ULTRASONICS

1.1 Introduction

Vibrating body produces sound. Human ear is sensitive to sound waves of frequencies ranging from 20 Hz to 20,000 Hz. Sound waves of frequencies greater than 20,000 Hz are called **ultrasonic waves**. Human beings cannot sense this sound.

Ultrasonic waves are generated by bats and dolphins and they use the reflection of the waves to find their way. Dogs can hear ultrasonic sounds.

1.2 Generation of Ultrasonic Waves

The methods by which ultrasonic waves can be generated ar

1. Magnetostriction generator
2. Piezo-electric generator.

1.2.1 Magnetostriction Generator

Principle

Magnetostriction generator is base on the priniciple of magnetostriction effect. When a ferromagnetic rod like iron or nickel is kept in a magnetic field parallel to its length the rod expands or contracts producing a change in length. This is known as **Magnetostriction effect**.

Construction

The magnetostriction generator consists of a nickel rod which is laminated, insulated and pasted to avoid Eddy current loss. The rod is clamped in the middle and coils $L1$ and $L2$ are wound on the two ends of the rod. Coil $L1$ is connected to the base circuit and coil $L2$ is connected to the collector circuit as in Fig 1.1. The inductor $L2$ and capacitor $C1$ form the tank circuit. The coil $L1$ is used as a feedback loop. The battery connected between the emitter and collector provides the necessary biasing.

Working

When the power supply is switched on, the collector current rises and sets up an alternating current of frequency $f =$

This alternating current flowing round the coil $L2$ provides an alternating magnetic field of frequency $f =$ along the length of the rod. Here l is the length of the rod, E the youngs modulus of the material of the rod, p its density and $n = 1,2,3 \cdots$ .. Now the rod starts vibrating due to the magnetostriction effect. When the frequency of vibration of the rod matches the frequency of the tank circuit ultrasonic waves are produced. This can be achieved by adjusting the capacitor *C1* and tuning the developed alternating current frequency with the natural frequency of the rod.

The coil $L1$ helps in increasing the amplitude of the ultrasonic waves. The longitudinal expansion and contraction of the rod produces an e.m.f in the coil $L1$ which is applied to the base of the transistor which in turn increases the amplitude of high frequency oscillations in coil $L2$ due to positive feed-back.

Advantages

i. Magnetostriction oscillators are mechanically rugged.
ii. The construction cost is low.
iii. They are capable of producing large acoustical power with fairly good efficiency (as 60 %)

Drawbacks

i. It can produce frequencies upto 3 MHz only.
ii. The frequency of oscillations depends on temperature.

1.2.2 Piezo Electric Generator

Principle-Piezo electric generator is based on the principle of inverse plezo electric effect

When certain crystals like quartz are subjected to mechanical stress electric charges appear on the opposites sides of the crystal. This effect is called **Piezo** electric effect, and effect is reversible. When electric field is applied on the opposite faces of the crystal, it undergoes mechanical deformation. This is the **inverse piezo electric effect**. This effect is used for generating ultrasonic waves using piezoelectric oscillator. The materials which exhibit this effect are called Piezo electric transducers.

Example : Quartz, barium titanate.

Natural quartz has a hexagonal structure with a pyramid attached to each end. The line joining the end points of the pyramid is called z-axis. The lines passing through the opposites corners are X-axis. The line perpendicular to opposite edges is Y-axis shown in (Fig 2). When the crystal is cut perpendicular to X-axis it is called X-cut crystal. When the crystal is cut perpendicular to Y-axis it is called Y-cut crystal.

The natural frequency of the quartz specimen

Where, t - thickness of the material

E - Youngs modulus of the material and

ρ - density of the material

Experimental setup

The circuit diagram is shown in Fig 1.3. This is a base tuned oscillator circuit. A slice of quartz crystal is placed between the metal plates *A* and *B* so as to form a parallel plate capacitor with the crystal as the dielectric. This is coupled to the electronic oscillation through primary coil *L3* of the transformer.

Coils *L2* and *L1* of oscillator circuit are taken from the secondary of the transformer. The collector coil *L2* is inductively coupled to base coil *L1*. The coil *L1* and variable capacitor *C*1 form the tank circuit of the oscillator.

Working

When the batttery is switched on, the oscillator produces high frequency oscillations. An oscillatory e.m.f is induced in the coil *L3* due to transformer action. So, the crystal is now under high frequency alternating voltage.

The capacitance of C_1 is varied in such a way that the frequency of oscillations produced is $f =$ and is in resonance with the natural frequency of the crystal. Now the crystal vibrates with large amplitude due to resonance and, high power ultrasonic waves are produced.

Advantages

i. Ultrasonic frequencies as high as 500 MHz can be generated.
ii. The output power is high. It is not affected by temperature and humidity.
iii. It is more efficient than magnetostriction oscillator.

Disadvantages

i. The cost of the quartz crystal is very high.
ii. Cutting and shaping the crystal is very complex.

1.3. Detection of Ultrasonic Waves

Ultrasonic waves are beyond the audible limit. Hence it is very essential to develop a method to detect the ultrasonic wave. The various detection methods are

1. Kundt's tube method
2. Piezo electric detector
3. Thermal detector
4. Sensitive Flame method

(i) Kundt's Tube Method

The Kundt's tube apparatus consists of a long circular glass tube of length 1 m and diameter 0.03 - 0.04m. One end of the tube is fitted with an adjustable piston rod with cork. The quartz crystal placed in between the two metal plates is placed at the mouth of the other end of the tube. Lycopodium power is spread uniformly inside the tube.

Like sound waves, stationary waves are produced in the air contained in the long glass tube which is placed horizontally. The lycopodium powder gets collected in the form of heaps at the nodes and is blown off at the antinodes. By measuring the average distance between the adjacent heaps, the wavelengths and hence the ultrasonic velocity can be calculated.

The wavelength of the ultrasonic waves $\lambda = 2d$.
Where is d the distance between the successive nodes.
Ultrasonic velocity in the medium $V = f\lambda = 2fd$

(ii) Piezo electric detector

This method is based on the principle of piezo-electric effect. When one pair of the faces of a quartz crystal is exposed to ultrasonic waves, opposite charges are developed on the pair of opposite faces. These charges are amplified and detected using an electronic circuit.

(iii) Thermal detector

This is the most commonly used method of detection of ultrasonic waves. A fine platinum wire is placed in the region to be tested for ultrasonic waves. At nodes due to alternate compressions and rarefactions, alternate heating and cooling is produced. Change in temperature at the node brings about changes in the electrical resistance of the platinum wire. This is detected by means of wheatstone's bridge. No change in temperature occurs at the antinodes.

(iv) Sensitive Flame method

When ultrasonic waves are passed through a sensitive flame, the intensity of the flame will change due to the high frequency of the ultrasonic waves. By measuring the change in intensity of the flame, the ultrasonic waves can be detected.

1.4 Properties of Ultrasonics

1. Ultrasonic waves are longitudinal in nature.
2. They are highly energetic.
3. Like sound waves ultrasonic waves undergo reflection and refraction. They can also be absorbed.

4. When ultrasonic waves are passed through liquid, it produces stationary wave pattern and the liquid behave as an acoustic grating.
5. Ultrasonic waves can travel through longer distance.
6. The speed of propogation of ultrasonic wave increases with increase in frequency.
7. They produce cavitation effects in liquids.
8. Due to the small wavelength ultrasonics show very negligible diffraction.

1.5 Velocity of Ultrasonics waves in liquid using Acoustic grating

Principle

Ultrasonic wave consists of compression and rarefractions. When these waves are passed into liquid medium, the density of the liquid varies layer by layer and the liquid will act as a diffraction grating. This grating which is formed in liquid due to acoustical waves is called as acoustic grating.

When a monochromatic light is passed through this grating, the light gets diffracted. By determining the diffraction parameters, the velocity of ultrasonic waves can be determined.

Construction

The experimental setup for the formation of acoustic grating is shown in Fig.1.4. This consists of a glass tube filled with the liquid. A quartz crystal which is connected to an oscillating circuit is placed at the bottom of the glass tube. A monochromatic source of light and condensor lens are arranged at right angle to the tube.

Working

Light from the monochromatic source is passed into the liquid in a direction perpendicular to the direction of propogation of ultrasonic waves. When the ultrasonic wave travel through the liquid they get reflected from the opposite side of the vessel.

Longitudinal stationary waves are produced in the liquid medium due to the superposition of the forward and reflected waves. These stationary waves give rise to nodes and antinodes. At the nodes, the density of the liquid is maximum and so the refractive index is maximum. However at antinodes the density of the liquid is minimum and so the refractive index is minimum. Thus the nodes act as opacities and antinodes as transparencies and thereby the liquid coloumn acts as an acoustic grating.

When the light falls on this acoustic grating the diffraction pattern is formed. The diffraction pattern consists of central maximum and first order maxima on both sides. This can be viewed through the telescope.

Let θ be the angle of diffraction for the m^{th} order and d the distance between two adjacent nodes or antinodes.

Then we have

$$d \sin \theta = m \lambda$$

where λ is the wavelength of light used.

By knowing the value of θ, m and λ, d can be determined. Let λ_L be the wavelength of ultrasonic wave in liquid

Then $d = \lambda_L /2$

$$\lambda_L = 2d$$

If f is the frequency of ultrasonic oscillations then, the velocity of ultrasonic waves $V = f\lambda_L$

$$V = 2df \qquad (\because \lambda_L = 2d)$$

1.6 Cavitation

When ultrasonics pass through a liquid medium a large number of low pressure bubbles are produced. The high power compression and rarefraction of sound waves produced inside the liquid causes the continuous formation and collapse of millions of microscopic low pressure bubbles. This is called **cavitation.**

The collapsing of these bubbles produce tiny explosions relasing tremendous pressure of hundreds of atmospheres. The cavitations is effective at low frequencies between 20KHz - 40KHz. The size of vapour bubbles formed by cavitation is inversely proportional to the frequency of the ultrasonic waves.

The phenomenon of cavitation is used in

1. Ultrasonic cleaning
2. Emulsification
3. Locating minerals and oil deposits
4. Accelerating chemical reactions and
5. Forming stochiometric alloys and compounds.

1.7 Industrial Applications

1.7.1 Ultrasonic Welding

The properties of some materials change on heating. In such cases, the electric or gas welding is not advisable. Such materials can be welded at room temperature with the help of ultrasonic waves. Proper welding can be achieved by sending ultrasonic waves in between the surfaces of the weld during welding called cold welding. This effect is attributed to the momentary relaxation of the bonds.

Construction

When materials are welded through ultrasonic waves, the energy required comes in the form of mechanical vibrations. The welding tool called sonotrode (hammer) is attached to a powerful ultrasonic generator. The part to be welded is placed on the anvil and located just below to tip of sonotrode as shown in Fig 1.5

Working

When ultrasonic waves are produced, the sonotrode is made to vibrate ultrasonically. As a result, the parts to be welded are pressed simultaneously. The ultrasonic vibrating force disrupts the oxide layer of both materials. The atom diffuses from one part to the other when the oxides are dispersed. Since no oxides are at the interface, a true metallurgical bond is achieved. Thus the metals are joined by molecular transfer.

1.7.2 Ultrasonic Soldering

Metals like aluminium and copper form an oxide layer when contact with air. This oxide layer prevent solder from making contact with the metal.

Construction and Working

An ultrasonic soldering iron consist of an ultrasonic generator having a tip fixed at its lower and. The tip can be heat d by an electrical heating element. The experimental set up is shown in Fig. 1.6.

When ultrasonic vibration is applied to the solder in the tank, many cavitation bubbles are created. The size of the bubbles increases until they become unstable and impolde. When a bubble impolde, the solder around the bubble accelerates towards the bubble middle. This solder can then hit the surface of a part creating a strong impact which simultaneously cleans the surface and destroys the oxide film on the metal. This allows soldering without using flux.

Thus during the working process the tip of the soldering iron melts the solder on aluminium and the ultrasonic vibration removes the aluminium oxide layer.

1.7.3 Ultrasonic Cleaning

Contamination that is soluble or emulsified can usually be removed by means of conventional method in conjunction with suitable solvent or detergent solution. However) it cannot adequately remove particles or matter in the micron and submicron size.

Though a number of methods have been used for the purpose of removing micro particles from hard surfaces, the complete removal of insoluble particulate contamination from hard substrate surfaces can be done only by ultrasonic cleaning method.

Mechanism

When Ultrasonic waves pass through a liquid, bubbles are formed due to cavitation. These bubbles get collapse at a tremendous rate. Thus the cleaning fluid particles, hit the surface with a great force due to this cavitation effect and the cleaning action is achieved by using ultrasonic waves.

Intricate machine parts, precision parts of a watch and parts of space craft can be thoroughly cleaned from greasy matter by placing them inside the cleaning fluid and by passing ultrasonic waves through the fluid.

1.7.4. Ultrasonic Driller

Ultrasonic drilling is particularly used for drilling any odd shaped hole like triangular, square etc, on a hard and brittle material like glass. The drilling set-up consists of an ultrasonic generator and a drill head as in Fig. 1.7. The ultrasonic generator comprises an oscillator attached to the transducer. The transducer is made of thin nickel sheets to avoid eddy current loss.

The drill bit is kept just above the work piece on which the hole has to be drilled. An abrasive powder like carborandum powder is spread over the work piece and a little amount of water is added to the powder. The oscillator is switched on and the drill bit is lowered to touch the powder-water mixture. The ultrasonic waves produce cavitation in the mixture. The low pressure bubbles formed collapse at a tremendous rate and thereby the abrasive powder particles are made to bombard the work piece with a great force and the required hole is drilled on the work piece.

Advantages of ultrasonic driller over the conventional driller

1. Any odd shaped hole can be drilled.
2. Drilling can be made on a brittle material.
3. No final finish is required.
4. Silent operation.
5. Cheap method.

1.8 Sonar

Sonar stands for Sound Navigation and Ranging. This is based on the principle of Echo-sounding. When ultrasonic wave is transmitted through water, it is reflected by the objects in the water and produce an echo. The change in frequency helps to determine the direction and their distance in the sea.

The transducer is mounted on the ships hull without any air gap between them. Piezo electric transmitter in sonar generates the short pulses of ultrasonic waves.

The timing at which the pulse generated is recorded at the CRO for reference and this electrical pulse triggers the transducer which is kept at the base.

These ultrasonic waves are transmitted through the water in the sea. On striking the object the waves are reflected back and received in the river.

By knowing the velocity of sound in sea water, the distance of the object from the ship can be calculated as

$$v = 2d / t$$

$$d = v \times t / 2$$

Thus the position, distance and the direction of the moving object can be calculated.

1.9 Non Destructive Testing

Non destructive testing (NDT) is a method by which materials are tested without destructing or damaging the material and by passing some radiations through the material. The goal of NDT is to detect defects and give information about their distribution. There are many non distructive tests in use.

The common methods are

- Visual inspection
- Liquid penetrant testing
- Magnetic particle testing
- Eddy current testing
- Ultrasonic testing
- Radiography

1.9.1 Ultrasonic Flaw Detector

Ultrasonic waves travels in different medium with different velocities. Whenever there is a change in medium, the ultrasonic waves will be reflected back. Thus, from the intensity of the reflected echoes, the flaw can be detected without destroying the material.

Description

It consists of a piezo electric transducer coupled to the upper surface of the specimen (metal) without air gap between the specimen and the transducer. A frequency generator is connected to the transducer to generate high frequency pulses. The total set up is connected to an amplifier and to a cathode ray oscilloscope as shown in block diagram Fig. 1.9

The signal generated by the frequency generator is send to the piezoelectric transducer. Here the ultrasonic wave is split into two parts. One part is send to the specimen to collect information, whereas the other is send to the CRO for reference.

The wave travel through the specimen and is reflected back by the other end. The reflected ultrasonics (pulse B)are received by the transducer. These reflected signals are amplified and is found to be almost the same as that of the transmitted signals as shown in Fig.1.10 (a) which shows that there is no defect in the specimen.

If there is any defect on the specimen like a small hole the ultrasonics will be reflected by the holes i.e, defects due to the change in medium. These defects gives rise to another signal *'C'* in between pulses *'A'* and *'B'*. From the time delay between the transmitted and received pulses the position of the hole can be found. Also from the height of the pulse received the depth of the hole can be determined.

Advantages

1. It can reveal internal defects.
2. This method is highly sensitive to most of the cracks and flaws.
3. It gives immediate results.
4. It indicates the size and location of the flaws exactly.
5. Since there is no radiation in this process, it is a safe method.
6. The cost is very low.

Limitations

1. It is difficult to find the defects of the specimen which has complex shapes.
2. Trained, motivated technicians alone can perform this testing.

1.10 Pulse Echo System

The main components of a pulse echo system are transmitter, time-base generator, receiver, swept-gain generator and cathode ray oscilloscope (CRO). The transmitter gives sufficient amount of energy to the transducer, which emits a short burst of ultrasound waves. The built-in time-base generator gives a suitable voltage across the x-plates of the CRO, which helps a steady movement of the spot in the screen. The transducer is kept in close contact with the skin. A good couplant is used between the skin and the transducer to provide good coupling and also to avoid any excess reflection which occur at the air-solid boundary.

The ultrasound generated by the transducer is passed into the target. The ultrasound gets reflected back from the target. The same transducer (or a separate transducer) receives the reflected signal form the target of the patient. The received signal is amplified and then applied to the y-plates of the CRO.

There are several modes of display to amplify the received information on the CRT Screen. The most commonly used method in medical diagnostic are A-scan, B-scan and T - M scan or C-scan display. Let us discuss the various display method in detail.

A - Scan

A-scan is the simplest form of display and the prime factor in obtaining all the other scans. It gives only an one-dimensional image of the object. In this mode of display, the X-axis represent time taken by the pulse to the reach the reflecting surface and return back to the transducer. Y-axis represent the amplitude of the echoes. The size of the vertical displacement is a measurement of the echo amplitude.

Here, the transducer is fixed at one position and hence, any movement in the echo train is the result of movement of the interface target. The echo encephalogram is an example for A-scan display.

B - Scan

In the case of B-scan display, a brightness is related to the echo amplitude. The echo signal are not applied to the y-plates of the CRO as in the case of A-scan. Instead, they are used to control the brightness of the spot on the screen. This display gives a cross-sectional view of the test object and shows the position, orientation and depth of defects in the specimen. Here Y-axis represents the lapsed time and X-axis the position of the transducer. The schematic representation of the B-scan display is shown in Fig.1.12

This method requires a skilled technical operator since an intimate contact between the probe and skin through oil is required to avoid excess reflection of any air space.

The wide spread application of B-scan ultrasound in diagnostics are to detect pregnancy, multiple foetuses, the age of the foetus, the position of the placenta, etc.,

T-M Scan or C- Scan

In the T-M mode or time-position scan, the movement of echo generating tissues is displayed as a function of time, as shown Fig. 1.13. Applying a low-velocity time base generator across the y-plates of the CRO modify the static B-scan system. The B - scan moves vertically at a constant low-velocity when the sweep time is approximately 3 seconds. Under this condition, if the reflecting interference spot moves, a horizontal deflection in the vertical line pattern is obtained as shown in Fig. 1.13.

This type of display is very much useful in obtaining the pulsating structure such as heart, movement of the mitraval valve related to various period of the heart cycle etc.,

1.11 Sonograms

Sonograms are nothing but recordings of movement of heart. The graphic record of the heart sound is called **Phonocardiogram** and the instrument used to measure the heart sounds is called **phonocardiograph.**

Acoustic events of the heart can be divided into two categories ie., heart sounds and murmurs. Heart sounds have a transient character and are of short duration. Heart murmurs have a noisy characteristic and last for a longer time. In general, heart sounds are due to closing and opening of the valves, whereas the murmurs are due to the turbulent flow of blood in the heart and large vessels.

Recording set-up

A block diagram of the recording set up is shown in Fig. 1.14. The heart sounds are converted into electrical signals by means of a heart microphone fastened to the chest wall by an adhesive strip. The electrical signals from microphone are amplified by a phonocardiographic preamplifier followed by suitable filters and recorder. Further, the electrodes are also placed on the limps to pickup the electrical activity of the heart and these signals are amplified and recorded.

Special application of phonocardiogram

1. **Fetal Phonicardiogrtam:** A sthethoscopic microphone with a large chest piece is applied over that part of the maternal abdomen where auscultation revels fetal heart tones. Simultaneously with the fetal sound tracing, maternal ECG is recorded for comparison.

2. **Esophageal Phonocardiogram :** Basis of interest in the method lies in the fact that the heart sounds are collected from inside the chest. In general, sounds and murmurs have lower frequencies than when recorded by conventional techniques. The heart sounds are with shorter duration.

1.12 Determination of fetal heart movement and blood circulation

The Doppler ultrasonic methods provides diagnostic information about the motion of fetal heart, umbilical cord and placenta.

The required apparatus consists of a transmitter which emits a continuous ultrasonic wave towards the fetal and a receiver which pick up the reflected waves (fig. 1.21) ultrasonic waves of frequency of about 2 MHz is used in this apparatus.

A small amount of gel is placed between the probe and the abdominal wall to obtain good acoustic coupling.

When a continuous ultrasonic wave of frequency f is incident upon the fetal heart the reflected wave will have a higher frequency f' if the feal heart is moving towards the source of sound and a lower frequency f' if the fetal heart moves away from the source of sound.

The fetal heart is determined from the variations in the frequency. The variation of frequency is amplified and can be heared with a loud speaker or displayed in an oscilloscope.

With this method the presence of blood flow in the fetus and mother can be determined.

The blood flow in mothers blood vessels can be distinguished from that in the fetus due to differences in pulse rate. Different parts of the fetus can be examined, from the blood stream velocity in different parts of the fetus.

The change in length produced is independent of the direction of field and depends on the material and strength of field applied.

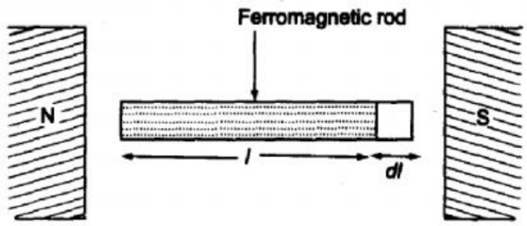

Fig. 1.1 Magnetostriction effect

Now ultrasonic waves will be produced when the frequency of vib rod matches with the frequency of the tank circuit.

Construction

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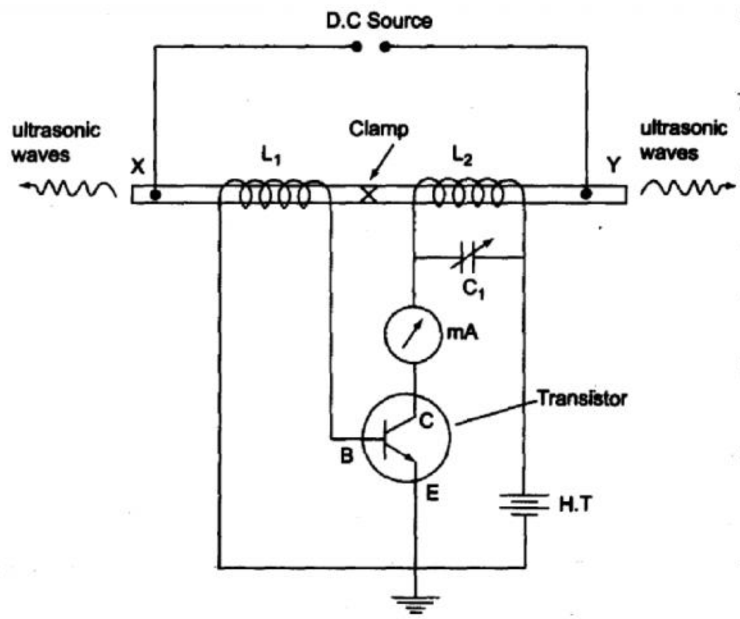

Fig. 1.2 Magnetostriction Generator

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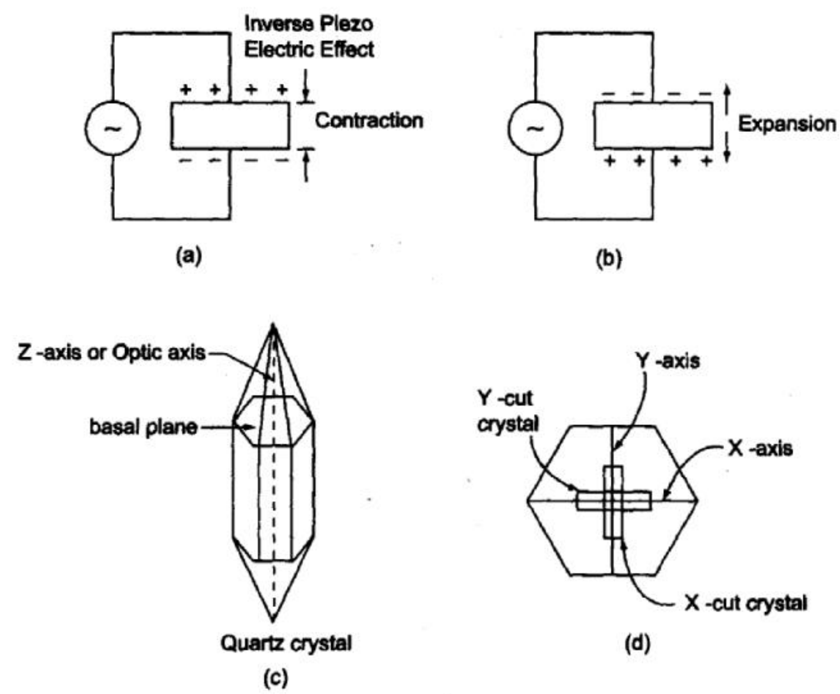

Fig. 1.3 (a) & (b) Contraction and expansion of crystal (c) & (d) Quartz crystal

The natural frequency of the quartz specimen $f = \frac{\rho}{2t}\sqrt{\frac{E}{\rho}}$

Where, t - thickness of the material

E - Youngs modulus of the material and

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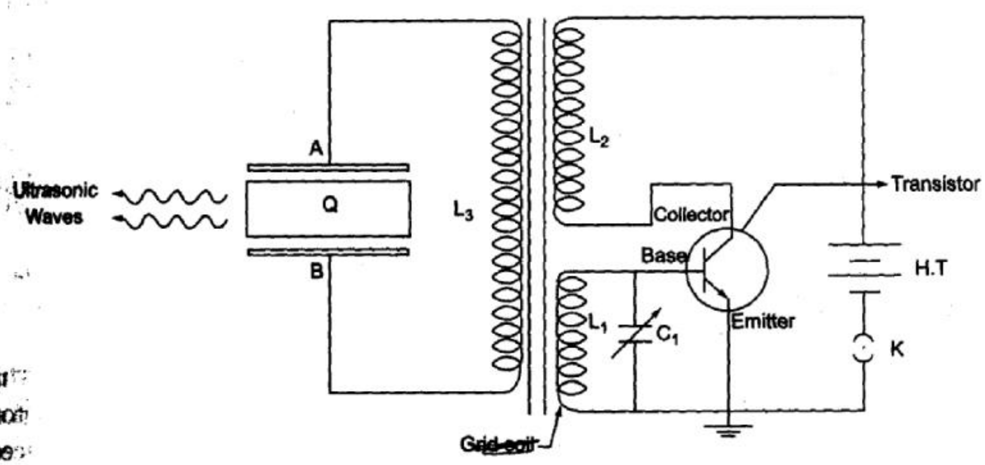

Fig. 1.4

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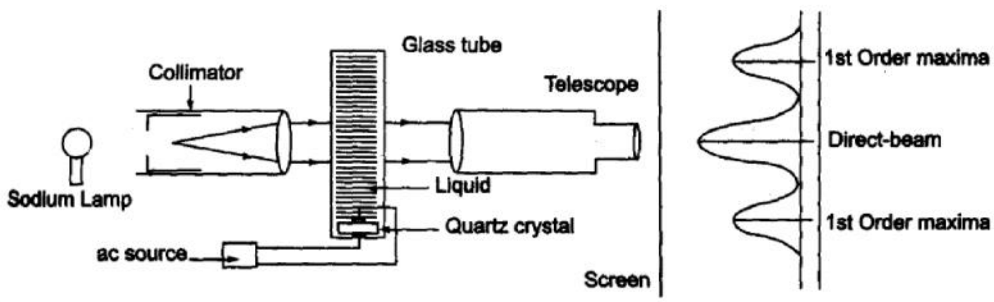

Fig. 1.8 Experimental setup for acoustic grating

Working

Light from the monochromatic source is passed into the liquid in a direction perpendicular to the direction of propogation of ultrasonic waves. When the ultrasonic wave travel through the liquid they get reflected from the opposite side of the vessel.

Longitudinal stationary waves are produced in the liquid medium due to the superposition of the forward and reflected waves. These stationary waves give rise to nodes and antinodes. At the nodes, the density of the liquid is maximum and so the refractive index is maximum. However at antinodes the density of the liquid is minimum and so the refractive index is minimum. Thus the nodes act as opacities and antinodes as transparencies and thereby the liquid coloumn acts as an acoustic grating.

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1.7 Industrial Applications

1.7.1 Ultrasonic Welding

The properties of some materials change on heating. In such cases, the electric or gas welding is not advisable. Such materials can be welded at room temperature with the help of ultrasonic waves. Proper welding can be achieved by sending ultrasonic waves in between the surfaces of the weld during welding called cold welding. This effect is attributed to the momentary relaxation of the bonds.

Construction

When materials are welded through ultrasonic waves, the energy required comes in the form of mechanical vibrations. The welding tool called sonotrode (hammer) is attached to a powerful ultrasonic generator. The part to be welded is placed on the anvil and located just below to tip of sonotrode as shown in Fig 1.10

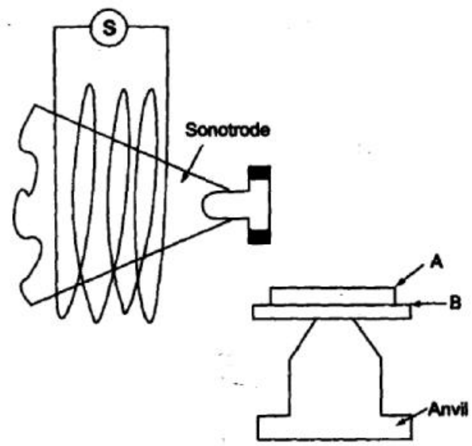

Fig. 1.10 ultrasonic welding

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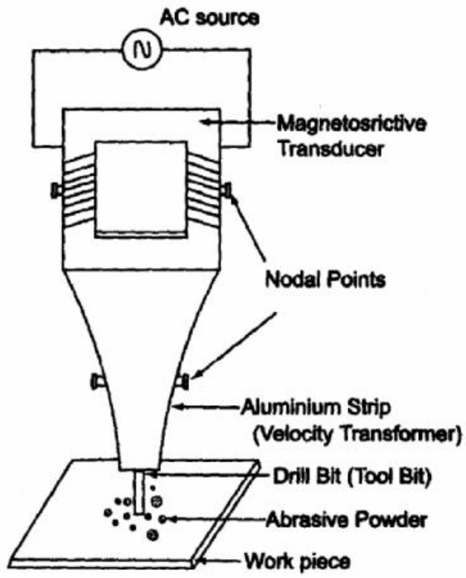

Fig. 1.13 Ultrasonic driller

Advantages of ultrasonic driller over the conventional driller

1. Any odd shaped hole can be drilled.
2. Drilling can be made on a brittle material.
3. No final finish is required.
4. Silent operation.
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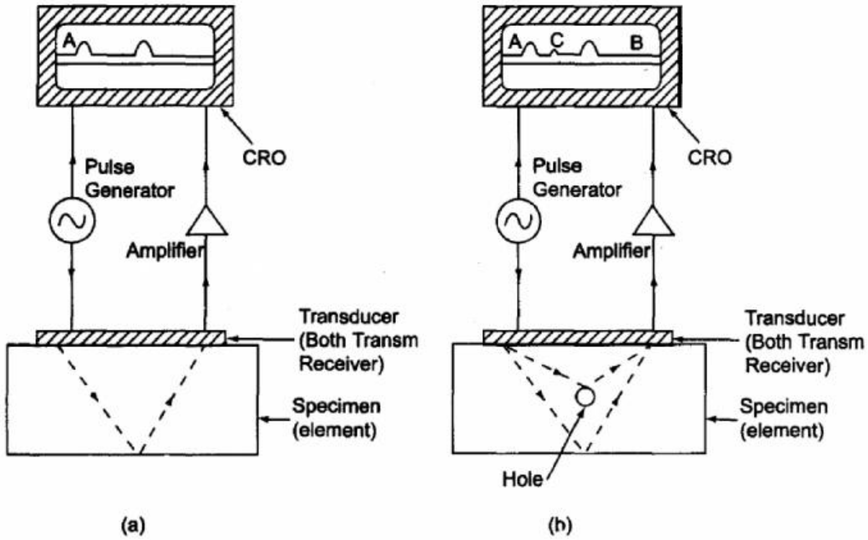

Fig. 1.16 ultrasonic flaw detection

Advantages

1. It can reveal internal defects.
2. This method is highly sensitive to most of the cracks and flaws.
3. It gives immediate results.
4. It indicates the size and location of the flaws exactly.
5. Since there is no radiation in this process, it is a safe method.
6. The cost is very low.

Limitations

1. It is difficult to find the defects of the specimen which has complex shapes.
2. Trained, motivated technicians alone can perform this testing.

Pulse Echo System

The main components of a pulse echo system are transmitter, time-base generator, receiver, swept-gain generator and cathode ray oscilloscope (CRO). The transmitter

Special application of phonocardiogram

1. **Fetal Phonicardiogrtam**: A sthethoscopic microphone with a large chest piece is applied over that part of the maternal abdomen where auscultation revels fetal heart tones. Simultaneously with the fetal sound tracing, maternal ECG is recorded for comparison.

2. **Esophageal Phonocardiogram**: Basis of interest in the method lies in the fact that the heart sounds are collected from inside the chest. In general, sounds and murmurs have lower frequencies than when recorded by conventional techniques. The heart sounds are with shorter duration.

1.12 Determination of fetal heart movement and blood circulation

The Doppler ultrasonic methods provides diagnostic information about the motion of fetal heart, umbilical cord and placenta.

The required apparatus consists of a transmitter which emits a continuous ultrasonic wave towards the fetal and a receiver which pick up the reflected waves (fig. 1.21) ultrasonic waves of frequency of about 2 MHz is used in this apparatus.

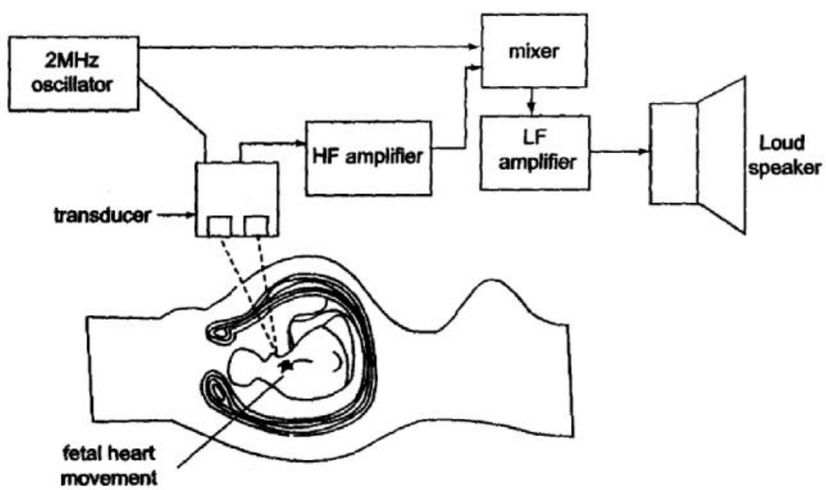

Fig. 1.21 Apparatus for the measurement of fetal heart movement

A small amount of gel is placed between the probe and the abdominal wall to obtain good acoustic coupling.

When a continuous ultrasonic wave of frequency f is incident upon the fetal heart the reflected wave will have a higher frequency f' if the feal heart is moving