed by experiment.

References

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