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► **To cite this version:**

Esam Eldin Ahmed Mohamed, Pascal Pomarede, Laurence Mathieu, Nico Declercq. Effects of path length on the linear and non-linear ultrasonic characterization of soft materials. *Forum Acusticum*, Dec 2020, Lyon, France. pp.3395-3397, 10.48465/fa.2020.0770 . hal-03233971

HAL Id: hal-03233971

<https://hal.science/hal-03233971>

Submitted on 26 May 2021

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EFFECT of PATHLENGTH ON THE LINEAR AND NON-LINEAR ULTRASONIC CHARACTERIZATION OF LIQUIDS AND SOFT MATERIALS

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ABSTRACT

Among the variable conditions that affect insonifying non-dispersive media, the source-receiver separation within near and far field regions of the employed transducer, has been found to play a prominent role. The effect of the ultrasonic propagation path-length on the linear and non-linear acoustic properties of liquids and soft materials is investigated quantitatively. The velocity of propagation of ultrasound waves and the non-linearity parameter were found to exhibit stability only beyond a certain separation distance. The results of measurements carried out over different frequencies and amplitudes for different samples as well as for different sonication modes are presented and discussed.

$$\frac{B}{A} = 2\rho c \left[\left[\frac{\partial c}{\partial p} \right]_T \right]_{\rho=\text{constant}} + (2 c T \vartheta c_p)^{-1} \left[\left[\frac{\partial c}{\partial T} \right]_p \right]_{\rho=\text{constant}}$$

where derivatives are held with respect to pressure p at constant temperature T and respectively with respect to temperature at constant pressure; ρ is the material density, assumed constant and ϑ is the volume coefficient of thermal expansion.

The relative non-linear coefficient, which is calculated as the ratio of the amplitude of higher harmonic signals to the amplitude of the fundamental frequency is, however, used to study materials comparatively [4].

We carried out measurements of the time of flight and the relative non-linearity coefficient at variable distances utilizing a transmission mode to investigate the effect of emitter-receiver separation.

1. INTRODUCTION

Versatile applications of ultrasound in material characterization and in medical applications involve the velocity of ultrasound and the non-linearity parameter. The velocity of ultrasound (c) in liquids and soft materials (which can be modelled as liquids) depends on many factors, mainly the adiabatic compressibility (β_s) and mechanical density (ρ) [1] as:

$$\beta_s = \frac{1}{\rho c^2}$$

Many techniques are applied for the accurate measurements of the velocities, namely, laser interferometric and ultrasonic pulse-echo methods [2]. The non-linearity co-efficient B/A is related to the phase velocity of acoustic waves [3] :

2. EXPERIMENTS AND OBSERVATIONS

We used non-focusing transducers of 0.5 MHz and 1 MHz and a large hydrophone of 30 mm active element diameter for reception. The large enough diameter allows measurements to be performed with the detector positioned within the transducer near-field and enabling minimizing the diffraction effects of acoustic fields.

For isotropic, non-dispersive samples the time of flight (ToF) depends only on the distance separation (D) and the velocity of propagation of ultrasound as:

$$ToF = \frac{D}{c}$$

The time of flight measurements were carried out for water in two configurations: 1. In a tank, where an immersion transducer was employed, as illustrated in figure 1a. and contained in an elastic transmissible polymer membrane where a contact transducer was used (figure 1b).

We utilized a C-polar scan system which allows an automated 5-axes (3d and 2 polar) movement, that provides the optimum alignment of the emitter and

receiver and precise control of the distance separation. The generator and detection system used is the Ritec RAM 5000 Snap, which allows the control of the output voltage of the gated amplifier and hence the input ultrasound amplitude.

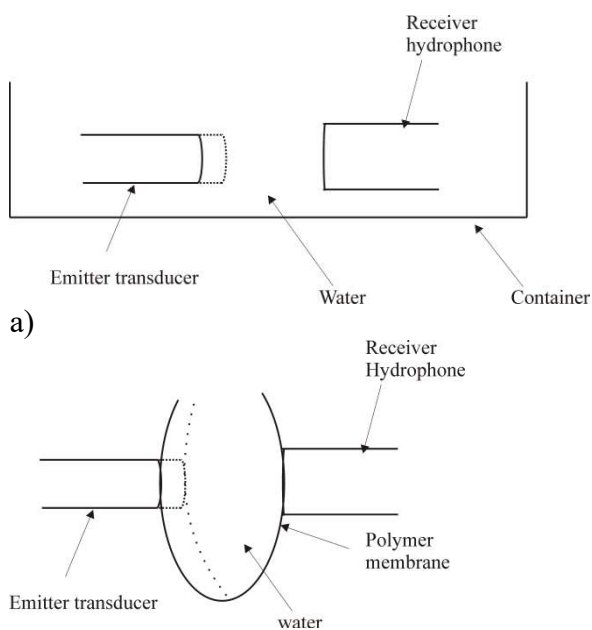


Figure 1. Experimental arrangement, the emitter transducer is displaced stepwise towards the receiver a) in the water container. A transducer of 1 MHz center frequency was used and b) through a polymer membrane. A transducer of 1 MHz center frequency was used.

Two sets of experiments were carried out for each configuration to explore the effects of the amplitude of the incident acoustic waves. In the first set, maximum amplitude of the gated amplifier and in the second a 1% of the amplitude were applied.

The velocity of propagation was found in both cases to vary considerably with the propagation distance in the near field as well as beyond the nearfield regions. However, the variations of the values of the velocity, show convergence only in a certain range that extend from 40 mm to 60 mm, where the error is minimum as depicted in Fig. 2.

The measurements of the B/A varied monotonically with the separation distance only for the same range of 40-60 mm.

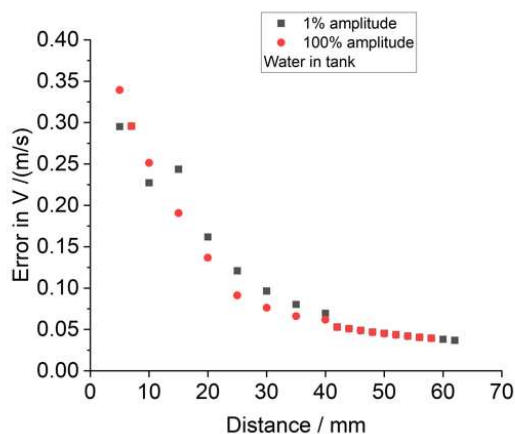


Figure 2. Error in measuring the phase velocity of ultrasound in water contained in a tank versus distance for low applied amplitude (red points) and for high amplitude (black points).

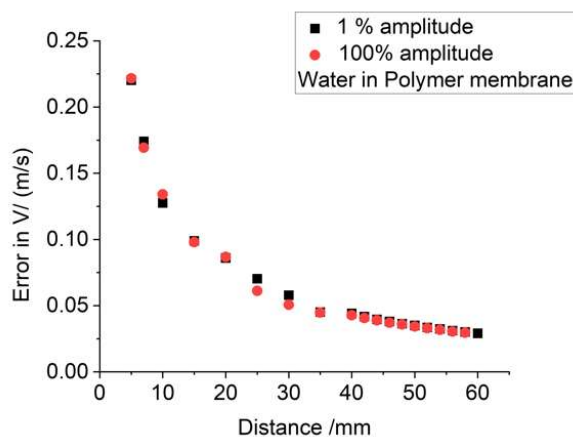


Figure 3. Error in measuring the phase velocity of ultrasound in water contained in a polymer membrane versus distance for low applied amplitude (red points) and for high amplitude (black points).

3. SUMMARY

Ultrasonic phase velocity at low amplitudes and the mean phase velocity in high amplitudes show dependence on the distance between the transmitter and receiver. We relate the variations in the velocity with distance to the variation of B/A with distance.

4. REFERENCES

[1] U. Kaatz, F. Eggers, and K. Lautscham, "Ultrasonic velocity measurements in liquids with high resolution - Techniques, selected applications

- and perspectives,” *Meas. Sci. Technol.*, vol. 19, no. 6, 2008.
- [2] B. Voleišienė and A. Voleišis, “Ultrasound velocity measurements in liquid media,” vol. 63, no. 4, 2008.
- [3] L. Bjørnø, “Introduction to nonlinear acoustics,” *Physics. Procedia.*, vol. 3, no. 1, pp. 5–16, 2010.
- [4] J. Kim, D. G. Song, and K. Y. Jhang, “Absolute Measurement and Relative Measurement of Ultrasonic Nonlinear Parameters,” *Res. Nondestruct. Eval.*, vol. 28, no. 4, pp. 211–225, 2017.