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# ULTRASONICS ABSORPTION MEASUREMENTS OF A LIQUID WITH BACKED TRANSDUCER

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An effect of backing of the transducer on the measured value of absorption of a liquid have been shown using shock excited system. The resulting deviation in the measured value of absorption from the accepted value has been observed to be large as 40%, depending on the damping produced. A mechanism to explain the observed variation of the measured value of absorption with backing has been put forward. Implication of the work in characterisation of ultrasonic probe have been discussed.

## 1. Introduction

While working on the measurement of ultrasonic absorption in liquids [1], the authors observed that appreciable error in measurement is introduced if the transducer is highly damped, even if usual precautions [2, 4] in the absorption measurement are taken. This phenomenon has not been discussed earlier in the literature. This led the authors to investigate whether this observation can be used to throw light on the damping of a transducer. Damping of the transducer is required to prevent ringing which is important for acheiving high resolution for analysing the defects close together and also with respect to the transducer. It finds application in transducers used for *NDT*, medical diagnostic and ultrasonic spectroscopy.

Present studies concern the measurement of absorption in a non-relaxational liquid using transducers having backing of various acoustic impedances. The dependence of the measured value of absorption on the damping characteristic of the transducer as studied by observing the ringing pattern, has been discussed. Measurements of absorption are also carried out with a number of normal *NDT* probes to examine this phenomenon. It has been attempted to explain the mechanism lying behind it and experimentally to verify it by examining the wave shape of the acoustic pulse.

### 2. Experimental

Ultrasonic absorption in liquids were measured with an ultrasonic flaw detector using backed and unbacked transducers. These transducers were prepared with piezoelectric ceramic *NPLZT-5A* [5] disc of diameter ($D$) 20 mm, and thickness ($t$) 0.6 mm using araldite and tungsten powder loaded araldite as backings which were cemented to the ceramic dise with salol for taking measurements with same disc. Ultrasonic pulses were sent into the liquid and the amplitude was noted. By varying the acoustic path length, the diminuation of echo height was measured from which absorption coefficient $\alpha/\nu^2$ was evaluated. The parallelism between the transducers face and the reflector was assured by adjusting the reflector-platform maximum echo height

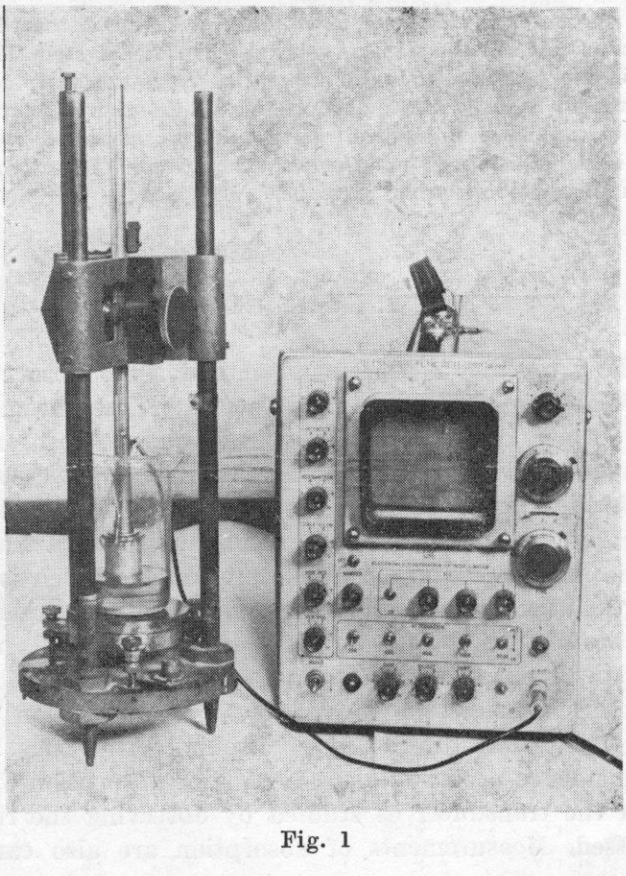

Fig. 1

and diffraction effects were avoided by working in the Fresnel region. An air backed thin stainless steel plate having thickness 0.4 mm was used as a reflector which was kept fixed at the bottom of the liquid cell (Fig. 1).

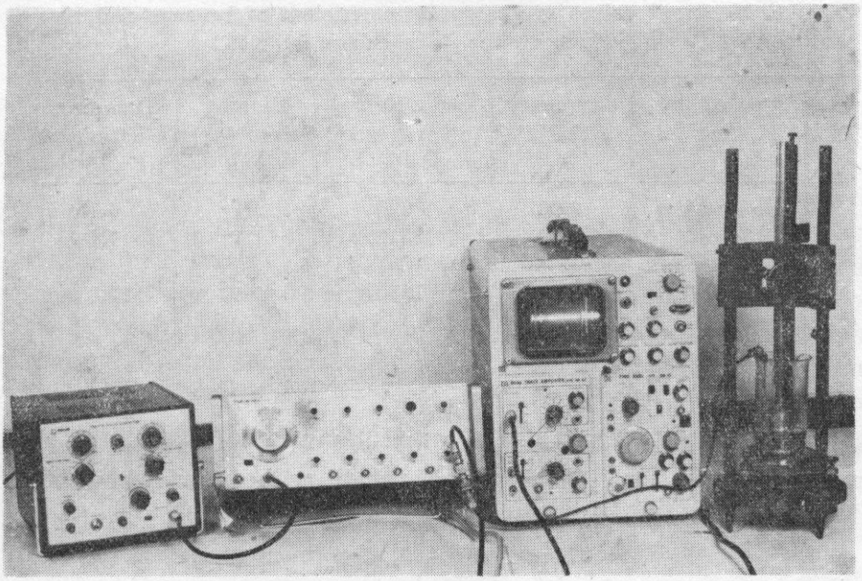

Fig. 2

Ringing characteristics of these transducers were studied using a pulsed *R. F. System* (Fig. 2) in which a sinusoidal continuous wave signal was modulated by pulses from a square wave generator to produce gated signals of known duration. The response of the transducer to the signal was monitored on an oscilloscope.

Examination of the waveshape of the acoustic pulse generated by these transducers was made using a wideband probe hydrophone in an unechoic water tank.

### 3. Results

The absorption coefficient $\alpha/\nu^2$ of benzene (L. R. GRADE) was measured at first with an airbacked transducer (ceramic disc diameter 20 mm, and thickness 0.9 mm) to test the performance of the set up. $\alpha/\nu^2$ of benzene was observed to be $\sim 990 \times 10^{-17}$ np cm$^{-1}$ sec$^2$ which is close to the value reported in literature [3], [4]. After that, with the backed transducers $\alpha/\nu^2$ of benzene was measured. The results are shown in the Table 1. The maximum scatter in measurements for a given absorption value is within 4%. From the Table 1, it is seen that there is a large deviation $\sim$(40%) in the measured value of absorption when tungdten-loaded araldite backing is used. Thus damping of the transducer introduced by the backing is seemed to affect the measured value of absorption.

**Table 1.** Measured values of absorption coefficient of benzene and ringing time of the transducers at 25°C

| Sl. No. | Type of backing | Frequency $\nu$ [MHz] | $\alpha/\nu^2 \times 10^{17}$ [np cm$^{-1}$ sec$^2$] | Ringing time [$\mu$s] | Damping coefficient $k \times 10^{-5}$ |
|---|---|---|---|---|---|
| 1 | Air Backing | 3.93 | 990 | 2.1 | 4.76 |
| 2 | Araldite Backing | 3.90 | 1312 | 1.4 | 7.14 |
| 3 | Tungsten loaded Araldite Backing | 3.89 | 1370 | 0.56 | 17.8 |

Damping of the transducer is studied with the measurement of the ringing time. The typical ringing patternsof the transducers are shown in Fig. 3. Using the equation

$$Y = Y_0 e^{-kt} \cos \omega t \qquad (1)$$

the ringing time $\tau = 1/k$ has been evaluated from these patterns.

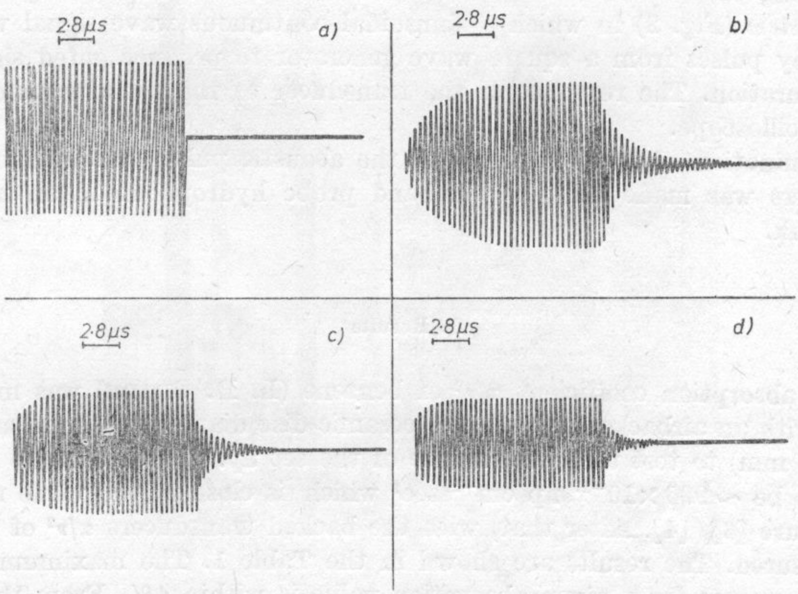


Fig. 3

Here $k$ is the damping coefficient and $\tau$ is defined as the time in which the sound amplitude is reduced to $1/e$ of its initial value. The value of $\tau$ and $k$ are ahown in the Table 1. It is seen from the Table 1 that as the backing is changed the ringing time $\tau$ is shortend and the measured value of absorption of the liquid increases, thus indicating a close correlation between the two.

## 4. Discussions

The deviation in measured value of absorption of the liquid observed in the present work can not be explained in terms of mechanical, acoustical or electronic causes as they have been taken into account at the time of measurement. PELLAM and GALT [2] and NOZDREV [3] however, discussed the effect of pulse width on the measurement of absorption of a liquid. According to them, error in absorption measurement can be occured if a short pulse is used and fractional error in absorption, $\Delta\alpha$, can be correlated with frequency spread, $\Delta\nu$, as:

$$\Delta\alpha/\alpha = [\Delta\nu/(2\nu_0)]^2, \qquad (2)$$

where $\nu_0$ is the resonant frequency of the transducer.

But using a long pulse, error due to above cause can be eliminated. In the present case, the authors suggest the following mechanism to explain the observed results. The flaw detector generates a transient pulse to shock excite the transducer. The Fourier transform of this pulse has got a wide spectrum in the frequency domain. The air-backed transducer has got a sharper resonance and excited into a narrower range of frequency while heavily bac-

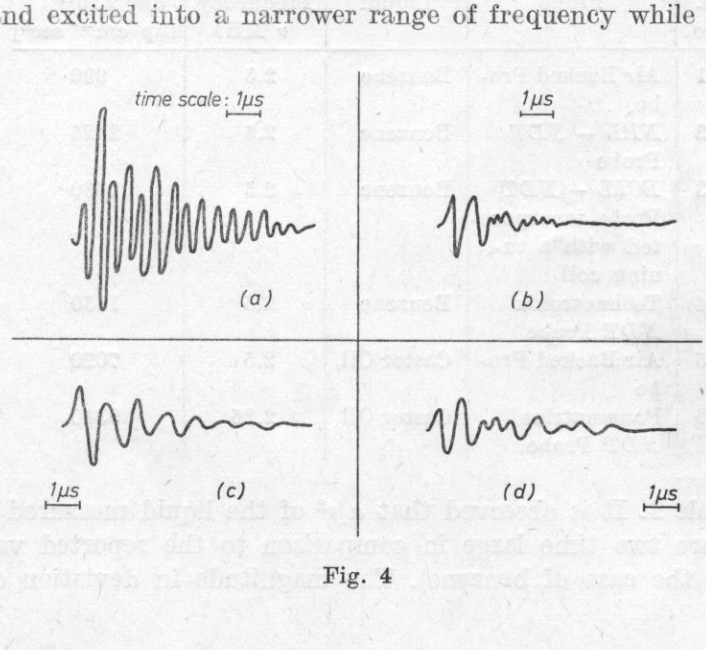


Fig. 4

ked one has a broader resonance curve and excited into wider range of frequency. The frequency spread $\Delta\nu$ in the later is larger than in the former depending upon the backing and hence the error in measurement of $\alpha$ will occur because the individual frequency component of the spectrum is attenuated in different degree since the absorption has a frequency dependence.

The experimental evidence that a marked frequency spread is produced in the transducer is shown in the Fig. 4. From the hydrophone response of the acoustic pulse generated by an airbacked transducer due to shock excitation (Fig. 4a), it is seen that there is a given pulse containing a number of cycles with no frequency change where as in that of the backed transducer (Fig. 4b) there is a broading of cycles in the pulse which is due to superposition of various vibration in different frequency range. Also acoustic pulses of other commercial probes are shown in Figs 4c and 4d.

## 5. Concluding Remarks

The application of this work is visualised in the characterisation of *NDT* probe. These probes use a high degree of backing which can result in significant changes in the measured value of absorption coefficient of the liquid. Some results which are obtained with different *NDT* commercial probes are

**Table 2.** Measured value of absorption coefficient of liquids using NDT probes at room temperature 25°C

| Sl. No. | Probe | Liquid | Frequency $\nu$ MHz | $\alpha/\nu^2 \times 10^{17}$ [np cm$^{-1}$ sec$^2$] |
|---|---|---|---|---|
| 1 | Air Backed Probe | Benzene | 2.5 | 990 |
| 2 | *NPL – NDT* Probe | Benzene | 2.5 | 2425 |
| 3 | *ECIL – NDT* Probe incorporated with a tuning coil | Benzene | 2.5 | 1680 |
| 4 | Technotronix *NDT* Probe | Benzene | 2.5 | 1650 |
| 5 | Air Backed Probe | Castor Oil | 2.5 | 7020 |
| 6 | Panamatrios *NDT* Probe | Castor Oil | 2.25 | 9340 |

shown in Table 2. It is observed that $\alpha/\nu^2$ of the liquid measured with these transducers are two time large in comparison to the reported value in the literature (in the case of benzene). The magnitude in deviation of $\alpha/\nu^2$ can thus be used as an indication of the degree of damping due to the backing. The method is novel in approach and involves no complicated instrumentation.

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