Ultrasonic Transducers

- **Ultrasonic transducers** and **ultrasonic sensors** are devices that generate or sense ultrasound energy.
- They can be divided into three broad categories: transmitters, receivers and transceivers.
- Transmitters convert electrical signals into ultrasound, receivers convert ultrasound into electrical signals, and transceivers can both transmit and receive ultrasound.
- Some transducers are,
  - Piezo-electric transducers
  - Polyvinylidene Fluoride transducers
  - Electro-magnetic Acoustic Transducers
  - Laser generated ultrasound

Piezo-electric transducers

- The conversion of electrical pulses to mechanical vibrations and the conversion of returned mechanical vibrations back into electrical energy is the basis for ultrasonic testing.
- The active element is basically a piece of polarized material (i.e. some parts of the molecule are positively charged, while other parts of the molecule are negatively charged) with electrodes attached to two of its opposite faces. When an electric field is applied across the material, the polarized molecules will align themselves with the electric field, resulting in induced dipoles within the molecular or crystal structure of the material. This alignment of molecules will cause the material to change dimensions. This phenomenon is known as electrostriction.
- In addition, a permanently-polarized material such as quartz (SiO2) or barium titanate (BaTiO3) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. This phenomenon is known as the piezoelectric effect.

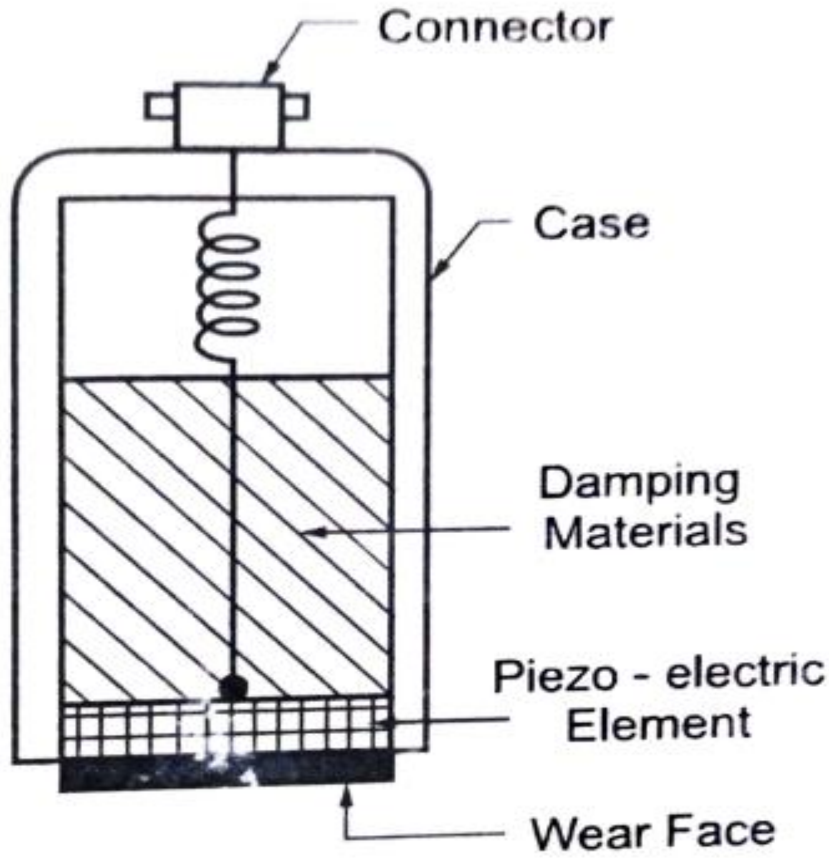


Fig. 4.19: Piezo - Electric Transducer

Electro-magnetic Acoustic Transducers

- Electromagnetic-acoustic transducers (EMAT) acts through totally different physical principles and do not need couplant.
- When a wire is placed near the surface of an electrically conducting object and is driven by a current at the desired ultrasonic frequency, eddy currents will be induced in a near surface region of the object. If a static magnetic field is also present, these eddy currents will experience Lorentz forces of the form

$$\boldsymbol{F} = \boldsymbol{J} \times \boldsymbol{B}$$

- ***F*** is the body force per unit volume, ***J*** is the induced dynamic current density, and ***B*** is the static magnetic induction.
- The most important application of EMATs has been in nondestructive evaluation (NDE) applications such as flaw detection or material property characterization.
- Couplant free transduction allows operation without contact at elevated temperatures and in remote locations.

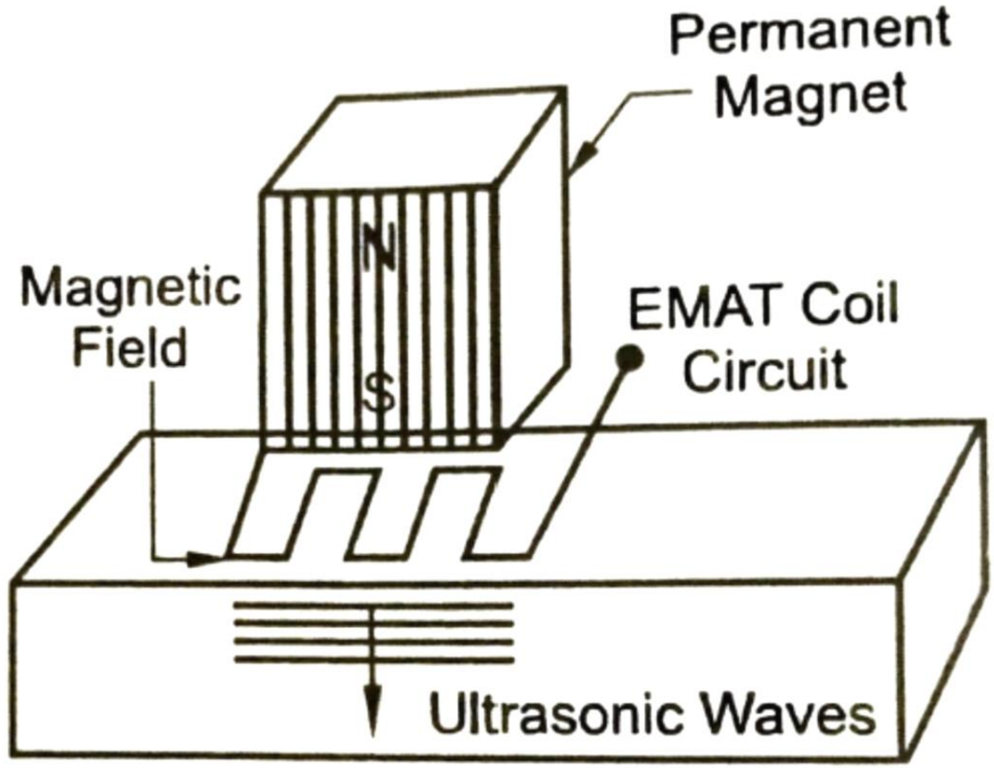
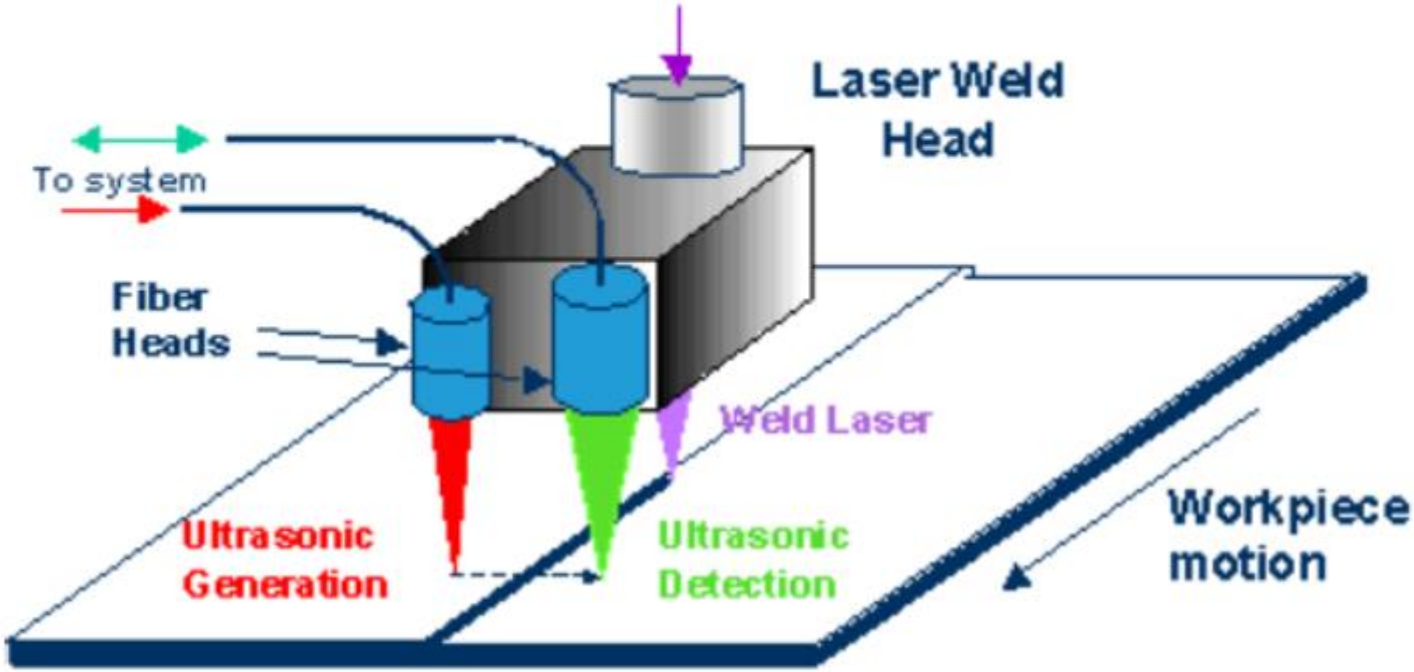


Fig. 4.20: EMAT Transducer

Laser generated ultrasound

- The "Laser Ultrasonic" technique is part of those measurement techniques known as "non-destructive techniques or NDT“.
- However, to fall within the scope of non-destructive measurements, it is preferred to avoid this phenomenon by using low power lasers.
- Laser ultrasonic's is a contactless ultrasonic inspection technique based on excitation and ultrasound measurement using two lasers.
- A laser pulse is directed onto the sample under test and the interaction with the surface generates an ultrasonic pulse that propagates through the material. The reading of the vibrations produced by the ultrasounds can be subsequently measured by the self-mixing vibrometer.
- When the laser beam hits the surface of the material, its behavior may vary according to the power of the laser used.

- In the case of high power, there is a real "ablation" or "vaporization" of the material at the point of incidence between the laser and the surface: this causes the disappearance of a small portion of material and a small recall force, due to compression longitudinal, which would be the origin of the ultrasonic wave.
- The use of a high power laser, with consequent vaporization of the material, is the optimal way to obtain an ultrasonic response from the object.
- Ultrasound detection can therefore be divided into 3 steps: the conversion from ultrasound to phase-modulated optical signal, the transition from phase modulation to amplitude and finally the reading of the amplitude modulated signal with consequent conversion into an electrical signal.

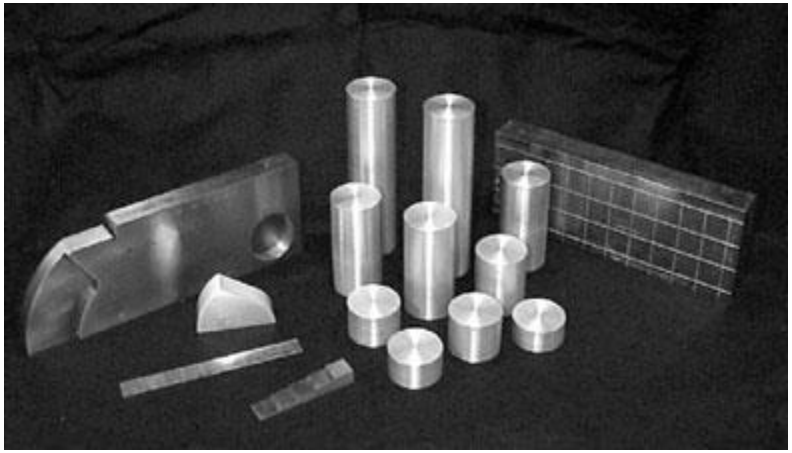


Laser Weld Head
To system
Fiber Heads
Weld Laser
Ultrasonic Generation
Ultrasonic Detection
Workpiece motion

Calibration and Reference blocks

- Calibration refers to the act of evaluating and adjusting the precision and accuracy of measurement equipment.
- In ultrasonic testing, several forms of calibration must occur. First, the electronics of the equipment must be calibrated to ensure that they are performing as designed. It is also usually necessary for the operator to perform a "user calibration" of the equipment.
- This user calibration is necessary because most ultrasonic equipment can be reconfigured for use in a large variety of applications.
- The user must "calibrate" the system, which includes the equipment settings, the transducer, and the test setup, to validate that the desired level of precision and accuracy are achieved.
- In ultrasonic testing, there is also a need for reference standards.
- Reference standards are used to establish a general level of consistency in measurements and to help interpret and quantify the information contained in the received signal.
- Reference standards are used to validate that the equipment and the setup provide similar results from one day to the next and that similar results are produced by different systems.

- Reference standards also help the inspector to estimate the size of flaws. In a pulse-echo type setup, signal strength depends on both the size of the flaw and the distance between the flaw and the transducer.
- The inspector can use a reference standard with an artificially induced flaw of known size and at approximately the same distance away for the transducer to produce a signal. By comparing the signal from the reference standard to that received from the actual flaw, the inspector can estimate the flaw size.
- Calibration and reference standards for ultrasonic testing come in many shapes and sizes. The type of standard used is dependent on the NDE application and the form and shape of the object being evaluated.
- The material of the reference standard should be the same as the material being inspected and the artificially induced flaw should closely resemble that of the actual flaw.



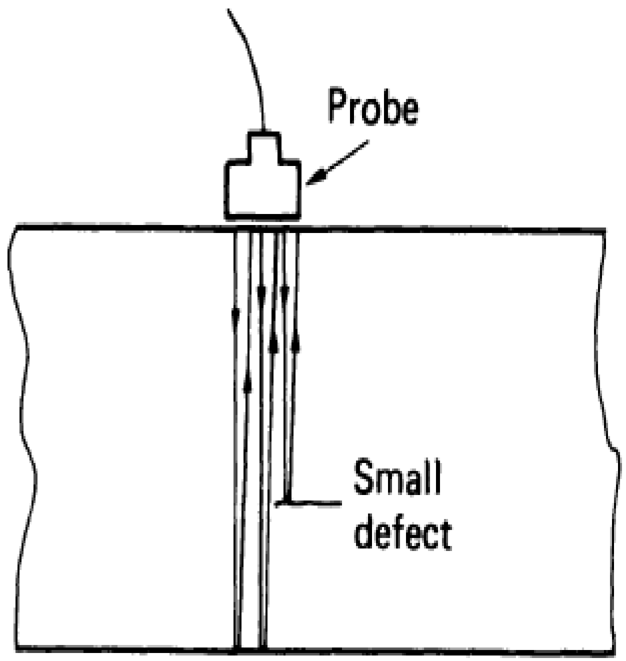
https://www.nde-ed.org/EducationResources/CommunityCollege/Ultrasonics/CalibrationMeth/calibrationmethods.htm

Type **of display**

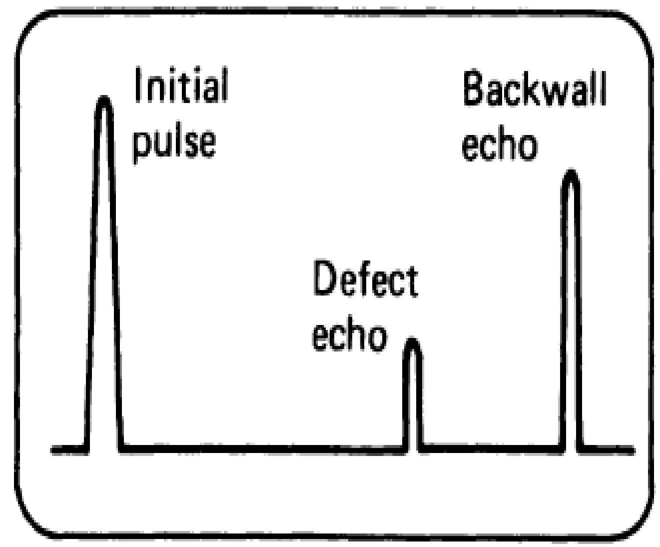
- The information obtained during an ultrasonic test can be displayed in several ways.
  - A scan
  - B scan
  - C scan

A scan display

- The most commonly used system is the 'A' scan display. (**Amplitude mode display)**
- A blip appears on the CRT screen at the left-hand side, corresponding to the initial pulse, and further blips appear on the time base, corresponding to any signal echoes received.
- The height of the echo is generally proportional to the size of the reflecting surface but it is affected by the distance travelled by the signal and attenuation effects within the material.
- The linear position of the echo is proportional to the distance of the reflecting surface from the probe, assuming a linear time base. This is the normal type of display for hand probe inspection techniques.
- A disadvantage of 'A' scan is that there may be no permanent record, unless a photograph is taken of the screen image, although the more sophisticated modern equipment has the facility for digital recording.


Probe
Small
defect

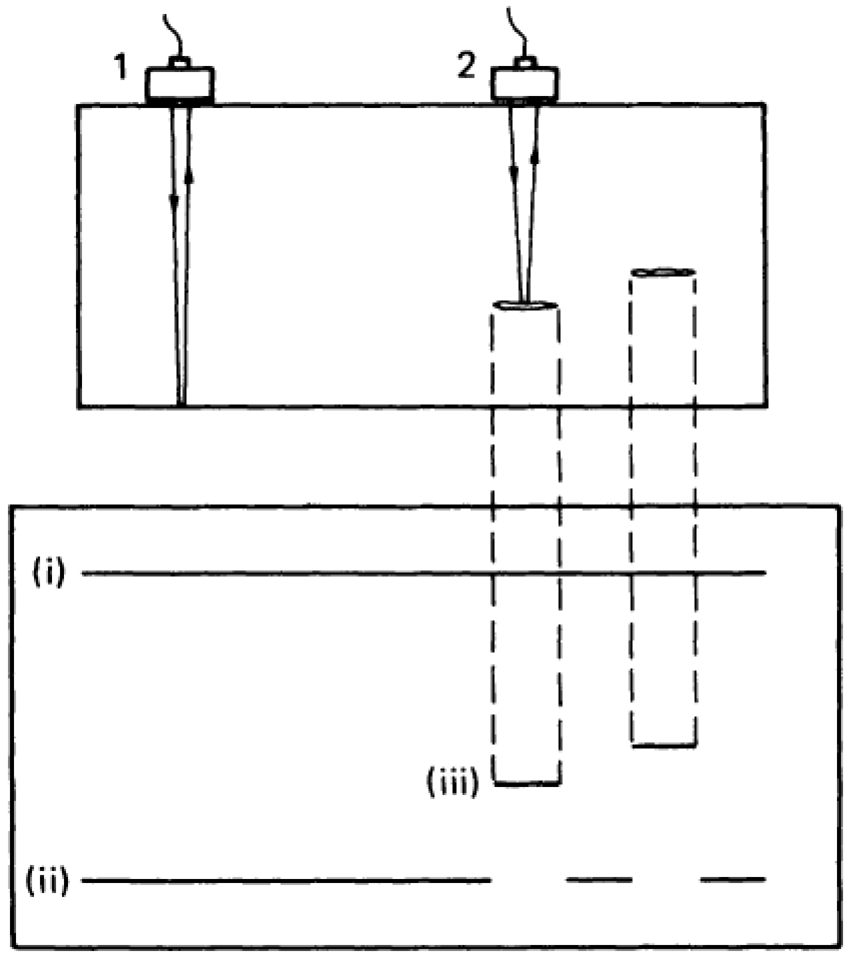
(a)


Initial
pulse
Backwall
echo
Defect
echo

(b)

'B' scan display

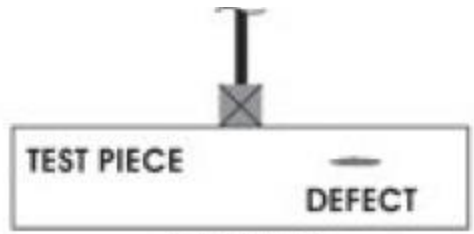
- The 'B' scan enables a record to be made of the position of defects within a material. {**Brightness Mode Scan**}
- The system is illustrated in figure. There needs to be co ordination between the probe position and the trace, and the use of 'B' sc an is confined to automatic and semi-automatic testing techniques.
- With the probe in position 'I‘ the indication on the screen is as shown in figure, with (i) representing the initial signal and (ii) representing the back wall.
- When the probe is moved to position '2', line (iii) on the display represents the defect. This representation of the test piece cross-section may be recorded on a paper chart, photographed, or viewed on a long-persistence screen.



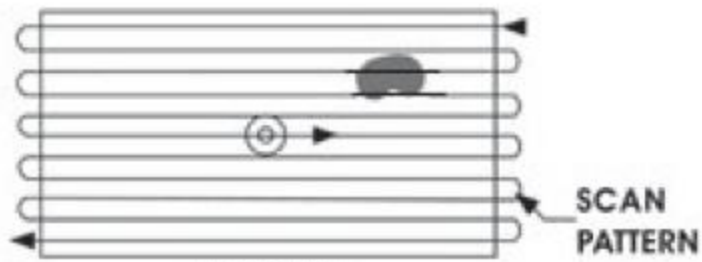
1
2
(i)
(iii)
(ii)

'C' *scan display (***Time –Motion Mode***)*

- While 'B' scan gives a representation of a side elevation of the test piece, another method, termed 'C' sc an can be used to produce a plan view. 'C' scan display is confined to automatic testing.
- This method is used to obtain the information about the moving object.
- This combines the features of both A-Scan as well as B-Scan.



SIDE VIEW



TOP VIEW

C-SCAN PRESENTATION

Applications

The applications of Ultrasonic Transducers are

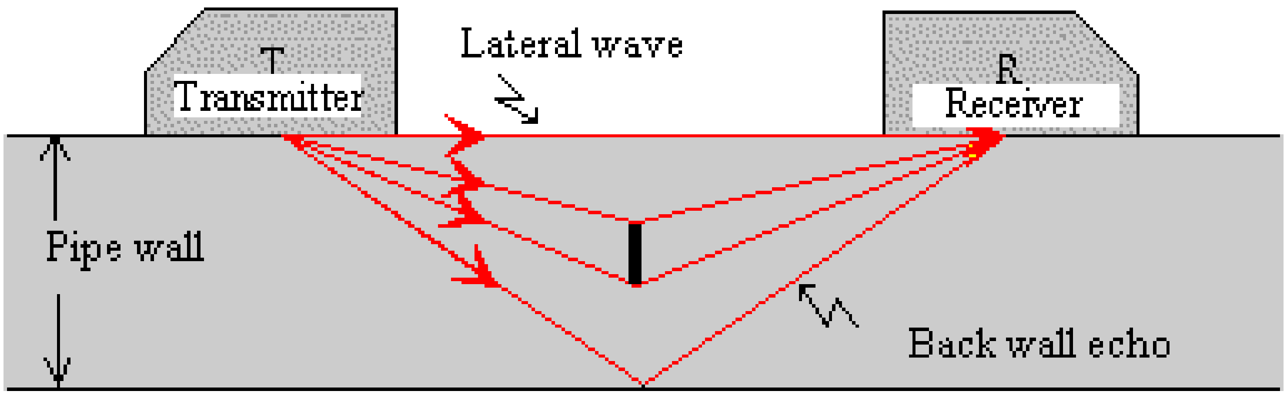
- These transducers have many applications in different fields like industrial, medical, etc. These are having more applications because of ultrasonic waves. This helps finds the targets, measure the distance of the objects to the target, to find the position of the object, to calculate the level also the ultrasonic transducers are helpful.
- In the medical field, the ultrasonic transducer is having the applications in diagnostic testing, surgical devices while treating cancer, internal organ testing, heart checkups, eyes and uterus checkups ultrasonic transducers are useful.
- In the industrial field, ultrasonic transducers have few important applications. By these transducers, they can measure the distance of certain objects to avoid a collision, in production line management, liquid level control, wire break detection, people detection for counting, vehicle detection and many more.

Advantages and Disadvantages

- Any system has advantages and a few disadvantages. Here will discuss the **advantages of the ultrasonic transducer.**
- These ultrasonic transducers can able to measure in any type of material. They can sense all types of materials.
- The ultrasonic transducers are not affected by temperature, water, dust or any.
- In any type of environment, the ultrasonic transducers will work in a good manner.
- It can measure in high sensing distances also.
- The **disadvantages of these transducers** include the following.
- Ultrasonic transducers are sensitive to temperature variation. This temperature variation may change the ultrasonic reaction.
- It will face problems while reading the reflections from small objects, thin and soft objects.

Time of Flight Diffraction Technique

- TOFD uses the time of flight of an ultrasonic pulse to find the location of a reflector.
- It can also be used for weld overlays and the heat affected zones of other components as well such as piping, pressure vessels, clad material, **storage tanks**, and structural steel.
- TOFD works by emitting sound waves into a component and measuring the time from them to return. What makes TOFD different from other UT methods is that, rather than measuring only for the high amplitude sound waves that reflects off of the back of the component, it instead measures the response time of low amplitude waves that are diffracted by the tips of cracks.
- TOFD uses a pair of ultrasonic transducers, one as a transmitter and the other as a receiver. The low frequency waves propagate at an angle and only diffract back to the receiver if they hit a defect. If this happens, the time it takes for both waves to make it to the receiver can be used to create a complete image of the weld and identify the size and location of the damage.



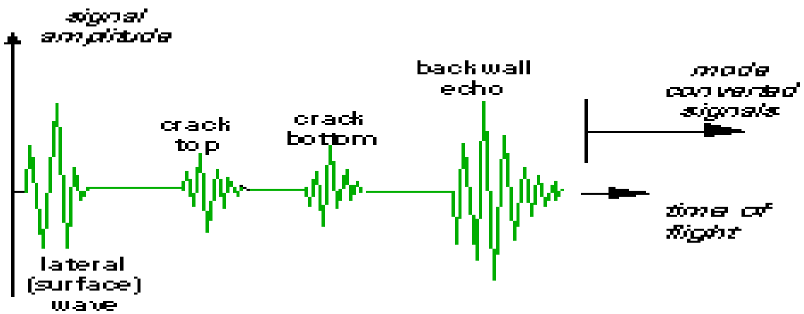


Fig. 4 - schematic of TOFD A-scan

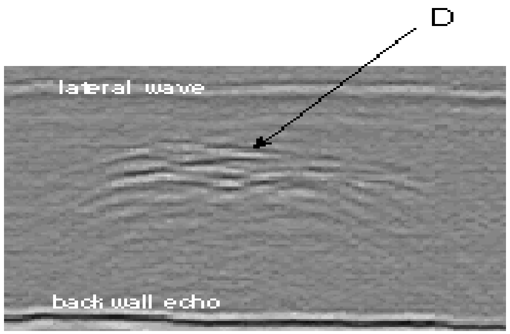


Fig. 5 - TOFD D-scan of butt weld and defect

Time of Flight Diffraction Technique

- It can locate and measure the size of many different types of defects with incredible precision. It also has a high degree of repeatability. Because of this, the growth of any flaws can be tracked over time.
  - Two angle beam probes (usual 45°) are placed as a transmitter-receiver arrangement and are connected together (Fig 1). The distance of the probes is calculated according to the wall thickness.
  - Longitudinal waves are usually applied. The sound beam spread is large to maximize the extent of the scan.
  - The A-scan (Fig 4) [9] shows the so-called lateral wave, the back wall echoes and between both signals other signals can possibly appear, which can occur due to inhomogeneity. The A-Scan is not rectified in the TOFD technique.
  - TOFD technique is always applied with imaging methods.