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IC.1. INTRODUCTION

The different techniques are developed for determining the ultrasonic propagation parameters at achieving better accuracy with more and more sophistication. The ultrasonic technique as an advantage over other methods because one is free to select small size of crystal for measurement where and could apply small stress and the absorption would still be of appreciable value for making observations. Low frequency in isotropic media low frequency in crystalline media and resonance method are Low frequency ultrasonic techniques. The high frequency ultrasonic technique, Singh around technique, Pulse echo-overlap technique, continuous technique, interferometric technique and phase comparison technique, ultrasonic propagation parameters measuring technique developed at physics department, Brahmanand pg college, Rath, hamirpur are ultrasonic pulse-echo interferometer SDUI-003, composite piezoelectric oscillator, ultrasonic time intervalometer UTI-101, ultrasonic flaw detector ESM-2, ultrasonic interferometer F-81 and M-84 and ultrasonic thickness gauge ETM-2DL. One can, undoubtedly, say that ultrasound finds extensive applications in different aspects of modern life. Advanced simulation tools used in the design for inspect ability of sound behavior in materials. The latest developments have greatly increased the interest in ultrasonics and have made the subject to be an active one the study of ultrasonic at present extends an unlimited field of activity for investigator and it opens up immense opportunities for their applications in this decade considerable interest has been taken in investigations of ultrasonic and chemical behaviour of milk having various animals found in Bundelkhand region cow, buffalo and goat, many have enriched this field by their experimental and theoretical approach in last ten years. No complete experiment or theoretical effort has been made so far in obtaining the temperature variation of velocity of ultrasonic wave of various frequencies in pure milk of different animals viz, cow, buffalo, and goat mixed water collected from several sources such as underground water possessing different velocity. Integration of ultrasound application in cassava-based ethanol plants can significantly improve ethanol yields and reduce the overall production costs\textsuperscript{1-2}.  

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there has been an increasing interest in the study of molecular interaction and a number of techniques have been used to investigate the interactions between the components of binary liquid mixtures\textsuperscript{3-6}.

**IC.2. INTERFEROMETER TECHNIQUE**

The interferometer (Fig.IC.1 and Fig. IC.2) consists of the following two parts:

(a) The high frequency generator   (b) The measuring cell

The high frequency generator is designed to excite the quartz plate fixed at the bottom of the measuring cell at its resonant frequency to generate ultrasonic waves in the experimental liquid in the ‘Measuring Cell’. A micro ammeter to observe the changes in current and two controls for the purpose of sensitivity regulation and initial adjustments of micro ammeter are provided on the high frequency generator.

The measuring cell is a specially designed double walled cell for maintaining the temperature of liquid constant during the experiment. A fine micrometer screw has been provided at the top, which can lower or raise the reflector plate in the cell through a known distance. It has a quartz plate fixed at its bottom. The measuring cell is connected to the output terminal of the high frequency generator through a shielded cable. The cell is filled with the experimental liquid before switching on the generator. The ultrasonic waves
move normal from the 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 meter on high frequency generator shows a maximum. A number of maximum readings of anode current are passed on and their ‘n’ is counted. The total distance (d) thus moved by the micrometer gives the value of 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.

The ultrasonic interferometer may be used for determination of ultrasonic velocity in electrolytic and non electrolytic solutions, sound absorption in medium absorbing liquid, adiabatic compressibility and internal pressure, acoustical and thermodynamic properties, reaction rates and formulation of complexes, excess enthalpies of binary and trinary systems, excess properties of binary and trinary systems, latent heat of vaporization of liquids, ultrasonic behaviour in liquid crystals, molecular relaxation parameters, ion-solvent interaction, acoustic properties of substances near the critical and freezing temperatures, intermolecular interaction, chemical and structural nature of liquid, phase transition study in liquids, visco-effects, excess volume and free volume. The measurements have to be done for ultrasonic velocity in different frequency range for different fatty oils, petroleum oils and petroleum oils with certain impurity.

**IC.3. PULSE-ECHO INTERFEROMETER TECHNIQUE**

The ultrasonic pulse echo interferometer SDUI-003 (Fig.IC.4) uses exclusively monolithic and discrete solid-state devices. Hence, it is quit compact and reliable. The unit has been safe guarded against possible abuses like shorting the **Figure IC.3 Pulse-echo** output etc. The interferometer has been
**Interferometer Technique** tested for continuous operation for more than 4 years and its performance has been reported as excellent.

The transmitter signal starts essentially from a gated video oscillator connected in a Wien-bridge configuration to generate r-f pulses centered around 10 MHz. The pulse width of the r-f pulse is variable from about 2 micro second to 20 micro seconds by means of a transmitter pulse width control circuit which is basically a non stable multi vibrator. The repetition rate of the r-f pulse is determined by the repetition rate generator, built using a SE-566 integrated circuit. The frequency of the repetition Rate generator could be varied smoothly by means of course, medium and fine variation knobs provided on the front panel to achieve a precise superposition of the echoes. The frequency range covered is 40 to 400 KHz. The frequency stability of the generator is around to 10 ppm and the short-term stability, which is the primary consideration for pulse superposition is excellent. The repetition rate of the repetition Rate generator could be conveniently measured by means of a 6-digit frequency mode. The pulsed r-f signal is amplified by means of an r-f power amplifier and is fed into the quartz transducer through the transmission gate.

The transmission gate is used to isolate the input of the receiver amplifier circuit from the high voltage transmitter signal. The typical r-f signal is around 20V peak to peak across the transducer through a 50-ohm coaxial cable.

The receiver amplifier consists of four stages. The main amplifier consists of two stages of differential video amplifier type LM 733, which is a monolithic differential input, differential output amplifier of wide bandwidth with variable gain. No external frequency compensation is required for this amplifier and it has excellent gain stability and low phase distortion. The third and fourth amplifier stages are built around the high frequency transistor type 2N 3866. The overall voltage gain that is achieved in the complete receiver chain is more than 60 dB. The gain is varied by varying the potentiometer control, provided in the front panel as a gain control knob. The output of the amplifier is available on the front panel of the pulse interferometer unit through a BNC connector and this could be connected to the Y unit of the oscilloscope for viewing and superposition of the
echoes. In order to power the various modules of the pulse interferometer, a number of voltage sources with different current ratings and regulation characteristics are required. The power supplies are built around the precision monolithic voltage regulators type 723. The 20V power supply for the r-f power amplifier stage has fold back short circuit protection incorporated in the power supply to ensure safety under accidental short circuit conditions. The resistor $R_{fb}$ forms the fold back circuit. A booster transistor has been added to provide the necessary output current without causing excessive dissipation in the regulators. The voltage needed to power MC 1445 integrated circuit and LM 733 is derived from separate power supplies.

**IC.4. COMPOSITE PIEZOELECTRIC TECHNIQUE**

The composite piezoelectric oscillator (Fig.IC.4) determines the ultrasonic velocities in metals, rocks, plastic specimen and crystal etc. the elastic constants of metals, rocks, polymers and crystals etc., temperature dependence of ultrasonic velocity and elastic constants of solid.

*Figure IC.4 Composite Piezoelectric Technique*

Specimens and loss factor or internal friction. Elastic modulii of solids are of interest in understanding the nature of forces between the atoms or ions that constitute the solid. One of the methods used to study the elastic behaviour of solids is the composite piezoelectric oscillator technique. It is simple and elegant and can also be used to evaluate the loss factor or internal friction. Temperature dependence of the elastic behaviour of solids is another study that can be carried out using this technique.

In this technique, the specimen in the form of a rectangular rod is cemented to a quartz rod of identical cross section and the resonant frequency $f_c$ of the composite system is determined using the apparatus. The resonant frequency of
the quartz rod \( (f_q) \) is also determined. From knowledge of \( f_q, f_c \) and the masses of the quartz \( (m_q) \) and the specimen \( (m_s) \), the resonant frequency of the specimen \( f_s \) is evaluated using the relation

\[
f_s = f_c + \frac{m_q}{m_s} (f_c - f_q)
\]

Using the values of \( f_s \), the length of the specimen and the density of the specimen, one can evaluate the velocity of ultrasonic waves in the specimen and its elastic moduli.

**IC.5. TIME INTERVALOMETER TECHNIQUE**

![Figure IC.6 Time Intervalometer Technique](image)

The ultrasonic time intervalometer Technique (Fig. IC.5) is intended for precise Measurement of ultrasonic velocity in solids and liquids using pulse-echo overlap technique. The absolute accuracy of velocity measurement using this technique may be as high as 2 parts in \( 10^4 \), while the relative sensitivity \((\Delta V)\) can be as high as 10 parts in \( 10^6 \).

The instrument uses a broadband pulse to excite the transducer. All the circuitry required for pulse-echo overlap such as high voltage pulse to excite the transducer, a continuous wave oscillator with high resolution and low phase jitter, delayed strobe pulse generators to aid intensification of the trace, eight digit frequency counters are built into this compact instrument. Except for the oscilloscope, the instrument does not require any other equipment for its operation. One of the important features of this instrument is provision of extra facility, which enables one to achieve overlap with scopes having no intensity
modulation facility. The instrument can be easily checked periodically with the transducer provided with the instrument.

The instrument may be used in the true transmission or normal pulse echo mode. In the true transmission mode, one transducer is employed as a sender and another as a receiver. The sending transducer is connected to the T/R BNC while the receiver is connected to the RCVR in BNC. In pulse echo mode, only one transducer is employed. This transducer acts both as a sender and receiver. The instrument can be used in several applications such as:

(a) High precision velocity measurements in solids and liquids.
(b) Velocity changes at low temperature.
(c) Velocity changes at high pressure.
(d) Ultrasonic relaxation studies.
(e) Thickness gauging.
(f) Flaw detection.

Internally, ultrasonic time intervalometer is composed of

(a) Power supply
(b) Pulsar
(c) Receiver
(d) Stable continuous wave source (Repetition rate generator)
(e) Frequency counter
(f) Strobe and delay generators.

IC.6. FLAW DETECTION TECHNIQUE

The ultrasonic flaw detector ESM₂ (Fig.III.7) is a universal instrument that has found a varied range of applications in the field of nondestructive testing of materials with ultrasonic energy. It can Figure IC.6 Flaw Detector accept a battery pack as a source of Technique.
power thereby enhancing its portability. On the other hand, exceptional features make it eminently suitable as a tabletop instrument. The ESM\textsubscript{2} can be operated both in the pulse transmission as well as in the pulse reflection mode over a large frequency range of 0.5 to 12.0 MHz. It can also employ single probe, double probe and TR probe methods, depending upon the application.

The large flat–face of the CRT with optimized line thickness and internal graticule is suitable for use under most conditions of illumination. The trace can be evaluated over a wide angle of view from a large distance. For locations with very high ambient illumination, the viewing hood supplied with the instrument may be used. The ESM\textsubscript{2} has an accurately calibrated gain control system which can be varied in 2dB steps through a range of 0 – 80 dB.

The ESM\textsubscript{2} can be used for a wide range of thickness of material from 10mm to 5,000mm. Furthermore, for all material of thickness larger than 10mm any portion of the trace corresponding to 10mm or more of material can be displayed over entire width of the screen. It is thus possible to make accurate evaluation of wall thickness. The instrument can be used with either a set of re-chargeable batteries or can be operated directly from mains. For use with re-chargeable batteries, the battery pack ERBI is to be used. The Ni-Cd batteries, have a long life, over drain of the battery is prevented by automatic cutout provided in the instrument, which cuts out the battery when the voltage falls below a certain limit. A fully charged battery pack can operate the instrument continuously at least for eight hours. With proper maintenance the battery pack should last for well over thousand charge cycles.

To operate the equipment on the mains supply of 230 volts, 50Hz the power pack-cum-battery charger model NTLGR must be used. The output of the model NTLGR is stabilized to accept up to ± 10% variation in the mains voltage.

With the help of model NTLGR, Power pack cum battery charger, the batteries can be charged either alone or also when the EMS\textsubscript{2} is being operated from the NTLGR. Care should be taken to prevent overcharging of the batteries, as regular overcharging leads to shortening of the life of the batteries. Fully discharged batteries should be charged for 14 hours. Partially discharged batteries should be charged for 1.4 times the hours of use. The
housing of ESM2 is molded from tough plastic. The handle can be set to 11 different positions and can also be used as a support for the instrument.

**IC.6.1 PROCEDURE FOR MEASUREMENT**

The measuring cell is connected to the output terminal of high frequency generator through the shielded cable. The liquid is filled in the cell before switching in the generator. The ultrasonic waves moves normal from the quartz crystal till they are reflected back from the moveable plate and the standing waves are formed in the liquid between the reflector plate and 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 wavelength (\(\lambda\)) with the help of following relation:

\[ d = n \frac{\lambda}{2} \]  

If we calculate the value of wavelength from above formula then we can calculate the velocity of the liquid by the following relation

\[ V = \frac{\lambda}{f} \]  

**IC.7. THICKNESS GAUGE TECHNIQUE**

The ultrasonic thickness gauge Technique (Fig. IC.7) is based on ultrasonic principle and transit time measurement. It is designed to make accurate and reliable measurements from one side of the component. ETM-2DL is microcontroller based, hand held precision thickness gauge with a built
in data logger, connectively to a standard printer and PC interface for test data storage. Data logger has, capacity to store 1000 thickness readings, save reading in selected bank (Data logger has 10 banks, each bank contains 100 memory locations. Each bank no. will be displayed as b01 to b10. If any bank is full ‘OFL’ is displayed, so user can not save the reading in that bank), display save readings and erase saved reading. The measuring thickness range of gauge is 1.0mm to 199.9mm with a resolution of 0.1mm or 0.039 inch to 7.87 inch and velocity range is 1.40M/msec-7.99M/msec or 0.056 inches/ μsec-0.314 inches/ μsec. ETM-2 DL is microprocessor based digital thickness measuring gauge. It is designed to measure accurately and reliably from one side of a parallel walled component. It can be operated in the temperature range 0-50°C. The small size, hand held gauge uses highly advanced sophisticated manufacturing technology to offer simplicity and ease of operation. No prior training is essential to make good measurements. In spite of its small size it has a large LCD display for strain free working. It is suitable to make measurements on plates, pipes, corroded sections, pressure vessels, small tubes, ferrous and non-ferrous components and machined parts, plastics, glass and ceramic among a variety of application to measure the wall thickness, even if their surfaces are at an elevated temperature. Special features: sealed touch key pad, auto calibration for mild steel, big LCD display, V-path corrected for high accuracy, long working with "AA" size cells, wide range of probes, small pocket size, metric-English conversion, microprocessor based, surface mount device technology, stable, repeatable and accurate. The ultrasonic thickness gauge accurately displays readings in either inches or millimeters after performing a simple calibration to a known thickness or sound velocity. A range of probes is available to select the most suitable one for a specific application. As P.81 (general purpose application), P.86 (smaller diameter tube, thin plates and in limited access application), P.61 (general purpose application), P.66 (smaller diameter tube, thin plates and in limited access application), P.45 (general purpose application but at elevated surface, up to 450°C), P.21 (high penetration type for attenuating materials like alloy steel and non Ferrous). Ultrasonic waves are generated in the probes and are transmitted through to the test spot by locating the probe correctly. Hence use of couplant is always necessary to remove air bubble between a transducer and a test piece to provide better acoustic coupling. There are various types of couplants for different applications. EZG (General Purpose Couplant, Water Soluble), EZGVHT (High
Temperature Couplant), EZG (General Purpose Couplant, Water Soluble), EZGHF (Halogen Free Couplant, Non-Toxic Corrosive), EZGT (Very High Temperature Couplant). Special High Temperature Cables and Dual Cables with two connectors at each end to fit dual crystal transducer are also available. For replacing the batteries, open the gauge back cover by sliding the cover towards your side and replace the old batteries with the new ones.

![Figure IC.8 Block diagram of Ultrasonic Thickness Gauge](image)

**Figure IC.8 Block diagram of Ultrasonic Thickness Gauge**

Figure represents a generalized block diagram of a modern microprocessor-controlled ultrasonic gauge. The pulsar, under control of the microprocessor, provides a unidirectional broadband voltage impulse to a heavily damped broadband ultrasonic transducer. The broadband ultrasonic pulse generated by the transducer is coupled into the test piece, normally with the aid of a liquid coupling medium. Returning echoes are received by the transducer and converted back into electrical pulses, which in turn are fed to the receiver Automatic Gain Control (AGC) amplifier. The microprocessor-based control and timing logic circuits both synchronize the pulser and select the appropriate echo signals to be used for time interval measurement. If echoes are not detected during a given measurement period, the gauge will shut down to save power until a new measurement cycle is required. If echoes are detected, the timing circuit will precisely measure an interval appropriate for the selected measurement mode, and then repeat this process a number of times to obtain a stable, averaged reading. The microprocessor then uses this time interval measurement, along with the sound velocity and zero offset
information stored in the Random Access Memory (RAM), to calculate thickness. This thickness measurement⁹ is then displayed on the Liquid Crystal Display (LCD) and updated at a selected rate. Many modern gauges incorporate an internal data logger and are capable of storing several thousand thickness measurements along with identification codes and setup information in RAM. These stored readings may be recalled to the gauge's display or uploaded to a printer or computer for further analysis.

**IC.7.1 Accuracy and Resolution**

Figure represents schematically the distribution of a number of readings taken on a component. Note that the observations are not evenly distributed, but a bunched at discrete reading values. Resolution⁹ is the smallest increment of quantity that can be recognised. Here, seen that the readings recorded appear at discrete values with none in between. When applied to a flaw detector; Resolution means the closest together that two echoes can be and still be distinguished. This is an important difference. For high resolution in a flaw detector, a very short pulse is required, so that overlap in minimized. This is not the case in a thickness gauge, where the pulse width affects the minimum reading, but not the resolution. Accuracy¹⁰ is a measure of the statistical error in the readings that may be obtained, as a result of the imperfections in the instrument. It is a combination of a number of terms representing uncertainty in the measurement and calibration processes. A third term that is used is repeatability. This is the error in readings caused by a combinaton of the instrument and its use. Repeatability cannot be better than accuracy, and can be much worse. For example, a screw micrometer may have a resolution of 0.01mm, that being its scale division. The accuracy is limited by the cutting of the thread, hysteresis in the screw, the setting of the zero point and the reading of the measurement. The latter two are both equal to the resolution, so even if the former two are negligible, the accuracy cannot
be better than 0.02mm. Such a relation between accuracy and resolution is common. The use of a micrometer requires a degree of skill to get the tension right. In the hands of an unskilled user, the repeatability can be 0.05mm or worse.

**IC.7.2 Measurement Principles Introduction**

Ultrasonic nondestructive testing (NDT) characterizing material thickness, integrity, or other physical properties by means of high-frequency sound waves--has become a widely used technique for quality control. In thickness gauging, ultrasonic techniques permit quick and reliable measurement of thickness without requiring access to both sides of a part. Accuracies as high as ±1 micron or ±0.0001 inch are achievable in some applications. Most engineering materials can be measured ultrasonically, including metals, plastic, ceramics, composites, epoxies, and glass, as well as liquid levels and the thickness of certain biological specimens. On-line or in-process measurement of extruded plastics or rolled metal is often possible, as is measurement of single layers or coatings in multilayer materials. Modern hand held gauges are simple to use and highly reliable. Precision ultrasonic thickness gages usually operate at frequencies between 500 KHz and 100 MHZ, using piezoelectric transducers to generate bursts of sound waves when excited by electrical pulses. A wide variety of transducers with various acoustic characteristics have been developed to meet the needs of industrial applications. Typically, lower frequencies will be used to optimize penetration when measuring thick, highly attenuating, or highly scattering materials, while higher frequencies will be recommended to optimize resolution in thinner, non-attenuating, non-scattering materials. A pulse-echo ultrasonic thickness gage determines the thickness of a part or structure by accurately measuring the time required for a short ultrasonic pulse generated by a transducer to travel through the thickness of the material, reflect from the back or inside surface, and be returned to the transducer. In most applications this time interval is only a few microseconds or less. Additionally, in actual practice, a zero offset is usually subtracted from the measured time interval to account for certain fixed electronic and mechanical delays. In the common case of measurements involving direct contact transducers, the zero offset compensates for the transit time of the sound pulse through the transducer's wear plate and the couplant layer, as well as any electronic switching
This zero offset is set as part of instrument calibration procedures and is necessary for highest accuracy and linearity. Making measurements with any analytical method or instrument requires calibration to ensure the accuracy of the measurement. There are two common calibration procedures: using a working curve, and the standard-addition method. Both of these methods require one or more standards of known composition to calibrate the measurement. Instrumental methods are usually calibrated with standards that are prepared (or purchased) using a non-instrumental analysis. There are two direct analytical methods: gravimetry and coulometry. Titration is similar but requires preparation of a primary standard. The chief advantage of the working curve method is that it is rapid in that a single set of standards can be used for the measurement of multiple samples. The standard-addition method requires multiple measurements for each sample, but can reduce inaccuracies due to interferences and matrix effects.

A transducer for an ultrasonic thickness gauge of the pitch and catch type has transmitting and receiving transducer elements on adjoining blocks of delay material separated by an acoustic barrier is calibrated by operating the receiving transducer element in pulse-echo mode. The lengths of the two delay blocks differ by an amount calculated to make the pulse-echo travel time in the longer delay block greater than pitch and catch travel time by an amount at least equal to the geometric delay of the transducer to provide an unambiguous readout during pulse-echo operation when the gauge is adjusted to the proper zero point calibration for the transducer. A transducer for a self-calibrating ultrasonic thickness gauge comprises first and second blocks of delay material and an acoustic barrier separating the blocks, a first transducer means mounted on the first block capable of transmitting ultrasonic waves, and a second transducer means mounted on the second block, capable of receiving ultrasonic waves during pitch-and-catch operation of the gauge, and also being capable of operation in the pulse-echo mode, in which the second block has a configuration such that an ultrasonic wave passing through the second block has a longer path than the path of the wave in the first block, the difference between the lengths of wave paths in the blocks being selected so that the difference in time of wave travel through the blocks due to the difference in paths offsets the geometric time delay in transmission of an ultrasonic wave through the transducer in the pitch-and-catch mode.
**IC.7.3 Procedure for Measurement**

Ultrasonic waves are generated in the probes and are transmitted through to the test spot by locating the probe correctly. The ultrasonic waves are travel under the probe, through the cross section and are reflected back by the material boundary. The time taken for the to and fro travel is recorded and converted to display the thickness. Ultrasonic pulse generated by a transducer to travel through the thickness of the material, reflect from the back or inside surface, and be returned to the transducer. In most applications this time interval is only a few microseconds or less. The measured two-way transit time is divided by two to account for the down-and-back travel path, and then multiplied by the velocity of sound in the test material. The result is expressed in the well-known relationship:

\[
d = \frac{V}{2} t/2 \quad (IC.5)
\]

Where
\[
d = \text{the thickness of the test piece},
\]
\[
V = \text{the velocity of sound waves in the test material},
\]
\[
t = \text{the measured round-trip transit time}.
\]

**IC.8. RESULT AND DISCUSSION**

Ultrasonic testing has been practiced for many decades now. Initial rapid developments in instrumentation spurred by the technological advanced from the 1950 continuous today’s. Ultrasonic has been widely used to study the properties of liquids. The acoustical properties. Compressibility impedance and viscosity evaluated from ultrasonic velocity and density measurements have been used to elucidate the structure and the nature of molecular interactions in aqueous and non-aqueous solutions. There has been an increasing interest in the study of molecular interactions between the components of binary liquids mixtures. In the present work measurements of ultrasonic velocities for different animal’s milk with certain impurity has been made with the help of multy frequency ultrasonic interferometer at different frequencies. Changes in velocity with frequency are restudied.
IC.9. REFERENCES