Optical determination of sound speed in liquids

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Abstract
Knowledge of acoustic properties of liquids is essential, not only because of the practical applications, but because sound provides a way to investigate some of the fundamental properties of condensed matter. In this article we follow three goals:1-Measurement of sound speed in liquids(H_2O,Ch_3OH,CH_3CH_2OH, CH_2Cl_2,$CH_3COC_2HCH_3$) with optical way.2-studing temperature dependence of the velocity of sound in liquids.3-Measurement of sound speed in various mixture of liquids.

Keyword. Sound speed in liquids, temperature depending on sound speed in liquids,

Introduction

The propagation of sound waves in fluid media has considerable practical and fundamental significance. The most widespread application of sound liquids is underwater or ocean, acoustics. Because seawater is electrically conducting. It is a poor medium for propagation of electromagnetic waves and, as a result, sound waves are the best choice for a large-range underwater detection and imaging. Another major application for sound wave technology applied to a (mostly) liquid medium is medical diagnosis. Ultrasonic images complement those obtained with x rays, magnetic resonance, or positron emission and have the advantage of relatively low cost and low risk.

A stationary ultrasonic [1,2]wave in a glass cell full of liquids is traversed by a divergent beam of light .The sound wavelength can be determined from the central projection of sound field on the basis of the refractive index witch changes with the sound pressure.

Set up and procedure

The glass cell is 2/3 full of liquids, and the sound head is immersed in it to a depth of a few millimeters, with its face parallel to the bottom of the cell. The laser is enlarge with a lens of focal length +5 mm .The lens approx 0-20 cm, the protection screen about 150 cm ,away from the cell. The laser and the lens are adjusted so that the beam traverses the liquid between the sound head and the cell bottom.figure1.

Figure 1.Experimental set-up for measuring sound speed in liquids

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The experiment is carried out in a semi darkened room with the generator amplitude on the medium setting, the depth of immersion of the sound head is so adjusted as to procedure a well defined system of light and dark bands in the projected image.figure2.The distance between the bands is determined for various liquids and the liquid temperature measured in each case. Any gas bubbles forming on the surface of the sound speed and the walls of the cell are removed with a rod.

Figure 2.Image of screen

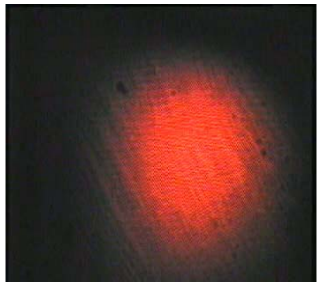


Figure3 show the relationship between variation in sound pressure **ΔP** and the location **x** for far phases of a stationary wave. The refractive index of the liquids also changes because of the pressure, variations, and the change in refractive index Δn can be regarded as proportional to the pressure variation **ΔP**. In phase t=0 and t=1/2T (where T is the vibration period),well-defined inference fringes occur, spaced apart by λ/2 .The light passing through is deflected into the vibration nodes in the regions where there is a considerable local variation of the refractive index, whereas in the antinodes areas it is hardly deflected at all. The vibration nodes thus appear as dark bands and the antinodes as light bands in the central projection. Phase t=1/4T and the t=3/4T ,in which the light passing through the liquid is not deflected. Only cause the projected image to lighten.

Figure 3.Refractive index for four Phases of a stationary wave.

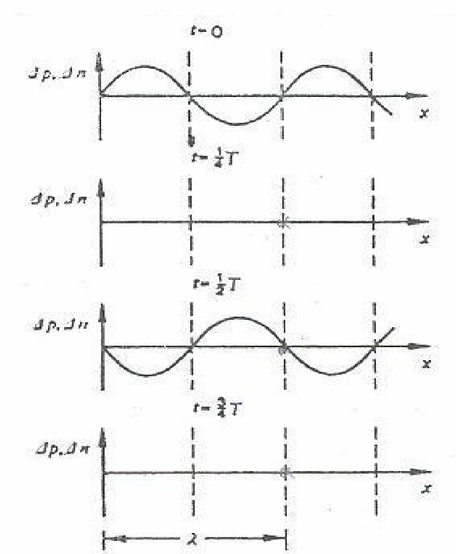
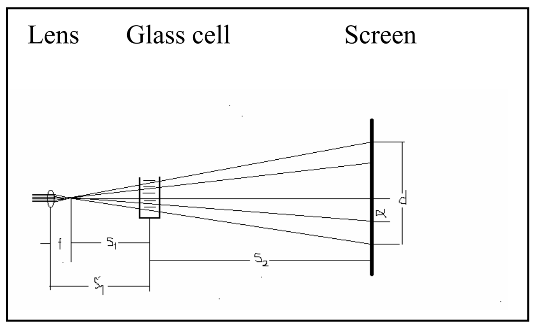


Figure 4.Path of rays in the central projection



The spacing of the interference fringes (λ/2), and therefore the wavelength λ, can be measured from the height of the projected image and the number N of fringes it contains, using the equation as shown in figure4:

$$\lambda = 2\alpha \frac{s_1}{s_1 + s_2} \qquad \text{where} \qquad \alpha = \frac{d}{N+1}$$

The sound propagation velocity is obtained from C=λ.f where f is the ultrasonic frequency. The standard error is calculated in accordance with the law of error propagation, the individual values being estimated as:

ΔS_1=3 mm ΔS_2=3 mm Δd=0.3 mm Δf=5 KHz

Table1.Typical examples of measurements at 25°C

liquid	S_1(cm)	S_2 (cm)	α (cm)	λ (cm)	C (m/s)
Water(dist.)	27	134	5.60±0.02	1.87	1496±5
Ethanol	27	134	4.70±0.02	1.50	1203 ±5
Methanol	30	180	5.06±0.02	1.45	1163±5
Acetate ethyl	30	180	3.70±0.02	1.05	836±5
Di cholera methane	30	180	4.61±0.02	1.31	1048±5

You can find the real quantity of sound speed in liquids at 25°C in CRC Handbook[3].

Temperature dependence:

Temperature dependence of the velocity of sound in liquids: Provided that oscillatory process is an adiabatic one, the relationship: $C = \sqrt{\frac{1}{\rho\beta_{ad}}}$

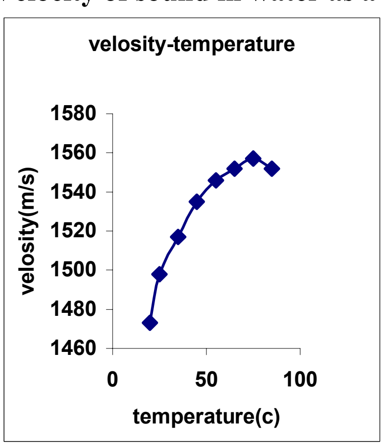
Where ρ is the density and β_{ad} the adiabatic compressibility.

The change of the velocity of sound with temperature is in the man determined by the temperature dependence of the compressibility. In all liquids with the exception of water the compressibility increases and the density decreases approximately linearly as the temperature arises. Water occupies a spatial position amongst liquids; the compressibility is reduced initially as the temperature rises to minimum of approx. 60°C and only then increases.
The velocity of sound in water therefore has positive temperature coefficient initially and, taking in to account the density, which becomes lower as the temperature rises, reaches a maximum value of 1557 m/s at 74˚C.Above this temperature the velocity of sound decreases. Notice that the liquid in the region of the acoustic field is heated up by ultrasonic absorbation.The measurements should therefore be made with as small as sound amplitude as possible. Attention is also to be paid to thorough mixing of the bath[4].

Table3.Typical examples of measurements for temperature depending of sound speed in liquids

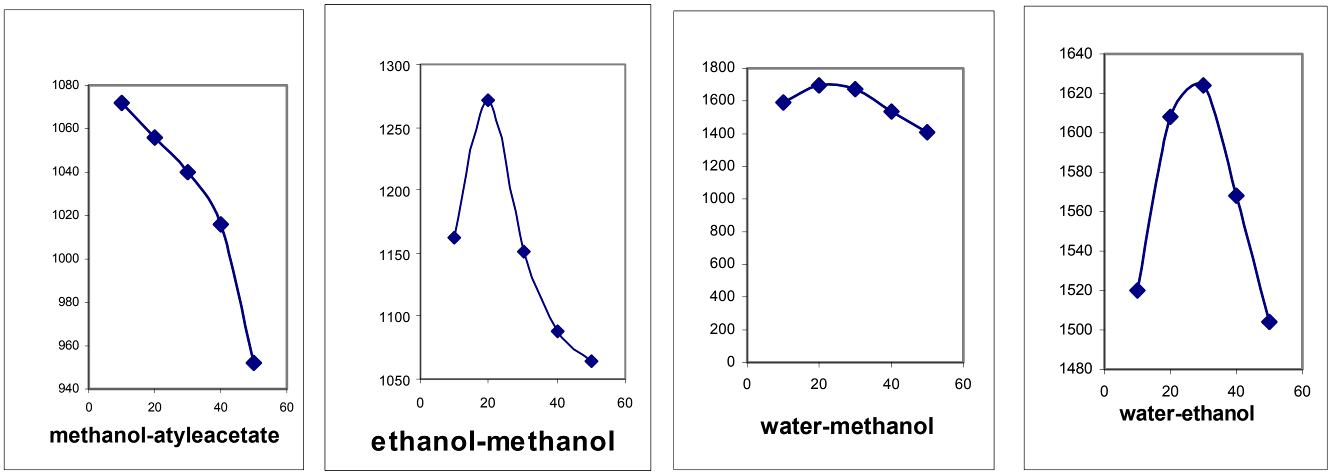
θ=25˙ ˚C	25 ±0/1	35 ±0/1	46 ±0/1	55 ± 0/1	66 ± 0/1	75± 0/1
S_1(cm)	27	28	28	28	28	28
S_2 (cm)	134	181	181	181	181	181
α (cm)	0/02 5/60±	6/02 ± 0/02	6/08 ± 0/02	6/14 ± 0/02	6/18 ± 0/02	6/22 ± 0/02
λ (cm)	1/87	1/89	1/90	1/92	1/94	1/95
C(m/s)	1496	1512	1527	1542	1552	156

Velocity of sound in water as a function of the temperature



It has been known for quite some time that the acoustic properties as a homogenous liquid depend on its chemical composition and there have been several successful attempts to use Ultrasound for characterizing the chemical properties such liquids[4].Finally we have measured sound speed in various mixtures of foregoing liquids in fgure4.

Figure4sound speed in mixture of liquids , Notice that the x axis is denote the volume ratio of liquids, and the y axis is denote to sound speed (m/s)



Conclusion

With simple equipment and easy method we could measure the sound speed in liquids. In this experiment we have studied the behavior of water in different temperature. Finally even the sound speed in mixture of liquids was measured that it's very important in industry.

Acknowledgement

We are grateful to Dr Ali Soldoozi for his friendly guidance.

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