Ultrasonic Testing (NDT)

1

* Used for bulk of the material.
  if flaw or defects are much below the surface
* Used for surface and subsurface of the materials.

Ultrasonic waves —
frequency > 20 KHz

for ultrasonic
$20 < f < 10\,MHz$

Nature of ultrasonic waves

wavelength 1 to 10mm
frequency — 0.1 to 15 MHz

$$\lambda = \frac{v}{f}$$

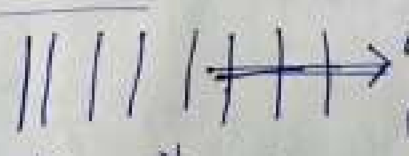
v — velocity
f = frequency

- travel at different speeds in different media
- In most of the metal, velocity change with frequency is not significant

Wave types —

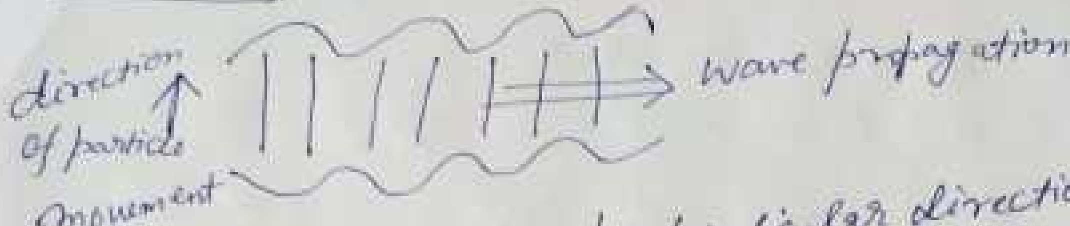
1- Longitudnal
2- Transverse

Longitudnal waves



* movement of particles (direction) parallel to direction of movement of wave

Transverse Waves



particle will move in a perpendicular direction particles are going up & down and wave is moving horizontally.

Movement of particles are not coordinated or easy in comparison of Longitudinal waves.

Velocity Longitudinal waves > Transverse direction

$$v = \sqrt{\frac{C_{IJ}}{\rho}}$$

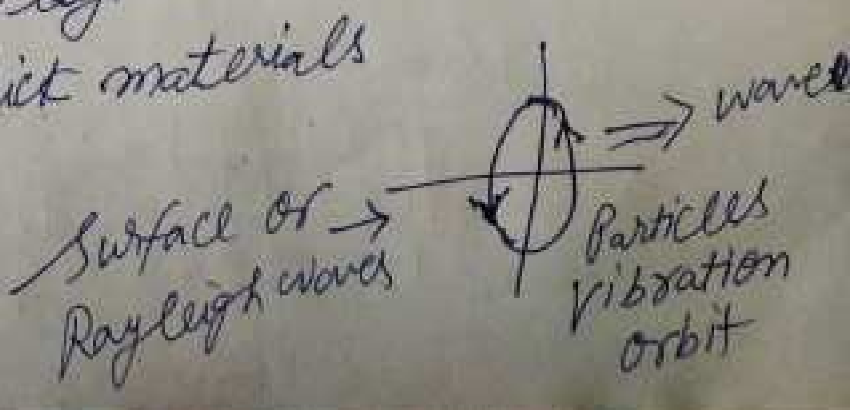
C_{IJ} - elastic Constant
↓
Youngs modulus → used for Longitudinal waves
Shear modulus
↓
transverse waves

ρ = density

Surfaces or Interfaces various

→ types of movement path
  eg example - elliptical or other Complex vibration

→* Surface or Rayleigh waves – which are generated in relatively thick materials



In thin plates

Plate waves

Lamb Component
Of the vibration perpendicular
⊥ to the surface

Symmetric Lamb or Extended

Love
parallel to the plane layer & perpendicular to the direction waves

Asymmetric Lamb
|
flexural mode

* Our focus will be on Longitudinal & transverse waves only in case of UT.

Basic principle — Reflection of sound waves or the echo of Sound

* If you talk loudly in a empty room, the wall will reflect the sound and we will get a echo.

In ultrasonic testing — Ultrasonic waves are send into the sample and when the these waves are reflected back, they are collected by a transducer which will finally generate a signal if there is any defect.

* Defect also act as a reflector which can reflect the sound waves.

+ Reflection interface is much smaller compare to wall.

* Energy in the refelected waves should be enough for the

transducer instrument to collect the signal pattern.

* Energy in the transmitted sound waves is depend on sound pressure which is created by this travelling waves.

* Sound waves travell through a medium by oscillatory movement of the atoms or the particles. This movement is arises due to local pressure created by sound.

* Excess pressure above the atmospheric pressure
This local pressure provides some movement to the atoms and due to the bonding between the atoms, it creates oscillatory movement which in turn create a wave. This is how the sound waves propagate through a particular medium.

Local pressure $P \propto Q$ (velocity of the movement)
↳ velocity to the particle or atoms

higher the p ⇒ higher the movement of atom or particle

$$P = Z Q$$

$$Z = \frac{P}{Q}$$

↓
Acoustic Impedance

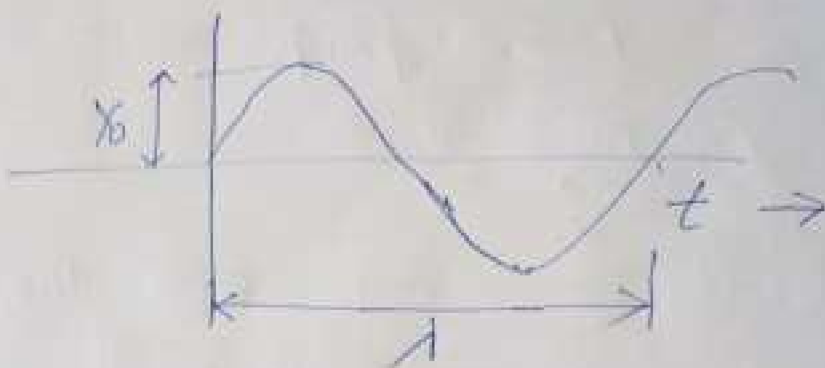
Energy of the transmitted wave

$$E = P^2 / 2\rho v$$

ρ → density of the medium
v → velocity of the sound waves

$$Y = Y_0 \sin(\omega t - kx)$$

Y_0 - amplitude
t = time
$\omega = 2\pi f$
k = wave number
$= \frac{2\pi}{\lambda}$



$$\delta = \frac{dy}{dt}$$

$$= \omega Y_0 \cos(\omega t - kx)$$

This is the effect -
Effect of sound waves when it travels through a medium, it provides this velocity δ and the resistance to the movement of sound waves is given by parameter acoustic impedance

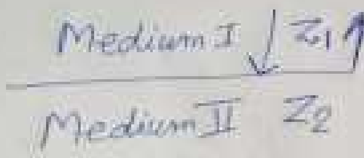
Lecture - 2 (Ultrasonic Testing)

Acoustic Impedance

$$Z = \frac{P}{\delta}$$

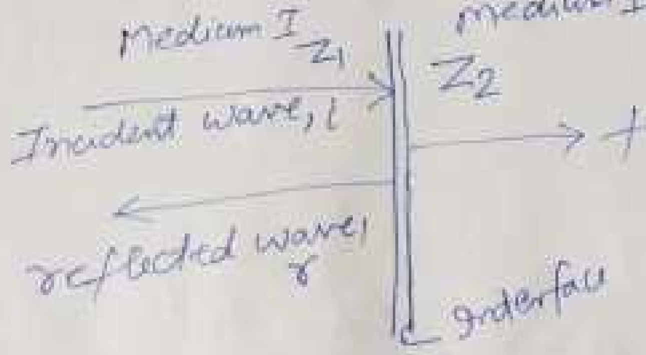
* Discontinuities or boundaries will give rise to change in Z. This change can be detected - Sound waves reflected from these boundaries because the energy in the reflected beam depend on this change.

If you have two medium 1 + 2



Energy of reflected beam $\propto Z_2 - Z_1$

Sound wave are moving ~~with~~ with a particular velocity



$$\left.\begin{array}{l} P_i + Q_r = Q_t \\ P_i + P_r = P_t \end{array}\right\}$$

* When there is a change in the impedance and when the sound encounters the interface, a part of the sound waves will be reflected and a part of the wave will be transmitted.

* Energy of the reflected beam is the main concern for doing NDT.

The interface could be defect itself so when the sound wave encounter the discontinuity, it will reflect a part of the sound wave. And Energy of the reflected beam depend on change in the Acoustic impedance across the interface.

that can be calculated

$$\left.\begin{array}{l} P_i + Q_r = Q_t \\ P_i + P_r = P_t \end{array}\right\}$$

$i \rightarrow$ incident beam

Q – velocity given to the atom

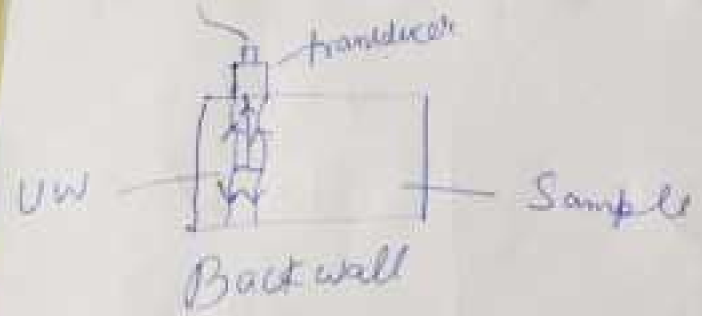
Across the interface

Fraction of energy reflected

$$R_E = \left(\frac{Z_2 - Z_1}{Z_1 + Z_2}\right)^2$$

So if you have enough energy in the reflected beam coming out from flaw then this can be easily capture through an instrument and then you can generate a defect signal and get the indications about the presence of defects & flaws in a given sample.

Ultrasonic Transducer –



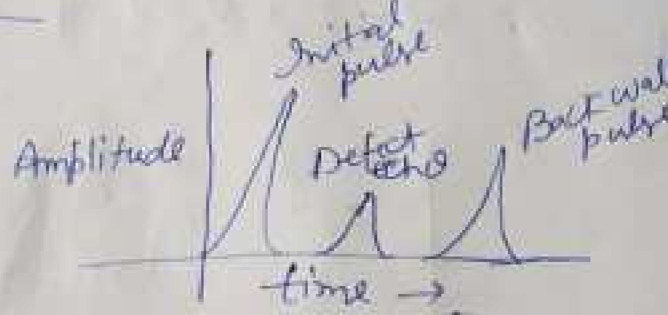


Fig. 2

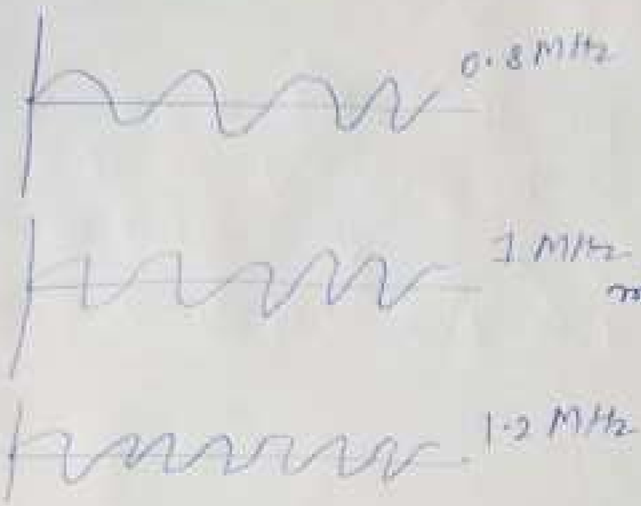
* transducer generates ultrasonic waves.
* Ultrasonic waves will goto other surface and hit the back wall and come back. In between if you have any defect somewhere so this will also be reflected from this defect and this will generate a signal shown in fig. 2 in the time base.

→ You will observe initial pulse first into the sample and after hitting the back wall, Back wall pulse will be observed.

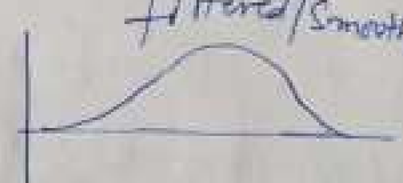
- If you have a defect ■ as shown in Fig. 1 then it will come between initial pulse and back wall pulse such as defect echo.

Pulse Shape and beam Shape –

* Ultrasonic waves are used in a particular frequency range.
* If you are selecting a particular frequency that may consist of mix frequency that may be + – to that selected frequency.



If you take resultant of all frequency choosen



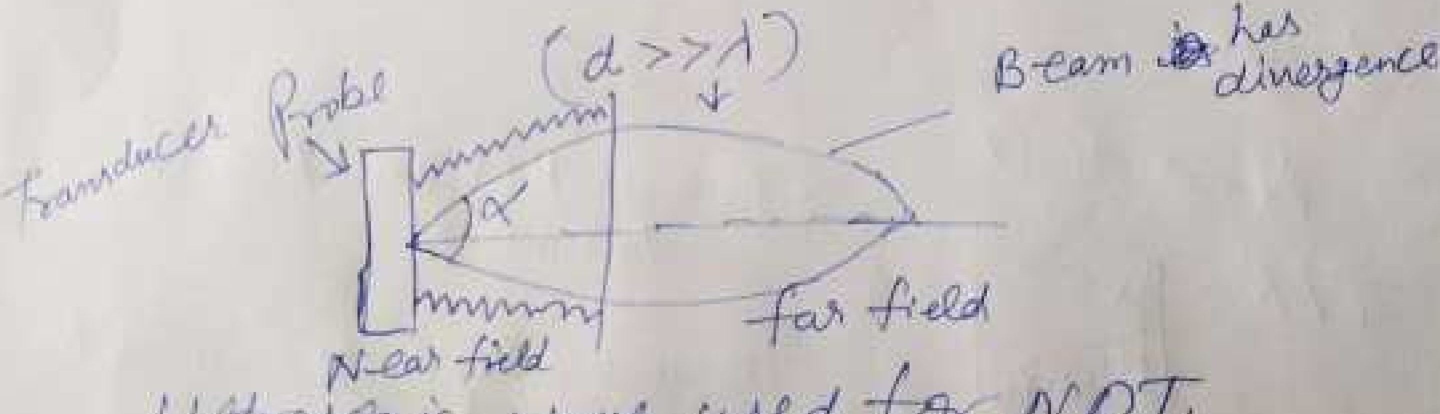
Beam Shape

$\lambda >> d$ (i) (ii) $\lambda = d$ $\lambda << d$ (iii)

d – diameter of transducer

* When you increase the size of transducer, it is much bigger compare to wavelength of soundwaves.
* this will not act as single point source like you have case in Ist scenario. ($\lambda >> d$)

* When $d >>> \lambda$ (d much larger than λ) then Source will act as multiple point source.
Same ultrasonic pulse or beam generated by a single transducer because of beam size w.r.t sound wave wavelength this will act as multiple point sources.
* So sound waves coming out from different sources interact with each other and there will be constructive and destructive interferences. So this directionality that you see is due to constructive interference.
* Therefore, In a particular direction you have a constructive interference and wave increases in that particular direction
* This phenomenon due to constructive interference from multiple sources is known as <u>diffractional effect.</u>



Ultrasonic wave used for NDT.

* Most of the transducer, lot of flactuation in the intensity and as it goes away from the transducer then beam become more uniform as these flactuations dried up and beam will become more uniform.

So there are two resonance

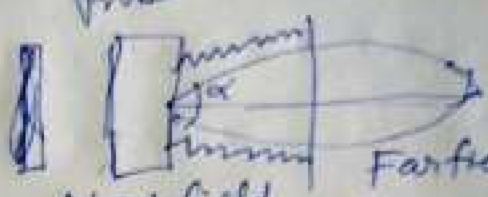
Near field — fresnel zone $\rightarrow N = \frac{d^2}{4\lambda} = \frac{d^2\nu}{V}$, $\lambda = \frac{V}{\nu}$

far field — fraun hofer zone

V = velocity

ν – frequency

$\sin \alpha = \frac{1.22\lambda}{d}$



for steel 1 MHz

$d = \frac{3''}{8}$ $\frac{1''}{2}$ $1''$

N 0.15 0.27 1.1

α 48°10' 34° 16°10'

As you vary the size of probe at particular frequency this is how the near field and far field would change.

Near field

T/R

→ Transmitter and Reciever transducer

Transmitter or probe can not recieve untill the transmission is completely stopped.

So in this case near field, if it is still vibrating that means it is still transmitting so any echo comes back within that time (when it is still vibrating) then it would not be able to recieve that echo.

So probe will have enough time for this fluctuations to dry down completely by the time the echo comes back to the probe, it will be ready for reciving.

So due to that delay (provided by delay layer), the ~~by the~~ probe will be ready for the recieving by the time echo comes back even if it is formed near surface respectively.

Other ways to avoid Dead Zone

- **Dual element probe**

  two active element — Ultrasonic pulses

  Piezoelectric element
  - One is used for transmitter
  - Other is used for reciever

- **Immersion Testing**

  Sample and/or probe are immersed in liquid such as water.

* It is well known that velocity of sound in water is much lower compared to dielectric metals. If you have metallic sample then immersed the sample inside water so when the echo come out from the sample, it has to travel through water part since the velocity of sound in water is

and that can happen if the echo comes back very fast comes back quickly. that means something is very close to the surface of the sample. Some defects or reflecting interference is very close to the probe then there is a chance that particular defect will be missed because the echo coming out from that defect will not be recieved by the transducer because it is still vibrating since echo is coming back very fast. So that particular distance is known as dead zone.

Dead zone = distance into the sample which can not be inspected due to the near field flacatuations

The probe can not recieve when it is still transmitting.

Dead zone can be addressed

- A shorter path
- Delay version of probe — Delay layer made of polymeric material in which velocity of sound is lower.

Since the velocity in this layer is lower. it delay the sound wave when it comes back to the probe.

much lower, it will delay the sound waves coming out from the sample by the time they reach the probe which is at top surface of the water of liquid. By the time it have enough time due to this delay for all those fluctuations to come down / dry down completely and the transducer is ready to recieve.

Ultrasonic probes

Ultrasonic transducer — a single spike of electrical signal of short rise-time is converted to high frequency mechanical vibrations.

* Main Component of ultrasonic transducer is a piezoelectric element which converts electrical signals into mechanical vibrations of ultrasonic waves

piezoelectric element — which vibrates at particular frequency when you apply an electrical signal and the vibration frequency will depend on thickness of the element

vibration frequency → vibrates with a λ which is twice the thickness of the element.

* for higher frequency - thickness will be lower
* elements will be cut out in thin wafer.

Commonly used piezoelectric material

→ Quartz – Single Crystal
PZT — Lead (Pb) P, Zirconate Z titanate T
Piezoelectric material

parameters which Controls the transmission and receiving properties

⇒ electrical signal → vibration
if electric field F is supplied, mechanical stresses (σ) is generated then

$F \propto \sigma$, → $F = \beta\sigma$

$\epsilon \propto F$, → $\epsilon = \alpha F$

(ϵ → Mechanical Strain)

→ If you have mechanical vibration/ strength that will also generate electrical signal.

Electro acoustic transducer
$F = \beta\sigma$, $\epsilon = \alpha F$

Main Component of ultrasonic transducer is a thin waffer of a piezoelectric element which when excited by an electrical signal it will generate the ultrasonic vibrations.

These element has to be housed properly inside a some kind of Casing where we provide all the electrical leads & other things to supply the electrical signal then you have also shield it from other mechanical vibrations to there will be enough damping at the background of this element.

* To have a good transmitter β should be high.
* To have a good reciever, α should be high.

$\sigma \propto \epsilon$ $\quad F = \beta\sigma \quad \epsilon = \alpha F$

$\sigma = Y\epsilon$

Y - Young modulus

$$Y = \frac{\sigma}{\epsilon} = \frac{F/\beta}{\alpha F}$$

$$\boxed{Y = \frac{1}{\alpha\beta}}$$

Y → material constant
Not possible to optimize α & β both together simultaneously in transducer.
You either have to compromize with the recieving ability or to compromize with the transmission ability.

⇒ Commonly used material piezoelectric materials the values of α & β are enough for transmitting & recieving.

Quartz large β - 58 $Vm^{-1}Pa^{-1}$
α is low - 2.3 m/V
] - good as a reciever

PZT high α value = 374
β value = 15
] - good piezoelectric element for ultrasonic transducer

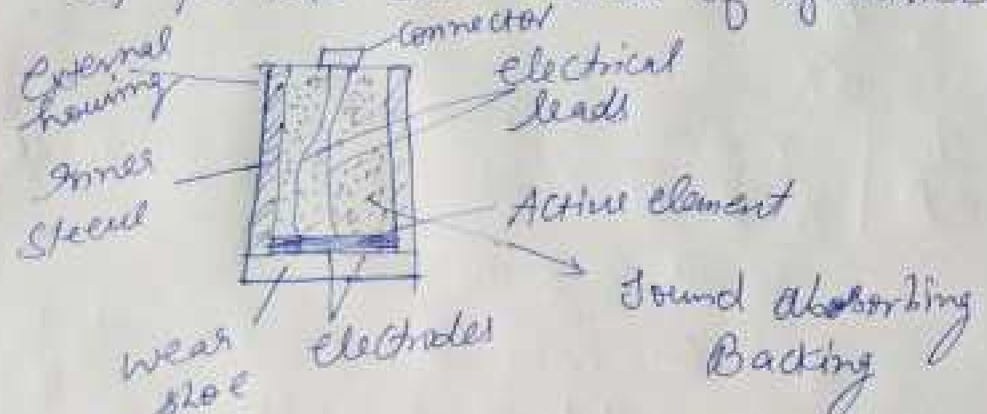
Damping Capacity - ability to absorb vibration

By the time echo comes back to the transducer, it should be ready to recieve them. It should not vibrate when echo comes back to the transducer. therefore it should also have damping capacity so that their vibration could be ~~easily~~ absorb quickly and the probe is ready to recieve after the transmission is over!

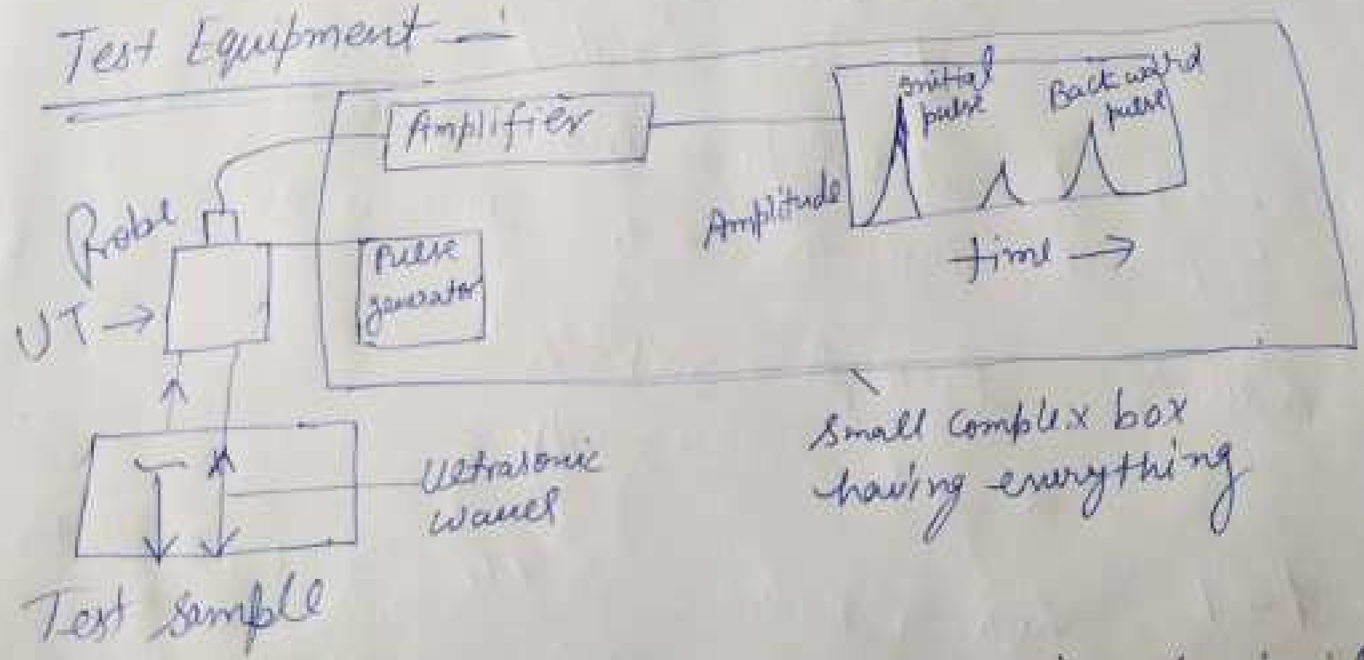
PZT → Good damping capacity

Construction of UT Probes

Mainly they are either cylindrical or rectangular shape. If you take cross-section of cylindrical

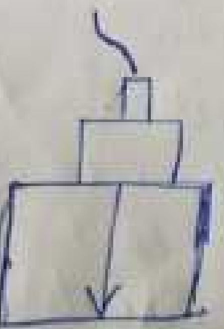


Test Equipment —

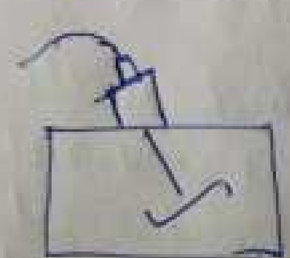


Incident Angle

→ Two condition (i) When incident angle α = 0 (ii) α have some angle

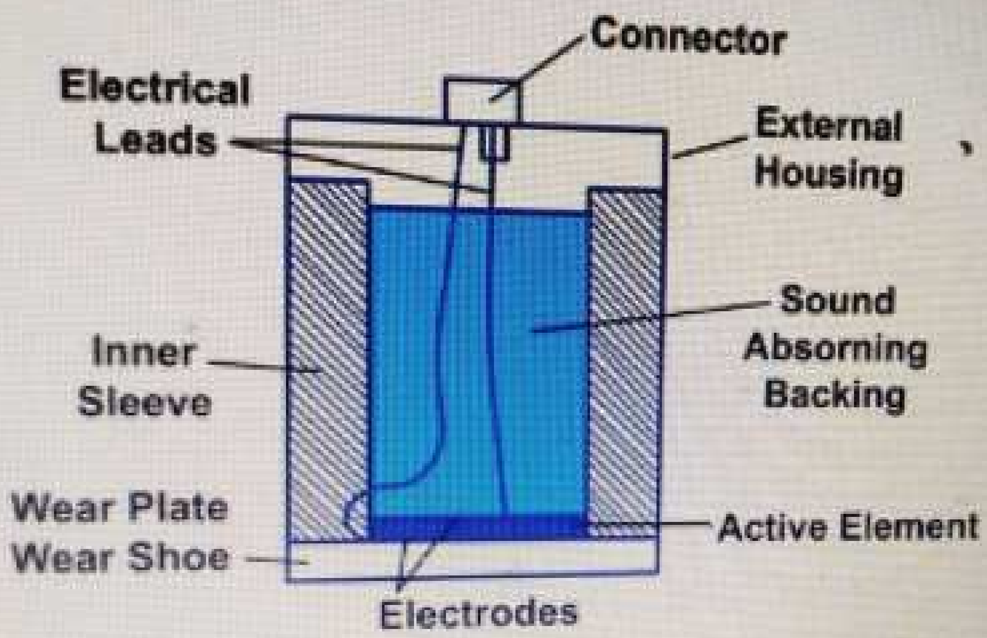


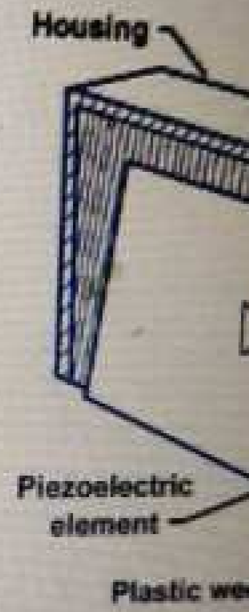
(i) Normal probe

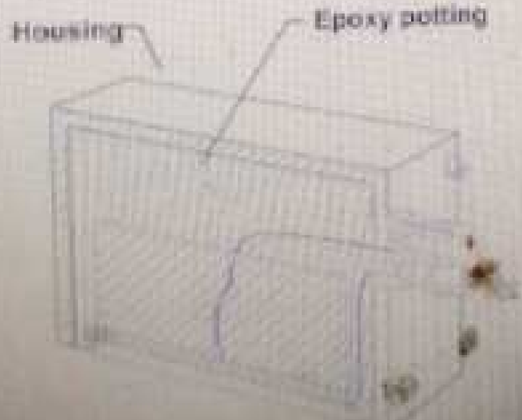


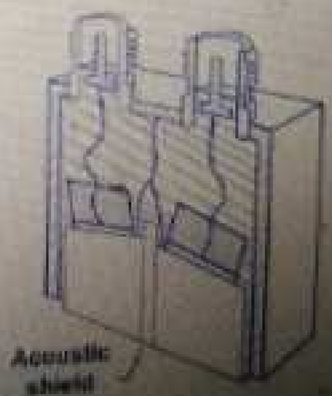
(ii) Angle probe

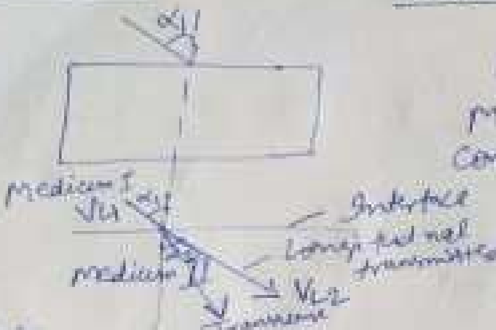
Ultrasonic testing Probe











Longitudinal wave

↓ mode conversion

Shear waves or transverse wave

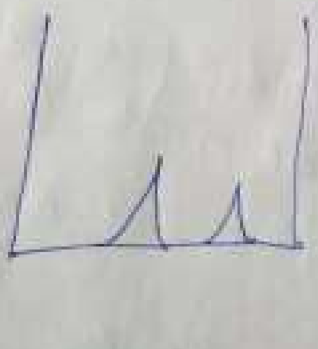
There is possibility that at the interface there will be kind of mode conversion, longitudinal waves converted into transverse waves or shear waves when the incident angle is more than 0.

When you are using angle for doing test that mean because of mode conversion two kinds of waves will enter the sample longitudinal wave & shear waves.

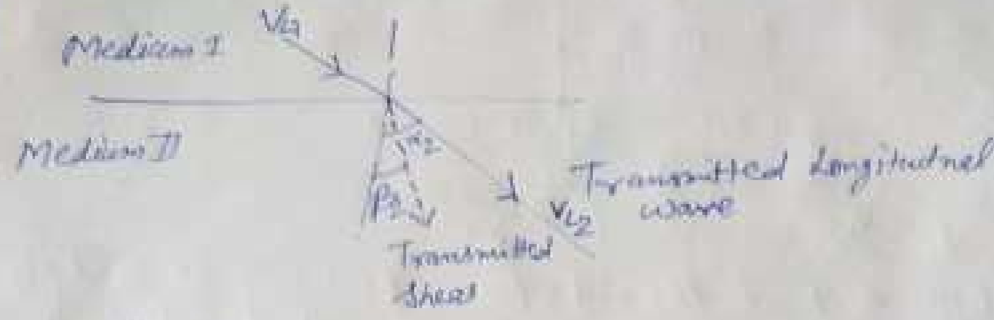
velocity of shear wave is lower than longitudinal wave

Shear wave velocity < Longitudinal waves

+ When these waves reflect back from interface & discontinuity also, they will arrive at the probe at different time, that means reflections from the same interface will arrive at different time, we see them on screen, this will confuse the examiner and that is why it is always have to be one kind of wave going into the sample and coming back to the probe.



Mode Conversion



Snell's Law

$$\frac{\sin\alpha_1}{\sin\alpha_2} = \frac{V_{L1}}{V_{L2}}$$

$$\frac{\sin\alpha_{Ist\,critical}}{\sin 90^\circ} = \frac{V_{L1}}{V_{L2}} \qquad \alpha_{Ist\,critical} = \sin^{-1}\left(\frac{V_{L1}}{V_{L2}}\right)$$

If angle is more than $\alpha_{Ist\,critical}$ then this longitudnal wave reflected back into the first medium and it will not be transmitted.

Longitudnal waves are not intering the sample ($\alpha_{critical} < \alpha$)

$$\frac{\sin\alpha_1}{\sin\beta_2} = \frac{V_{L1}}{V_{S2}}$$

V_{S2} - velocity of shear wave in medium 2

$$2^{nd}\ \text{critical angle} = \sin^{-1}\frac{V_{L1}}{V_{S2}}$$

Only Shear waves entering the sample (medium 2) then the incident angle should be in between Ist critical & 2nd critical angle. It should be greater then Ist Critical.

Ist Critical < incident angle < 2nd Critical

↓

Only shear waves enter the sample

<u>Steel sample</u> Probe – plexiglass face

Medium I – Plexiglass
Medium II – Steel

$V_{plas} = 2.67 km/s$ $V_{steel} = 5.95 km/s$

$V_{s\text{-}steel} = 3.2 km/s$

I^{st} Critical $= \sin^{-1} \frac{V_{L1}}{V_{L2}}$

$= \sin^{-1} \frac{2.62}{5.95}$

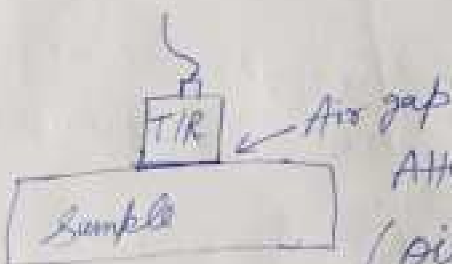
$= 27.5°$

II^{nd} Critical $= \sin^{-1} \frac{V_{L1}}{V_{S2}}$

$= \sin^{-1} \frac{2.67}{3.2}$

$= 56.6°$

Incident angle is $45°$ for this case



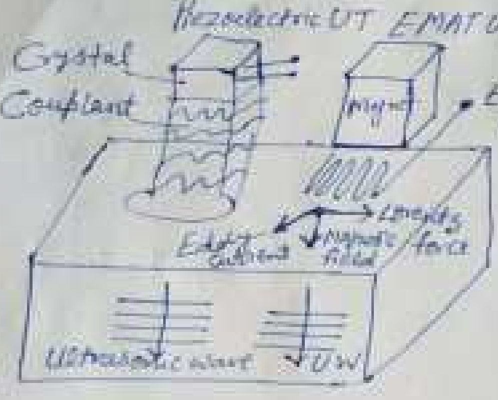
Attenuation
(oil, grease, gel)
Couplant

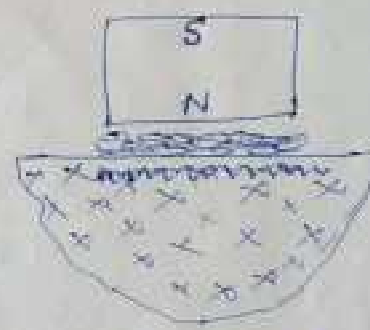
<u>Couplant must be</u>

- as thin as possible to avoid alteration of beam direction
- wet both transducer and test sample surface.
- able to fill all irregularities to provide a smooth surface.
- Allow free movement of the transducer.
- Easy to apply, easy to remove
- must <u>be</u> harmless to the surface.

Lecture - 6

Electromagnetic Acoustic Transducer (EMAT)





$$F = J \times B$$

* Based on electromagnetic induction
* have normal piezoelectric transducer
* do ~~most~~ not need contact of Ultrasonic transducer to the Surface of Sample.
* Ultrasonic waves are generated through electromagnetic induction. Therefore this kind of probe is known as Electromagnetic acoustic transducer.

Working principle

* Electromagnetic induction- If you have a Conductor carrying an alternating current, it will have an alternating magne[tic] field or a change in magnetic field around it and now if you bring another Conductor close to it due to change in magnetic field current will be induced in the second Conductor. This is the phenomena of electromagnetic induction or simply induction.

If you bring a magnet close to the surface, due to this another magnet field and induced current, a mechanical force will be generated which is known as Lorentz force.

Lorentz force $F = J \times B$ $B \rightarrow$ magnetic flux provided by magnet
J – Current density

* This mechanical force generate the ultrasonic vibrations. In this case unlike the piezoelectric UT, mechanical vibration or ultrasonic waves are generated in the sample itself due to interaction of induction current and external magnetic field.

Which is very different from piezoelectric unit where you need a pulse generator from electrical signal being send to this unit.

In this case the vibrations/ultrasonic waves are directly generated into the samples, therefore you do not need any couplant.

* If you have a system operating at higher temperature then the normal couplant like oil and grease can not be used at higher temperature.
* In those cases where couplants are not used, then you have to use this electromagnetic acoustic transducer.

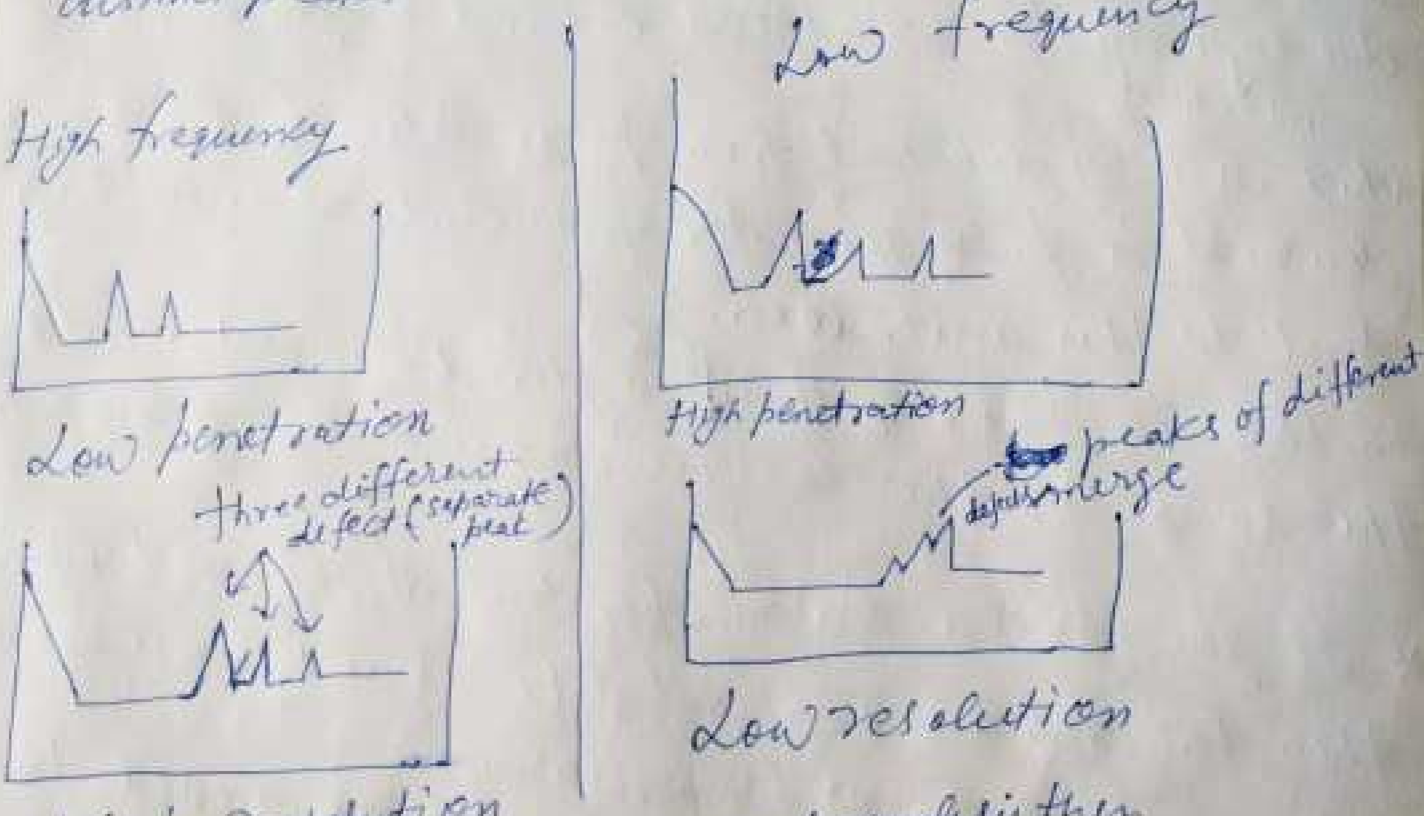
* **Selection of frequency**

Low frequency – penetration is high, resolution is low

* Resolution is the ability of probe to detect two flaws which are very close to each other.

If you have two defects very close or proximity to each other then you should have two different defect signal and appear as two different signal on display. That will happen when resolution is poor.

* when resolution is not good then these two signals coming out from two defects lying very close to each other may just merge into one and will appear as a broad peak instead of two different or distinct peaks.



* when you want to do close [surface analysis then] ultrasonic testing, then you should go for high frequency. Penetration will be lower, waves will be very close to the surface.
* If you want to go much below the surface higher depth type of inspection then you should select lower frequency. Penetration will be higher, waves will go into the depth (high depth from surface).

Signal to noise ratio

$\frac{S}{N} \rightarrow$ 3:1 is needed as minimum requirement.

$$\frac{S}{N} = \sqrt{\frac{16}{\rho v w_x w_y \Delta t}} \frac{A_{flaw}(f_0)}{FOM(f_0)}$$

w_x, w_y - Lateral beam width at the flaw depth

Δt = Pulse duration

$A_{flaw}(f_0) \rightarrow$ flaw scattering amplitude at centre frequency

$FOM(f_0) \rightarrow$ figure of merit of noise at centre frequency

ρ - density of the sample or medium

v - velocity of sound wave in material that sample is made of

These are the parameters which controls the signal to noise ratio. Based on this, we can see what are the parameters which will increase the detectability of the flaw.

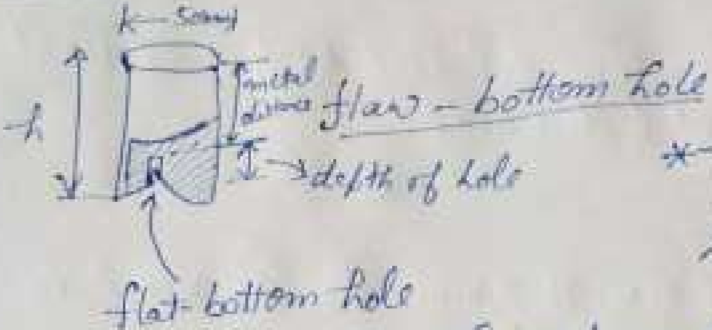
* If you decrease the lateral beam width, that means if you have a focused beam then the detectability of defects or signal to noise ratio will be max.
* Similarly if you decrease Δt, pulse duration is less which means if it is a short length / shorter pulse then again detectability will be better.
* S/N or detectability is directly propotional to the size of the flaw. Larger the flaw $\rightarrow$ better detectability
* If density ρ of material is higher or the velocity of sound waves in material is higher then detectability goes down.

This is how the signal to noise ratio will controlled the detectability of the particular flaw. these are the parameters which control the signal to noise ratio or in other words these are the parameters which control the detectability of the flaw in ultrasonic testing.

Calibration (Lecture - 7)

* Whenever the indications are indirect like in this case you get a defect signal, you could not see the defect directly that means the indications of the defect or flaw are indirect.
* Whenever the indications are indirect, it is neccessary to calibrate the instrument before you can use it. otherwise you may end of its results which are aronious.
* Two types of calibrations can be done –
  (i) Distance calibration
  (ii) Area → scattering area
* Reference blocks – some kind of artifical flaws which is already cut into them and the location of those flaws in the black is known.
* When you do the area calibration, area or size of the flaw is also known.

Calibration Block



* hole is drilled precisely in the centre of bottom surface of cylinder

* Cylinder have particular height and diameter. most of the cases diameter of 50mm is used.

Using this kind of block, we able to calibrate not only distance but the area also. So when you calibrate distance you need to vary the height of this block, keeping the size of flat bottom hole same. So when you vary the height then you vary this metal distance.

In case of distance amplitude calibration, this metal distance varied and the size of hole kept constant. On the other hand when you calibrate the area, metal distance is kept constant and size or area of hole varied.

By varying the metal distance and size of hole we can calibrate the distance and area respectively.

Series 'B' Blocks

Set of 19 blocks

diameter of the block – 50mm

flat bottom hole size – 20mm deep

flat bottom hole kept same in all the blocks

diameter of hole kept — 1.2, 2 and 3.2 mm

(In this range you can choose the diameter)

$\frac{3}{64}$ inch $\frac{5''}{64}$ in, $\frac{8''}{64}$

* You select one of the diameter and keep it constant then you vary the metal distance.

Metal distances

9 Block — 1.6 mm, 3.2 mm to 25 mm in increment of 3.2 mm

In terms of inches $\frac{1''}{16}$ $\frac{1''}{8}$ to 1''

10 blocks — 32 mm – 150 mm in increment of 13 mm ($\frac{1}{2}$ inch)

— $1\frac{1}{4}''$ – $5\frac{3}{4}''$

This is how these sets are used using different metal distances that you have.

Keeping the hole size constant, you can calibrate the distance.

First digit → diameter of the hole in one sixty fourth of an inch

X — XXXX → four digit - specify metal distance in inches

→ Block having number - 3-0075

↓ (3) → $\frac{3}{64}$ inch or 1.2 mm

(0075) → 00.75 in or 20 mm

Number is given to each block and created in similar way discussed above.

ASTM Blocks

50 mm diameter block

each with a 20 mm deep flat bottom hole

then you have different metal distances and different hole diameter in order to get either different distances for Calibrating the distance or different areas for Calibrating the area.

This is primarily the set of 10 blocks which can be combined with different distances and different areas to calibrate either distance or area and out of this 10 block

One block — 1.2 mm ($\frac{3}{64}$") diameter hole and metal distance of 75 mm (3" inch)

<u>Seven blocks</u>

2 mm diameter hole and metal distances of 3.2 mm 6.4 mm, 13, 20, 40, 75 and 150 mm.

2 Blocks — 3.2 mm diameter hole and metal distance of 75 mm

— 3.2 mm dia & metal distance 150 mm.

Block which is used is known as I I W —

International institute of welding

Calibrate both distance and angle.

Angle scale

Lecture - 8

Distance amplitude Calibration

1. Select the 5 - 0300 block

This block having flat bottom hole diameter of 5/64" or 2mm & metal distance is 3 inch or 75 mm

2mm diameter hole, 75 mm metal distance in order to Calibrate the distance.

Keep this hole size Constant and vary this metal distance by selecting other blocks and collect the numbers of data points in terms of distance.

We Collect the intensity of echos Coming out from this black bottom hole as a function of metal distance.

* data become flaw data and can be used for Calibrating the distance.

2. Move the probe over the block horizontally till you get a maximum signal from the flat - bottom hole. That means your ultrasonic transducer probe should be right above the hole so that you get a maximum signal

Once you get this maximum signal, you have to adjust it $\frac{1}{4}$ of the maximum height.

- Adjust gain control to make the max signal t[o] $\frac{1}{4}$ of the max height.

Gain ~~is~~ increasing or decreasing the sound wave signal

Gain = 20 log A_2 ... A_1 - Initial amplitude

Sound waves in terms of dB

$A_2 = 2A_1$

gain will be $= 20 \times \log 2$

$= 6\,dB$

This is how the gain is defined and there will be a knob on the instrument so through that turning that knob we can adjust the gain (either increase or decrease). In this case we need to decrease it by adjusting the gain so that the maximum height of the echo which you got from black flat hole (bottom) that should be brought down to $\frac{1}{4}$ th of the maximum height.

Once you set the gain control, make $\frac{1}{4}$ th of the max height you use the other blocks, the other metal distances that you have and after that for the other blocks, you do not touch this gain control. So gain control is fixed once in the beginning for the 1st block and when you obtain the echoes from the other blocks, In those cases you simply need to note down the height of the echo which is coming from flat bottom hole without adjusting the gain control.

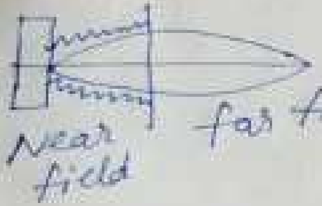
- Use other blocks, get a maximum signal from the flat bottom hole. Note the peak height.
- Read the heights of peaks without touching the gain control.

$I \propto \frac{1}{L^2}$

$I \rightarrow$ Intensity

L - distance

→ Distance amplitude curve



* In the near field, if the echo is coming from a very small distance from the probe then the probe will find difficult to recieve that echo.

+ On the other hand if the echo is coming from a larger distance within the near field then the recieving will be better and the signal intensity will be higher.

Far field → No flactuations, the signal intensity of the echos will decrease as the distance is increased.

+ The DAC Curve (Distance amplitude Correction Curve) first increases with distance then it decreases.

Area Calibration

+ Keep the metal distance fix and vary size of hole or Area of the hole

— 1, 2, 4, 5, ... Area of the hole $\propto n^2$

If you select number 5 hole then the relative area = 25

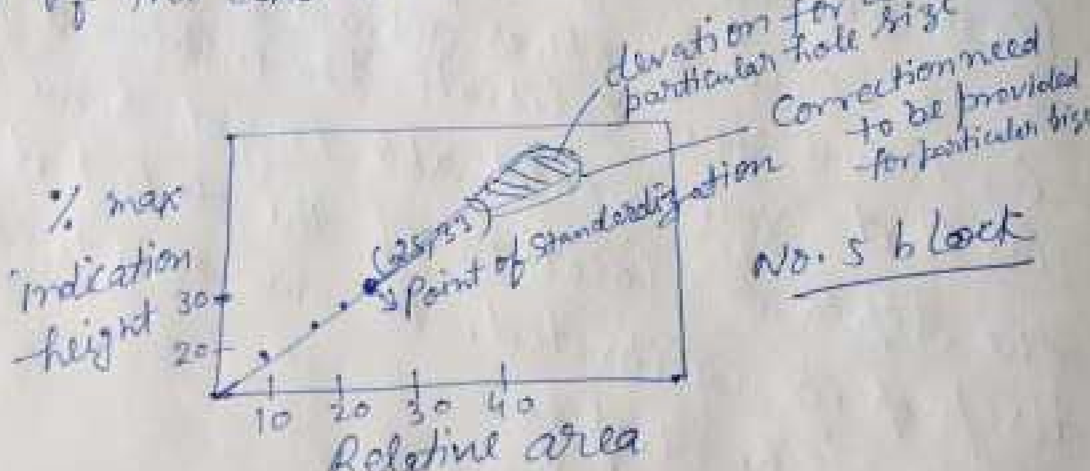
This numbers are given in accordance with the diameter of the holes in terms of $1/64^{th}$ inch.

Suppose if number is 1 then $1 - \frac{1}{64}''$ (0.4 mm)

$2 - \frac{2}{64}''$ (0.8 mm)

- No. 5 block is taken first
- Move the probe and get a maximum signal from the hole
- Adjust the gain control and make it $\frac{1}{3}$rd of the max height of the echo.
- Take the other blocks and get a max signal for each of them
- Read the height of echo from the hole without adjusting gain

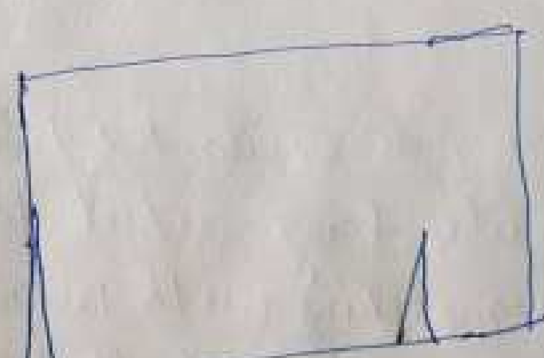
Intensity of the echo as a function of area of the holes



* You have calibrated the area by using these holes. Now while doing actual test, if you get a signal whose intensity is matching with intensity of any of the holes then you could say that size of that flaw is close to that size of that particular hole. But one thing you should remember that flat bottom hole that we introduced by precisely drilling is an ideal reflector. But actual flaws are not ideal reflector. What that does means that idea of the size that you are estimating from these particular curve is the lower limit of the size of the flaw.

The size which is matching with hole, you can say that size of the flaw is atleast equal to that particular hole whose echo intensity is matching with the echo intensity of that particular flaw.

This is how using this set of blocks, you will able to calibrate the instrument (Ultrasonic instrument) for distance and for area. So when you calibrate the instrument for distance, the advantage that you have, apart from make it free from error that is the first objective of doing calibration. In this case another advantage that you have is when you calibrate the instrument for distance is that you would able to get some idea about the depth or location of the defect if your instrument is properly calibrated. Because this time based you have in the display



* This time can be converted into distance if you know the velocity of sound waves in the material which is being test. Most of time it is known because most of the common metals/alloys and other materials, velocity of sound is known. So if you provide velocity of sound, this time can be converted into distance.

→

Distance = $\frac{v \times t}{2}$

waves are going back and forth & so it is divided by 2.

If your instrument is properly calibrated w.r.t depth or distance then you could see, what depth a defect is appearing. So that is where defect is lying which you could see directly on the display itself. This is the advantage you have when the instrument is properly calibrated.

Similary if you calibrate the instrument for the area then you will able to get some idea about the size of the flaw atleast the lower limit of the size.

So by doing calibration, you are not only getting error free result but you also get to know/get idea about the location and some idea of size of the defect. Thus UT provide some quantative result also although it is primarily a qualitative test but through this kind of calibration and this kind of calculation, you would able to get some idea about the depth at which ~~depth~~ defect are located and also some idea about the size of the flaws. This is how calibration helps you.

This is primarly for normal probe which is going perpendicular to the surface like this.
But there are many scaneriocases in which you have to use angle probe, you have to use an incident angle and for that case also you need to Calibrate the instrument. And you have to relize by using this kind of simple cylindrical block, you Can not Calibrate the angle probe because here there is no incident angle as such.
That means when you want to use angle probe you need some other kind of reference block/ Calibration block which would able to Calibrate the angle as well.

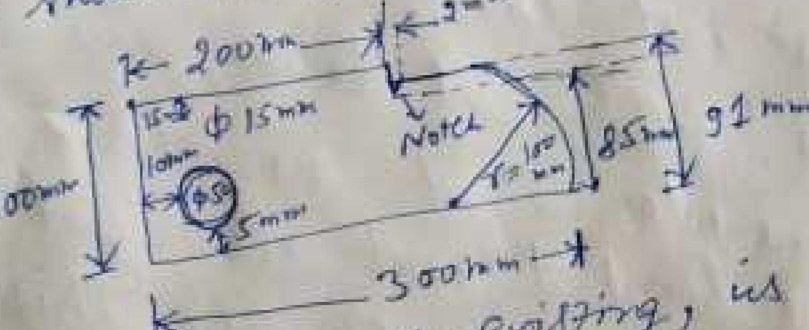
Lecture – 9

How to Calibrate an angle probe?

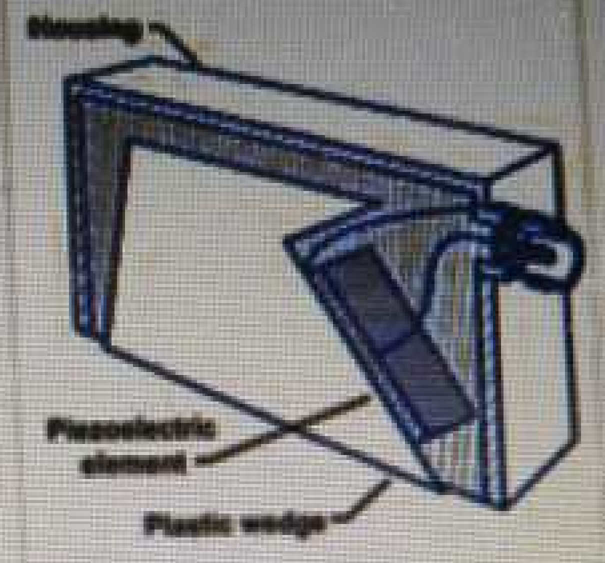
IIW Block
↓
International Institute of welding

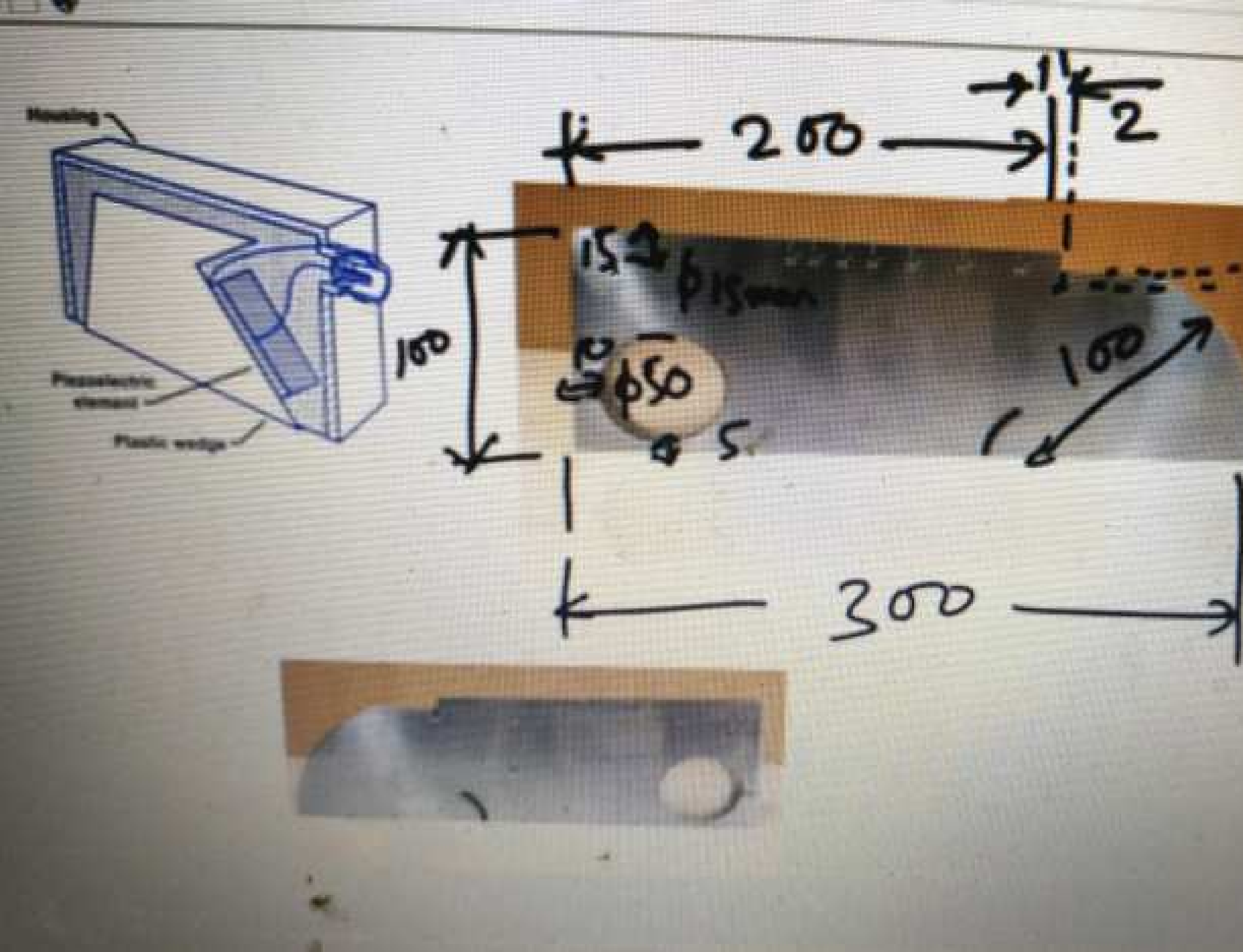
IIW Block are shown in figure below

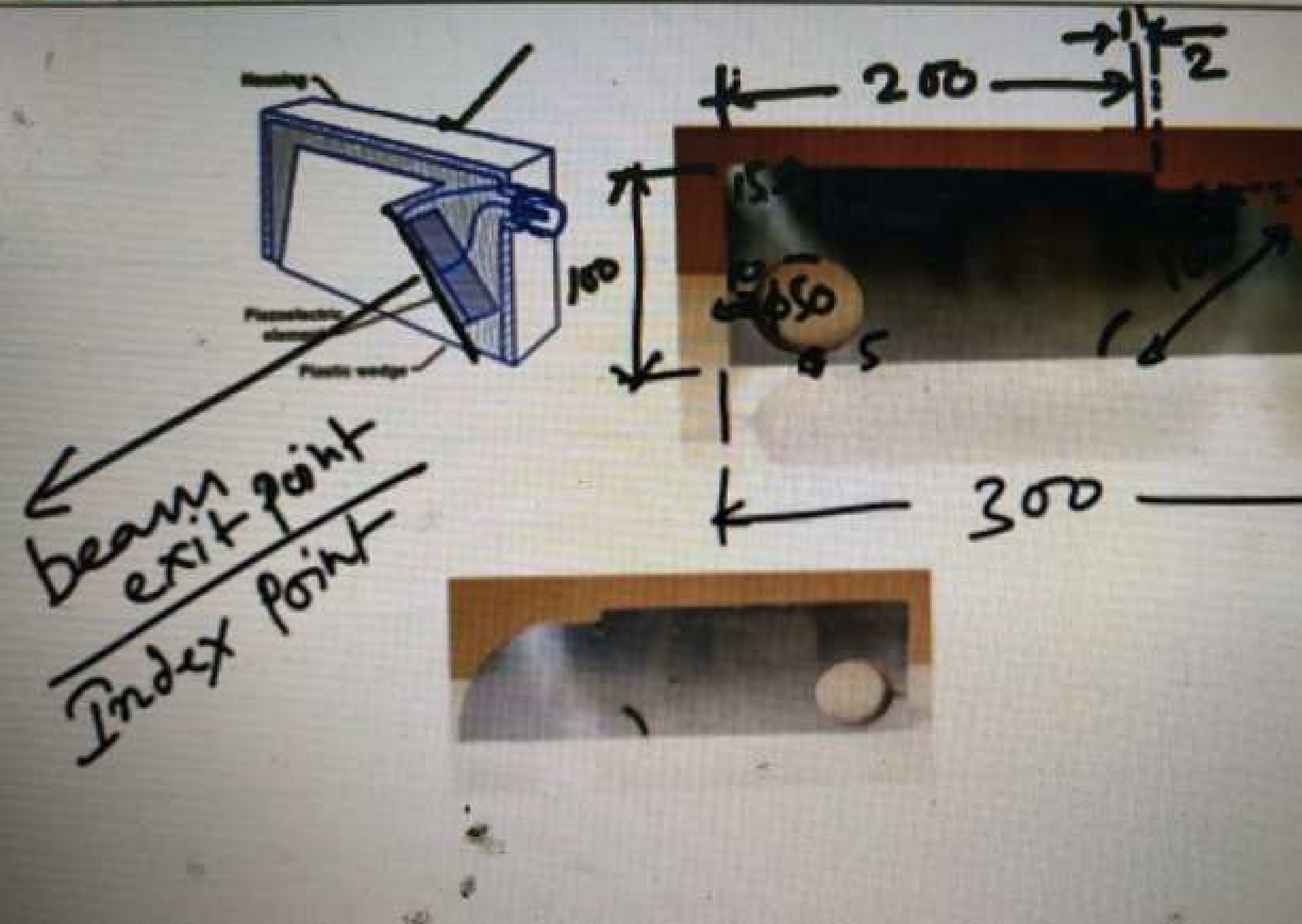
Typical dimension of this particular block.

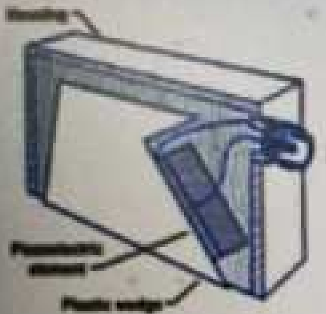


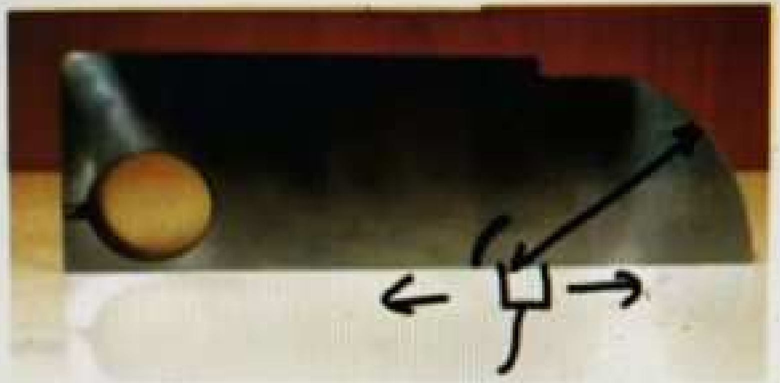
* The surface from where beam is exactly existing, is beam exist point. because the angle has to be Calculated w.r.t that particular point.


Housing
Piezoelectric element
Plastic wedge


Housing
Piezoelectric element
Plastic wedge
200
1
2
100
15
ϕ15mm
ϕ50
5
100
300


Housing
Piezoelectric element
Plastic wedge
200
2
100
15
Ø50
5
300
beam exit point
Index point





The
100
is
The
Poi
C
10

First thing you need to know the beam exist point then only you can talk about the angle.

Angle is measured with respect to the index point.
Beam exist point is also known as Index point.

The echo from the 100mm radius is maximum when the beam exit point is at Centre of the 100mm radius.

Beam angle

+ Get a max signal from the 50mm dia hole.

Beam angle for higher angle
60–70°

Beam spread

Move the probe on either side till the signal or echo becomes zero.

Note down angle on either side when the signal zero.

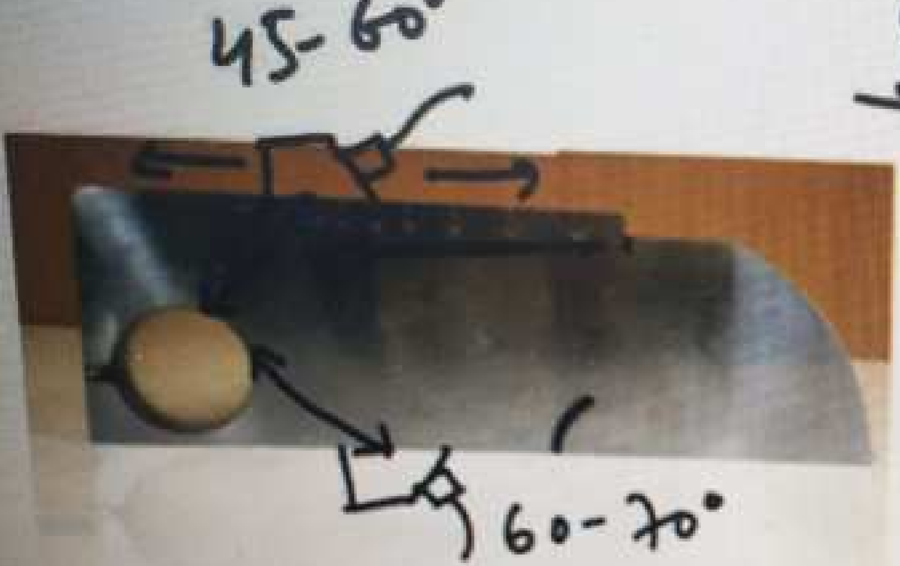
Dead Zone

If you get a clear signal
Dead zone ≤ 5mm

because you are getting a signal from 5 mm distance while utilizing that particular probe. So that will indicate that dead zone is less than 5mm.

* If you do not get a clear signal from this site then you can put probe over second place and you know the distance in this case is 10mm. So if you

Beam angle



Get a ma
from the
hole.

Beam ang

Note the angles on either side when the signal zero.

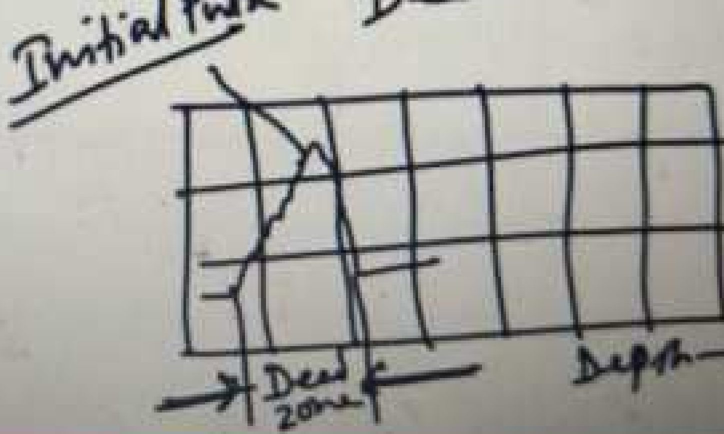
Spread

move the probe on either
the signal becom

Dead zon

If you get a

Dead zone

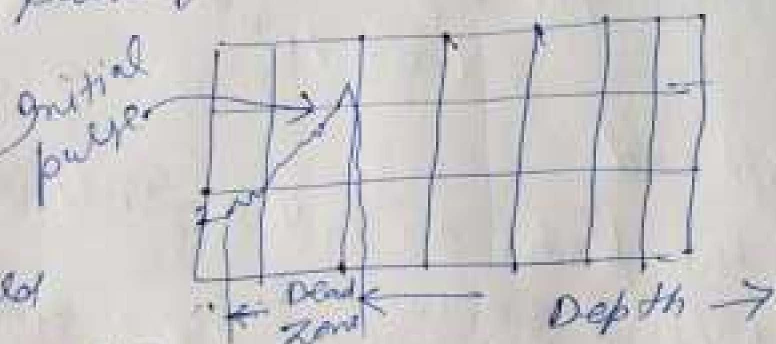


get a signal from 10mm distance not from 5 mm that will indicate dead zone is between 5 mm and 10mm. On the other hand if you do not get any signal from 10mm distance also then it will indicate that dead zone is more than 10 mm.

*So this is how you can get an idea about the dead zone also from this IIW Block.

Dead zone can be obtained from the display as well from the initial pulse you have.

→ within this particular distance (Dead zone) you could not see any other echo. probe is not recieving any echo at all.



Resolution of any Ultrasonic probe

Resolution means if you have two close space defect lying very close to each-other then you should able to get two different echos from this closely space defects instead of getting a single peak or two peaks merged into one.

If you get two separate echos from these two defects which are lying very close to each other then you say that resolution of that particular probe is good.

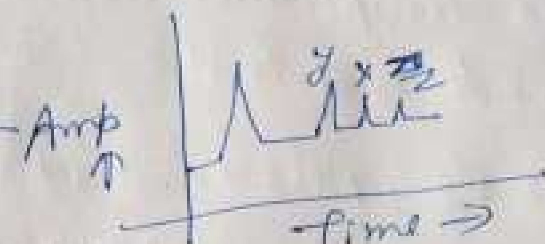
→

One the other hand if you do not get two separate echos from these two defects then you say that resolution is not good.

So with the help of this particular knob, you would able to find out the resolution of that particular probe is good or not. (2mm wide knotch)

* Place the probe on surface then get echos from the ~~knotch~~ this knotch at three different points.

If the resolution is good →



If the resolution is not good then you are not getting three different echos from these three different points.

IIW Blocks are also used for finding other important parameters like the resolution.

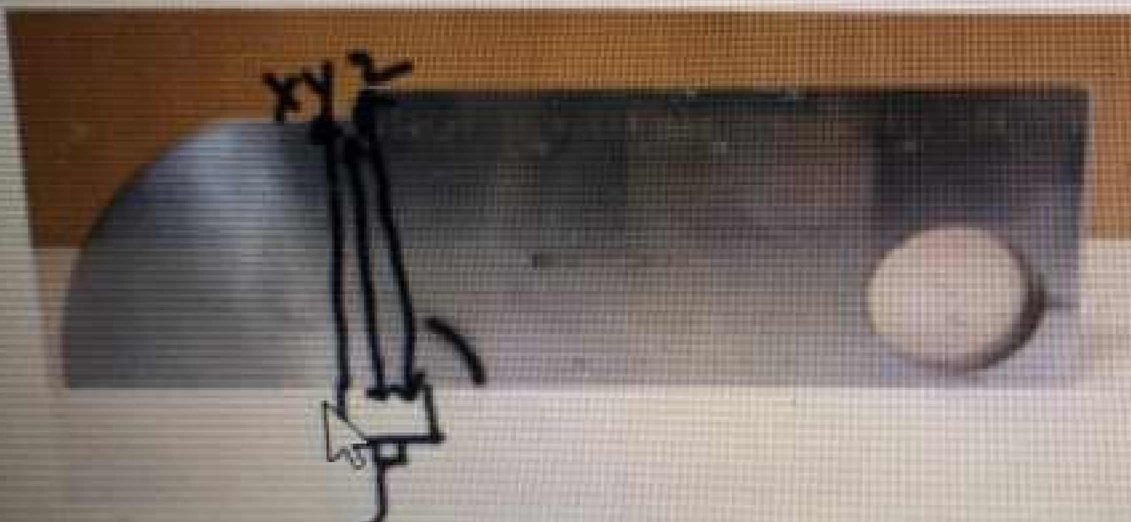
Summary of Calibration

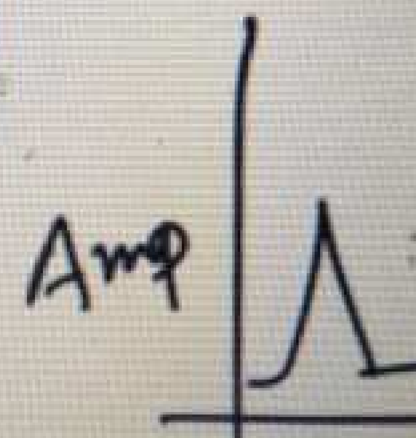
– Normal probes
↓
Calibrate the distance & area
Cylindrical block was used
this block has flat bottom hole at the bottom of cylinder & a particular metal distance

Distance Calibration → metal distance was varied.

Area Calibration – the area of hole was varied

Resolu





— Angle Probes — IIW Block

<u>Resolution</u>

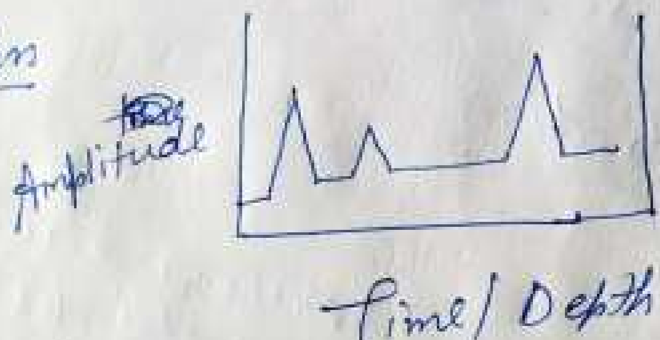
(Dead zone) → Sens

- Distance amplitude Calibration – DAC
- Area amplitude Calibration → cylindrical reference bill
- Angle, Resolution, dead zone, sensitivity → IIW Block can be used.

<u>Lecture -10</u>

Pulse echo display

(i) <u>A-Scan</u>



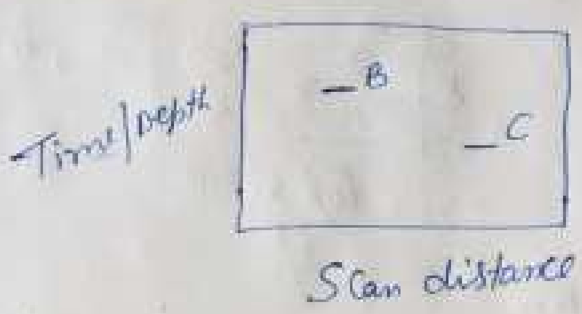
One dimensional view of the defects.

(ii) <u>B-Scan</u>

Gives you 2-D profile of the defects

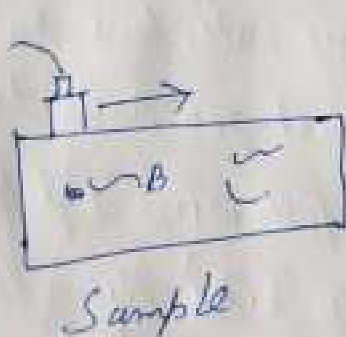
An imaginary section through the sample – where you can see both the back and front surfaces and you will see ~~[illegible]~~

at what depth defect are lying when defect echo appears (39)
on the display. thats how it generate 2-D profile of defects. this will be shown on flurosent screen and you



will see the defect echo as flurascing points coming into the display and staying there for sometime so that you have enough time to see and visulize them.

x fluroscent points on phosphor screen.



(iii)

C-Scan

Plan type 2-D view of the defects.

data is recorded by an X-Y plotter or displayed on computer sceen which is superimposed on the plan view of the sample.

In this case data is recorded as a function of each of the reflecting interfaces unlike the previous cases where you simply send the ultrasonic beam and get an echo from defects or other surfaces. In this case you need to collect the echos as a function of the position of reflecting interface.

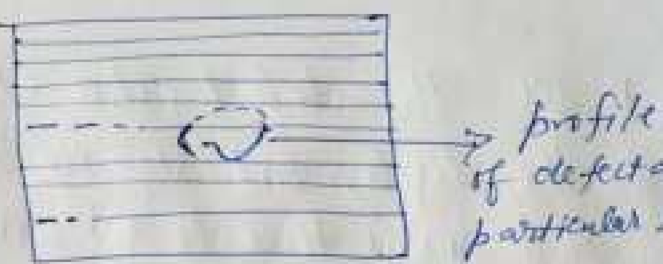
In order to do that you have to move the probe in a particular fashion like below (40)

Side view
(i)

Top view
(ii)

~~[illegible]~~

In order to generate plan type view of the defects, you need to collect the data as a function of the position of each of the reflecting interfaces. In order to do that you have to do the scan following a pattern shown in fig.(ii).



C-Scan
(iii)

you have to go like zig-zak manner and so on. If this defect you see in 2-D view, it looks like in fig.(ii).

Echoes are collected as a function of position of each reflecting interface and with that you get a scan/view like in fig.(iii)(C-Scan). These are the different types of scan/views displays in case of ultrasonic testing.

Applications

(i) Inspection of welds

welding process followed by NDT.

\+ for findout the soundness of the weld and find out the welding defects.

fig. 2

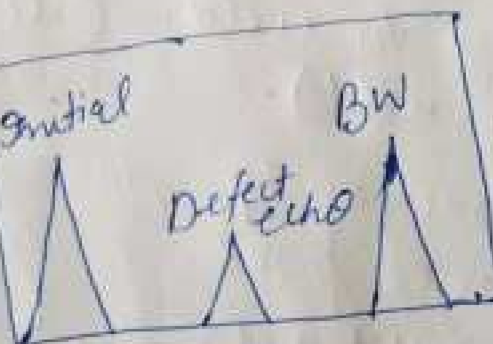
Zig-Zak manner because of incident angle

When you sent Ultrasonic wave at a particular angle, it will reflect back & forth as shown in figure 2. So first it will reflect from the back wall & then it is again go to the top surface and again come back. The back wall echo you see in a normal probe is not shown in this case.

→ This echo can come back only when it encounters an interface which could be a discontinuity/defect.

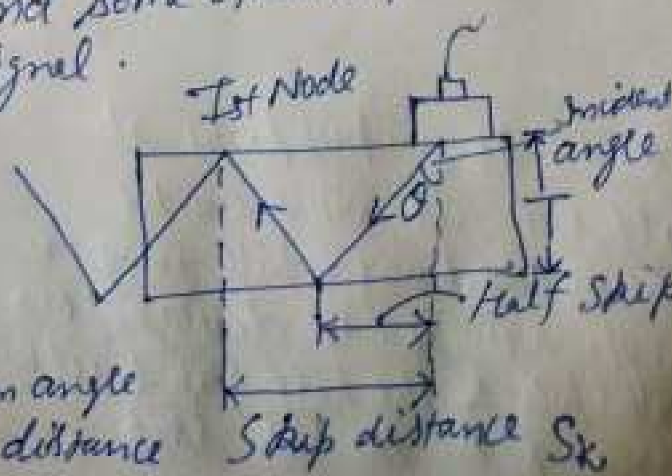
In this case you do not have back wall echo which we used in case of normal probe as the reference.

Our reference ~~was~~ was always back wall signal in previous section (normal probe).



for weld inspection

done by angle probe, you need to find some other reference which can be used like the back wall signal.

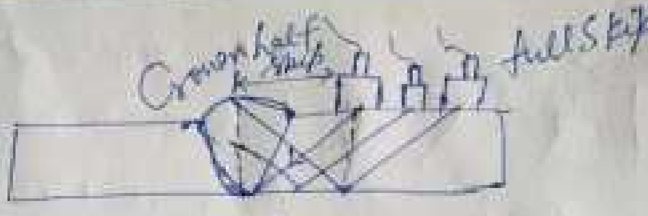


$$\frac{Sk/2}{T} = \tan\theta$$

$$Sk = 2T\tan\theta$$

For a given ~~beam angle~~ thickness & beam angle what will be the skip distance

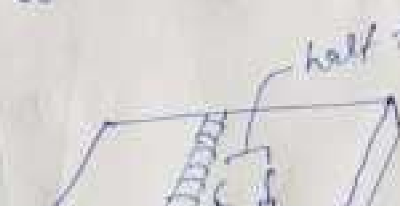
You have to move it from half skip to full skip, it is going from bottom to all the way to weld.



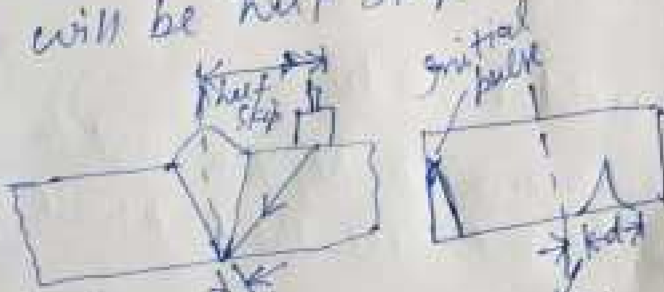
In case of inspecting weld, keep this probe at half skip & when you do that you could see that it will go all the way to bottom of the weld and then you have to move it to full skip from half skip then it will go all the way to the top.

When you keep it at half skip then it will go down and hit the root and then when you move it to full skip then it will go at top. Since you have to inspect entire weld from the root to the Crown, you need to move it from half skip to full skip because as it is going from bottom to all the way to weld. (Cover entire weld from root to top of weld).

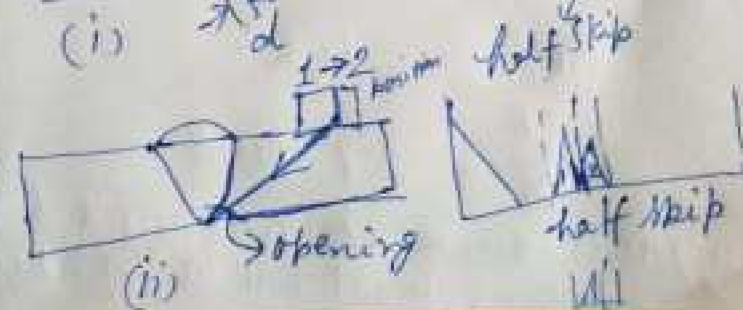
weld Inspection by using angle probe in case of Ultrasonic testing.

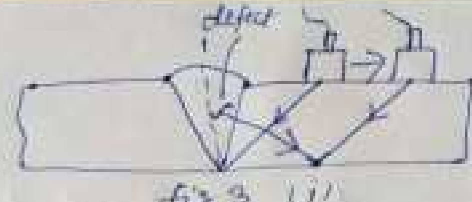


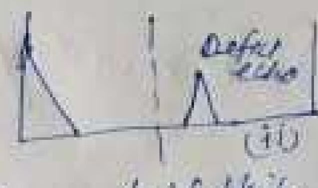
Reference will be half skip.



Case(ii) If you keep probe at half skip, it will encounter this defect/opening while going to root. Now you see display, your initial pulse & the half skip & it will appear before the half skip.







Defect echo appear after the half skip. In this case, distance is more than half skip, In order to get a signal from the defect which is lying inside the weld or in between the top & bottom of the weld. Then you have to keep the probe more than half skip and that is how the defect will appear after the half skip fig. 3 (ii).

Half skip distance serve as the reference for inspection of welds by Ultrasonic testing.

Applications of UT

- Castings – Defects like blow hole, Cracks, tears, Shrinkage, inclusions.
- Most suitable for mill products – Rolling, forging, extrusions (Defects generated)

Rolling – sheets, plates, strips (Defects)

- welding defects – porosity, entrapped slag, incomplete fusion, Cracks
- Bonded Joints – Brazing, Soldering joints, Adhesive bonding (Soundness of bonding by inspection of defects)

Summary

- Ultrasonic waves — Longitudinal, transverse/ Shear waves
- Basic principle - Echo/reflection of sound waves from an interface.
- Mode Conversion - Ist critical angle & IInd critical angle (Snell's Law)

Ist critical < θ < 2nd critical angle

- Different types of Ultrasonic transducer
  - (i) piezoelectric — Couplant (to exclude air gap)
  - (ii) EMAT - Couplant free operation
- Beam Shape - λ/d (λ → wavelength of sound waves, d - size of transducer)
- Calibration → distance and area

  Angle probe Calibration using IIW Blocks

———— x ————

END