Ultrasonic waves in a liquid

Aim:

To determine the velocity of ultrasonic waves in a liquid.

Apparatus and accessories:

A double walled cylindrical vessel (B) containing the experimental liquid, an RF power oscillator and a quartz crystal (frequency= 3 MHz) to generate ultrasonic waves, a quartz crystal plate fitted with a micrometer screw, an acmicroameter or a CRO .

Theory:

The velocity (υ) of ultrasonic waves in a liquid is given by

$$\upsilon = \nu\lambda \qquad (1)$$

where λ is the wavelength and ν is the frequency of the ultrasonic waves in the liquid.

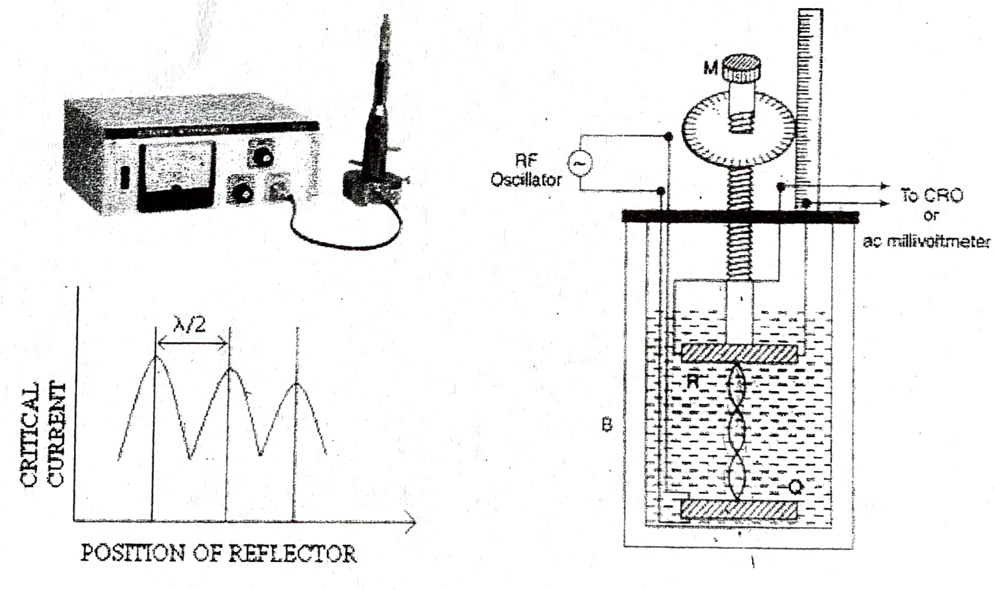

Figure 1

A quartz crystal Q connected to an RF oscillator, is placed at the bottom of a vessel (B) containing the liquid (Fig.1). Ultrasonic waves generated by the crystal, move up the liquid column in the vesseland are reflected from a similar crystal (R) placed above Q and are parallel to it inside the liquid. The position of the crystal R can be altered by the micrometer screw M. Stationary waves are formed inside the liquid due to the superposition of the incident and the reflected waves. The oscillator transfers a maximum energy to the reflecting crystal R when it is placed at a node of the stationary waves. Due to piezoelectric effect, this gives a maximum voltage between the ends of R, i.e., in a direction normal to the direction of wave propagation. The nodal positions are thus identified by observing this maximum voltage in a sensitive ac microameter or on a CRO, acting as the detector. The distance 'd' between two consecutive nodal positions can be determined by the micrometer. Here $d = \lambda / 2$ and so

$$\upsilon = 2d\nu \qquad \text{.............................(2)}$$

ν is in Hz and d is in m, υ is obtained in m/s.

Procedure:

1. Set up the apparatus as shown in Fig.1 Here B is the vessel containing the liquid, Q and R are two identical quartz crystals, and M is the micrometer. Position the reflecting crystal R at a convenient maximum height from Q inside the liquid and note the reading of the micrometer. Calculate the least count of the micrometer screw.
2. Switch on the RF power oscillator and adjust its frequency to the natural frequency(3 MHz) of the crystal Q. Lower the position of the crystal R slowly by the micrometer screw and observe the reading of the ac microameter (or the amplitude of the waveform on the CRO screen). Note the position of R from the micrometer reading when the microameter (or the CRO display) shows maximum value. Let this reading be r_1'.
3. Lower the position of the crstal R slowly by the micrometer screw M, and note its position from the micrometer scale corresponding to the level next maximum output in the detector (ac microameter or the CRO). Let the reading be r_2'.
4. Repeat step 3 to obtain other successive positions of R, i.e., of the nodes of the stationary waves. Let these reading be $r_3', r_4', \ldots\ldots r_n'$.

5. Reverse the direction of rotation of the micrometer M to raise the position of R and repeat the above observationsas, ,.... .

Once again, lower the position of the crystal R slowly by the micrometer screw M and repeat the above observationsas , ...

6. For each nodal position, three readings are obtained. Find the average value of the three readings. Let the average readings of the successive nodes r_1, r_2, r_3 .... r_n. From this set of readings, calculate the distance Δr between N (say, N=5) consecutive node positions (i.e., $r_{10} - r_5, r_9 - r_4, r_8 - r_3,$) and so on. Divide the mean Δr by N to obtain the distance d between to successive node positions. Determine υ from Eq. (2)
7. The entire experiment may be repeated with the liquid at different temperatures to show the variation of υ with the temperature (T) of the liquid.

Observations:

Least count of micrometer: ....

Table 1

Determination of the distance (d) between two successive nodes

Serial no. of nodes	Micrometer reading r ((cm)			Mean reading for a node (cm)	Distance Δr between 5 consecutive nodes (cm)	Mean Δr (cm)	$d = \frac{\Delta r}{5}$ (cm)
	Main scale	Circular scale	Total				
1	....	....	$r_1^1 = ...$	(r_1)	$r_{10} - r_5 = ...$		
	....	....	r_1^2				
			r_1^3				
	....	....			$r_9 - r_4 = ...$		
2	....	....	....	(r_2)			
	....	....	....				
	....	....	....		$r_8 - r_3 = ...$	....	....
					$r_7 - r_2 = ...$		
.	....	.....	....				
.					$r_6 - r_1 = ...$		
.							
10				(r_{10})			

Result :

The velocity of ultrasonic waves in water is found to be ....m/sec at room temperature.

Computation of percentage error:

We have

$$\upsilon = 2d\nu$$

So the proportional error is υ is

$$\frac{\delta\upsilon}{\upsilon} = \frac{\delta d}{d} = \frac{\delta(\Delta r)}{\Delta r} \quad (\nu \text{ is given})$$

Here $\delta(\Delta r)$ is two times the least count of the micrometer. Hence for a typical measured value of d, the proportional error can be found. Multiplying $\frac{\delta\upsilon}{\upsilon}$ by 100, we get the percentage error.

Precautions:

1. The length and the diameter of the cylindrical vessel should be much larger than the wavelength of the ultrasonic waves in the liquid.
2. The cylindrical vessel is double walled to maintain the temperature of the liquid constant during the experiment.
3. For each set of observations, rotate the micrometer screw always in one direction to avoid the back-lash error.
4. The least count of the micrometer must be much smaller than $\frac{\lambda}{2}$.
5. For greater sensitivity, a current amplifier can be used to amplify output current. This amplified current is then measured by the ac micrometer.
6. If the ac micrometer (or the CRO) readings are plotted against the micrometer readings for various positions of the crystal R, the graph will show the occurrence of maxima and minima. Measuring the distance between two successive maxima from the plot, λ can be calculated.