

A Theoretical Study of Experimental Analysis Ultrasonic Interferometer

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ABSTRACT: Ultrasound is acoustic (sound) energy in the form of waves having a frequency above the human hearing range. Ultrasound can be produced in research center by means of ultrasonic interferometer consuming with lesser cost and lesser area. This article explains the working principle of interferometer.

KEYWORD: Velocity, density, viscosity.

I.INTRODUCTION

An Ultrasonic interferometer is a simple and direct device to determine the ultrasonic velocity in liquids with high degree of accuracy. The principle used in the measurement of velocity (v) is based on the accurate determination of the wavelength (λ) in the medium. Ultrasonic waves of known frequency (f) are produced by a quartz crystal. If the separation between these two plates is exactly a whole multiple of the sound wavelength, standing wave are formed in the medium this acoustic resonance gives rise to an electrical on the generator driving the quartz crystal and the anode current of the generator become a maximum.

If the distance is now increased or decreased and the variation is exactly one half wavelength ($\lambda/2$) or multiple of it, anode current becomes maximum. From the knowledge of wavelength (λ) the velocity (v) can be obtained by the relation:

Velocity = Wavelength X Frequency

$$V = \lambda \times f$$

Where $\lambda = 2d/n$

II.DESRIPTION

The Ultrasonic Interferometer consists of the following parts:

(a) *The High Frequency Generator* is designed to excite the quartz crystal fixed at the bottom of the measuring cell at its resonant frequency to generate ultrasonic wave in the experimental liquid filled in the "Measuring Cell". A micrometer to observe the change in current and two controls for the purpose of sensitivity regulation and initial adjustment of the micrometer are provided on the panel of the high frequency Generator.

(b) *The Measuring Cell* is specially designed double walled cell for maintaining the temperature of the liquid constant during the experiment. A fine micrometer has been provided at the top, which can lower or raise the reflector plate in the liquid in the cell through a Known distance. It has a quartz crystal fixed at its bottom.

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III.ADJUSTMENTS OF ULTRASONIC INTERFEROMETER

Instrument is adjusted in the following manner:

1. Insert the cell in the square base socket and clamp it with the help of screw provided on one of its side.
2. Unscrew the knurled cap of cell and lift it away from double walled construction of the cell in the middle portion of it pour experimental liquid and screw the knurled caps
3. Two chutes in double wall construction are provided for water circulation to maintain desired temperature.
4. Connect the High Frequency Generator with cell by co-axial cable provided with the instrument.
5. In Multi Frequency Ultrasonic Interferometer frequency selector knobs should be positional at desired frequency and cell should be used of the same frequency.

For initial adjustment two knobs are provided on high frequency generator, one is marked with “Adj” the position of the needle on the Ammeter is adjusted and the knob marked “Gain ”is used to increase the sensitivity of the instrument for greater deflection if desired.

The ammeter is used to notice the number of maximum deflections while micrometer is moved up and in liquid as described in “Measurement” of this Instruction Manual.

Velocity Measurement

The measuring cell is connected to the output terminal of the high frequency generator through a shielded cable. The cell is filled with experimental liquid before switching on the generator. The ultrasonic waves move normal from the quartz crystal till they are reflected back from the movable plate and the standing waves are formed in the liquid in between the reflector plate and the quartz crystal. The micrometer is slowly moved till the anode current on the meter on the High Frequency Generator shows a maximum. A number of maximum readings of anode current are passed and their number “n” is counted. The total distance (d) thus by the micrometer gives the value of the wavelength (λ) with the help of the following relation:

$$d = n \times \lambda/2$$

Once the wavelength (λ) is known the velocity(v) in the liquid can be calculated with the help of the relation

$$V = \lambda \times f$$

Tuning Instruments for The High Frequency Generator

If deflection in the Ammeter is nil or insufficient for any particular liquid, the instrument may be turned in the following manner:

Turn C7 till maximum deflection is achieved in Ammeter. Then turn C8 (attached to output terminal) for minimum deflection.

1. Repeat the process by again turning C7 for maximum followed by turning C8 for minimum.
2. This can be done for a number of times till they are properly tuned.
3. Trimmer C7 and C8 are marked as A and B respectively on the backside of Generator.

Precautions

- A. Do not switch on the generator without filling the experimental liquid in the cell.
- B. Remove experimental liquid out of cell after use. Keep it cleaned and dried.
- C. Keep micrometer open at 25mm after use.
- D. Avoid sudden rise or fall in temperature of circulated liquid to prevent thermal shock to the quartz crystal.
- E. While cleaning the cell care should be taken not to spoil or scratch the gold plating on the quartz crystal.
- F. Give your generator 15 seconds warning up time before the observation.

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- G. The reflector R and the crystal surface of C should be perfectly parallel.
H. In order to obtain consistent value of the observations, the following errors are to be avoided.
(i) The reflection of waves from the walls of the vessel.
(ii) The frequency of vibration should be the same throughout the experiment.
(iii) The crystal vibrating area should be large enough to produce plane waves.

The velocities of the ultrasonic waves in all these electrolyte solutions are found at different temperatures by circulating water through the outer jacket of the measuring cell from the thermostat. The ultrasonic interferometer has an accuracy of ± 0.2 m/s. [1-3]

Technical specifications

High frequency generator

Mains Voltage	220v, 50 Hz
Measuring frequency	1, 3 and 5 MHz
Glow Lamp	6.3v. 0.3 amp.
Fuse	150 mA
Size	41x30x13 cm
Weight	3.5-Kg approx.

Measuring Cell

Maximum displacement of the reflector	25mm
Required Quantity of liquid	12 c.c.
Least count of micrometer	0.001mm
Size	10.5x11.5x31 cm
Weight	3.75 Kg approx.

Shielded Cable

Length of connecting cable between the generator and the cell 50 cm approx.

Determination of Density

Density is defined as the amount of mass in a unit volume of substance. Density is measured by the specific gravity bottle. The capacity of the specific gravity bottle is 10ml and it has capillary arms with narrow bore and provided at the ends with well fitting ground glass caps. The specific gravity bottle must be thoroughly cleaned with distilled water and dried before using. The cleaned specific gravity bottle is first weighed (W_0). Then it is filled with distilled water. The specific gravity bottle is suspended in the thermostatic water bath by means of a stand. The water in the bath is adjusted so that the temperature of water getting in to the content attain the temperature of the bath (about 10 to 15 minutes) the specific gravity bottle is removed from the bath and is dried outside by means of a cotton and its weight determined with the help of the digital balance (W_1). Then it is washed, dried and filled with the solution. It is placed as before in the bath at the same constant temperature and after few minutes it is dried outside by means of cotton and weighed (W_2). The weight of the specific gravity bottles with distilled water is determined for different temperatures. The weight of the specific gravity bottles at different temperatures. Density of the solution (ρ) at a particular temperature is calculated using the formula. [4]

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$$\rho = \left[\frac{\text{Weight of the solution (W2-W0)}}{\text{Weight of an equal volume of water (w1-w0)}} \times \text{Density of water at particular temperature} \right] \text{-----(1)}$$

Density of water at different temperatures is taken from the standard data. Thus the density of the solution is determined at different molalities and is at different temperature values.

Viscosity Measurements

Considering the flow of a liquid through a narrow pipe may further elucidate the significance of viscosity. All parts of the liquid do not move with the same velocity. A thin layer immediately in contact with the walls of the tube is almost stationary. Each succeeding thin layer of the liquid moves with gradually increasing velocity which becomes maximum as the center of the tube is approached. The resistance that one part of the liquid flowing with a different velocity is known as viscosity. Alternatively, viscosity may be looked upon as the force of friction between two layers of a liquid moving past one another with different velocities.

Suppose, a cylindrical liquid layer of area A moves over another similar layer at a distance S with a velocity difference u. Then, the tangential force of friction (f), required to maintain a constant difference of velocity, is given by [5]

$$f = \frac{\eta Au}{S} \text{-----(3.2)}$$

Where η is a constant at a given temperature, depending upon the nature of the liquid and is known as the co-efficient of viscosity.

The reciprocal of viscosity is called fluidity and is denoted by ϕ . Thus

$$\phi = 1/\eta$$

Determination of viscosity: There are a number of methods of different kinds of measuring velocity. The method commonly employed is based on Poiseuille's law which connects the rate of flow of a liquid through a capillary tube with co-efficient of viscosity of the liquid and is expressed by the equation

The usual procedure is to determine the viscosity of a liquid with reference to that of water. This is termed as relative viscosity. [6]

All that is needed to be done is to measure the times of flow for equal volumes of water and the liquid under

$$\eta = \frac{\pi r^4 t h \rho g}{8VI} \text{-----(3.5)}$$

examination, through the same capillary. If t_1 and t_2 are the time of flow of the same volume of water and the liquid respectively, η_1 and η_2 are their respective co-efficient of viscosity, that

$$\frac{\eta^1}{\eta^2} = \frac{\pi r^4 t_1 h \rho_1 g}{8VI} \times \frac{8VI}{\pi r^4 t_2 h \rho_2 g} \text{-----(3.6)}$$

Where ρ_1 and ρ_2 are the densities of water and the liquid respectively. The value of h is the same in both cases since equal volumes of both liquids are taken are therefore, they stand at the same height. Hence,

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$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2} \text{-----(3.7)}$$

Oswald’s viscometer

The Oswald’s viscometer used for measuring viscosity by the above method. It is first thoroughly cleaned with chromic acid mixture and dried. The co-efficient of the solutions are determined with a Canon-Fenske viscometer. It is a special kind of Oswald viscometer and the principle used is the same.[7]

The viscometer consists of two limbs with bulbs and marks. The timer of flow from one mark to the both for water and solution are noted accurately at a given temperature. Then, the co-efficient of viscosity of the solution is calculated using the formula,

Where ‘l’ stands for solution and ‘w’ stands for water.

$$\eta_l = \frac{\rho_l t_l}{\rho_w t_w} X \eta_w \text{-----(3.8)}$$

Effect of Temperature on Viscosity:

The whole theory the viscosity of a liquid generally decreases with rise in temperature. The liquid molecules keep on moving continuously into these vacancies. The co-efficient of viscosity, thus, falls appreciably with rise in temperature.

The relationship between co-efficient of viscosity of a liquid and temperature is expressed mathematically as[8,9]

$$\eta = A e^{\frac{E}{RT}} \text{-----(3.9)}$$

where A and E are constants for a given liquid. Most of the experimental data fit in this equation very well. E is called the activation energy for viscous flow.

Effect of Pressure

The viscosity of a liquid, however, increases with increase in pressure. This is attributed to decrease in the number of ‘holes’ as the pressure is increased. Consequently, it becomes more difficult for liquid molecule to move around one another and hence it becomes more difficult for them to flow.

IV.CONCLUSION

The ultrasonic velocity, density, viscosity and other parameter were theoretically calculated. These theoretical results are used to calculate experimental data.

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