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Theory and Practice of
Non Destructive Testing

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Ultrasonic Testing – 4

So in the last class we talked about this ultrasonic transducer element.

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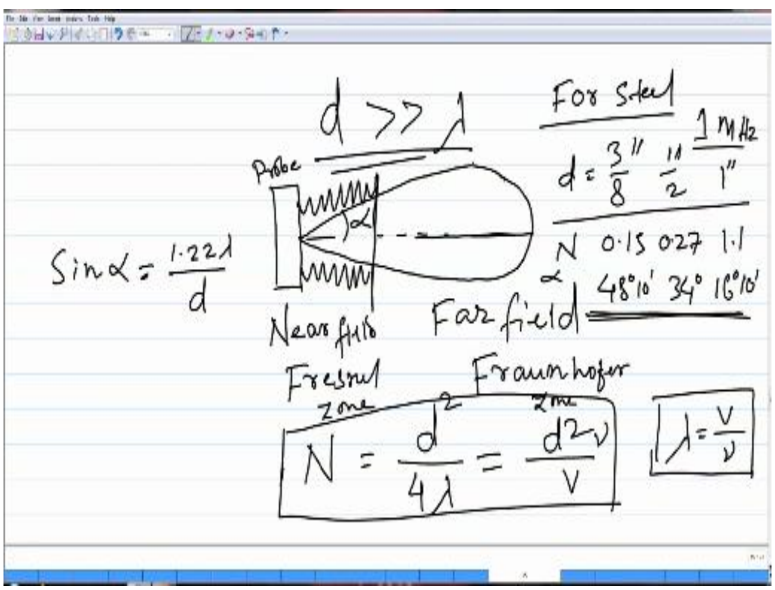

And before that we learned about this characteristics of the ultrasonic beam and then we saw there are two fields or two regions along this ultrasonic beam one is known as the near field where you have lot of fluctuations in the intensity of this sound wave and as you go away from the transducer then it becomes a kind of more uniform that zone is known as far field. And these two will depend on the size of the probe D and wavelength λ which can also be expressed in terms of the velocity of sound waves and the frequency.

So in this manner similarly the far field is characterized by this divergence angle α which again depends on the λ and D okay.

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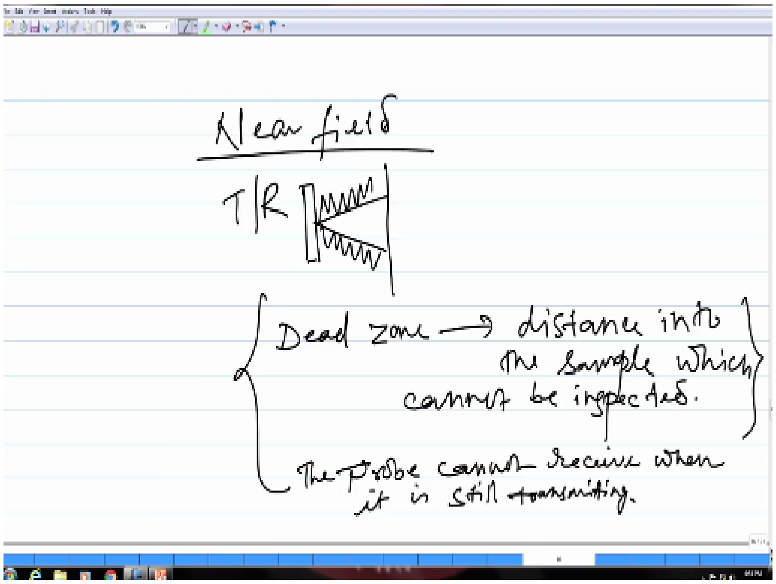

Then we saw due to this near field fluctuations there is something known as dead zone which is a distance into the sample close to the surface which cannot be inspected because of this fluctuations because a probe cannot receive and it is still transmitting okay. So if the vibrations are still there and by the time an echo comes back to the transducer then it will not be able to receive that echo okay, while it is still vibrating.

So that is the effect of near field which gives rise to this dead zone. And then we saw how this dead zone can be addressed, how this can be taken care.

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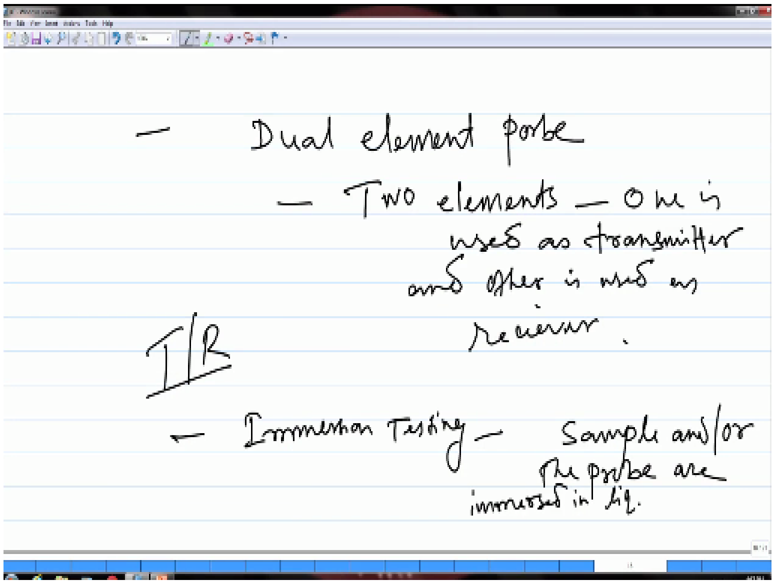

So there are different ways by which the dead zone effect can be addressed, one is using a shorter pulse or high frequency pulses, then the second method we talk about a delay version or a delay layer which will delay the echoes when they are coming back to the probe and that is how this delay layer will give enough time for the probe and for the fluctuations to die down completely.

And by the time the echo comes back, the probe will be ready to receive. And the other two methods by which this dead zone can be taken care are this one is using a dual element probe which has two elements one element is used as the transmitter and the other one is used as the receiver. So in this case since you have a second element which is only used as a transmitter could not have any dead zone problem in this case.

Last method that we talked about was through immersion testing where a you can immerse the probe and or the sample both inside in a liquid and since in the liquid like what are the velocity of water is much lower that will again delay the echoes and provide enough time for this fluctuations to come down and by the time the echo reaches the probe it will be ready to receive that okay.

So this is how the dead zone can be taken care of and then we started talking about this ultrasonic transducers, I mean what are the components of the transducer and how the ultrasonic pulses are generated.

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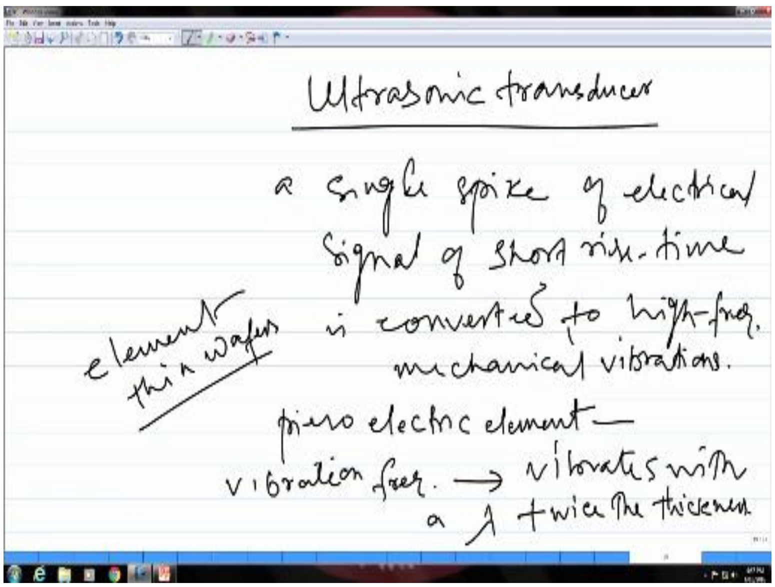

So what you do in an ultrasonic transducer you supply a single spike of electrical signal and you convert it into high frequency mechanical vibrations or these ultrasonic pulses okay.

So that means this is a property which converts electrical energy into mechanical vibration and as you all know that is known as a piezo electricity okay. So the main component of an ultrasonic transducer is this piezo electric element when you supply an electrical signal to this element it will vibrate the particular frequency which depends on the thickness of the element. So lower the thickness, higher will be the frequency and that is why these elements are cut out into thin vapors.

And this frequency different frequency can be generated by having these elements in different thicknesses. So this is what we saw in the lass class so today lets us talk about how this construction is for ultrasonic transducer what goes inside and then we see how it operates.

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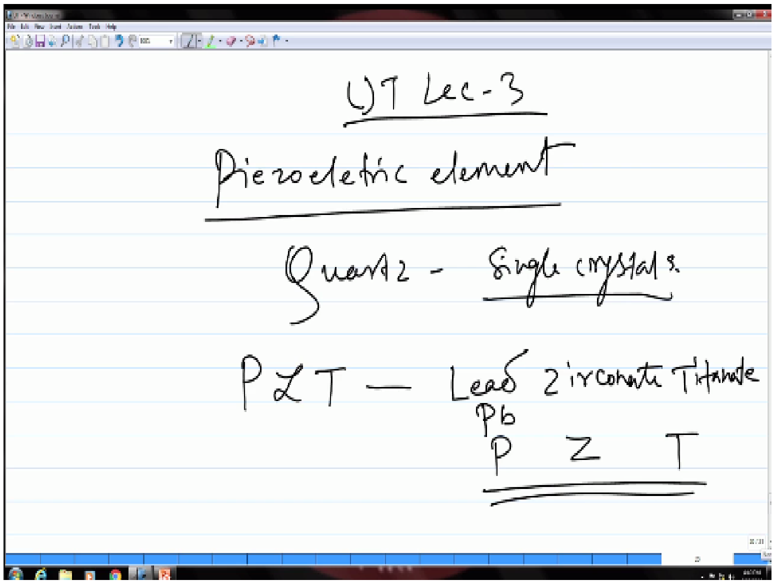

So the main component is this piezoelectric element as I said the most commonly know most common are most well know piezoelectric material as you might all know is quartz so single crystal staff quartz can be used as the piezoelectric element for ultrasonic quartz there is one more material which is known as PZT which also shows very good piezoelectric property the full form of this PZT lead Zirconate Titanate this P stands for lead Pb then Z is for Zirvconate and T is for Titanate.

So polycrystalline leads Zirconate Titanate shows very piezoelectric property so that gain can be used in ultrasonic transducers so let us see what are those parameters in a piezoelectric element which control the mechanical.

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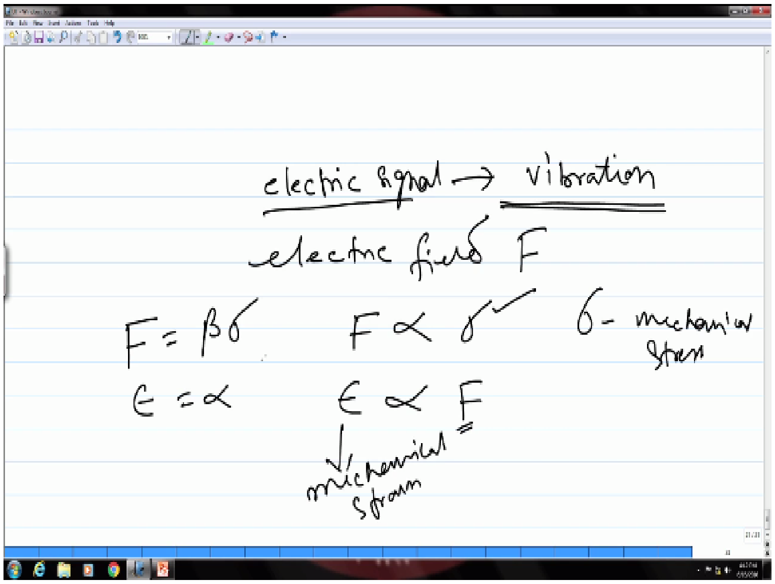

Vibrations so as I said you supply an electrical signal and that is converted into mechanical vibration so let us say if you supply an electrical field F it will generate mechanical stress σ similarly if you have a mechanical strength ε it will generate this electrical signals so this is either way electrical signal can converted into mechanical vibrations and vice versa so let us write this equations once again by introducing this proportional T constants α and β are the constants.

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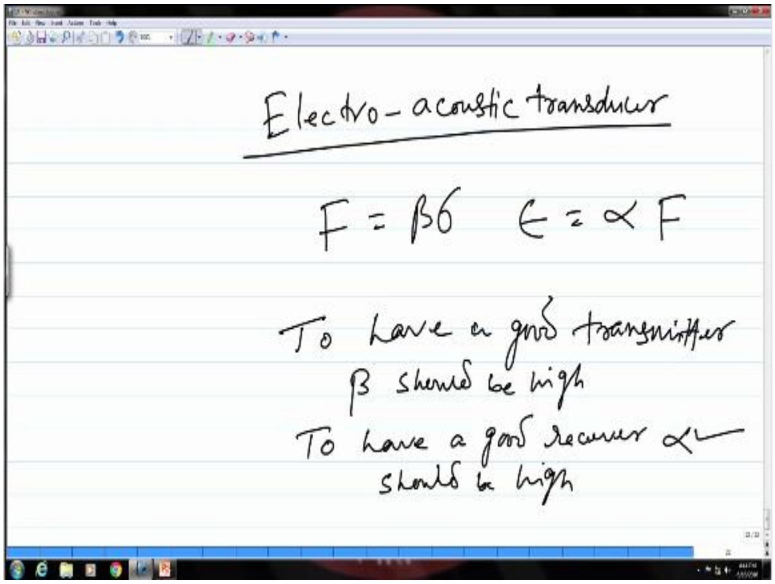

So this kind of transducer where in you convert analytical signal into mechanical vibrations these are known as electro acoustic transducer and these two constant that is just know introduced that is α and β these are the acoustic properties of the element which will control this electro acoustic transducer okay so far having a good transmission β should be high similarly to have a good receiver α should be high.

So this is how these two constants these two parameters α and β control this ultrasonic transducers so if you have both high it is good then in the same transducer you will have good receiving ability but let us see whether it is possible to optimize both or to have high values for both in the transducer now if you see these two are related by stress and strength.

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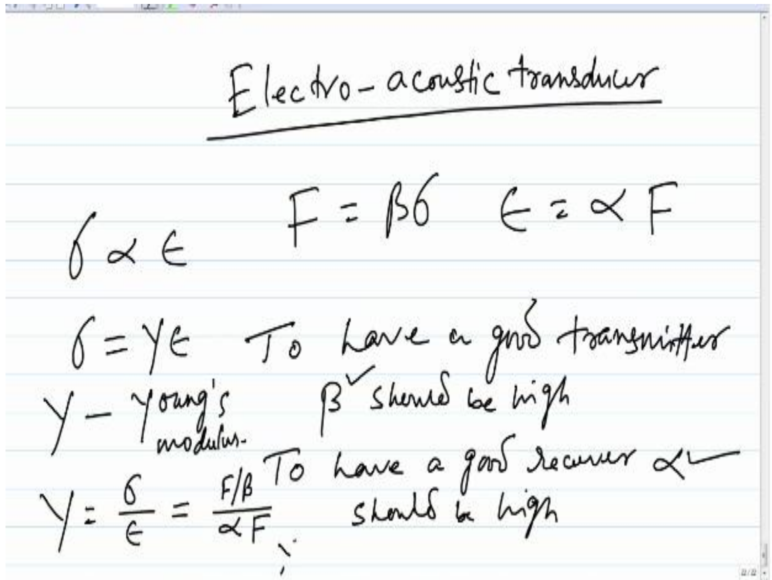

Which are also related to each other in these fashion and within the elastic limit this is related by hook's law in this fashion wherein Y is the young's modulus okay, right now if you are replace sigma and epsilon in terms of the electrical signal F where this is what you will have okay so that means Y becomes.

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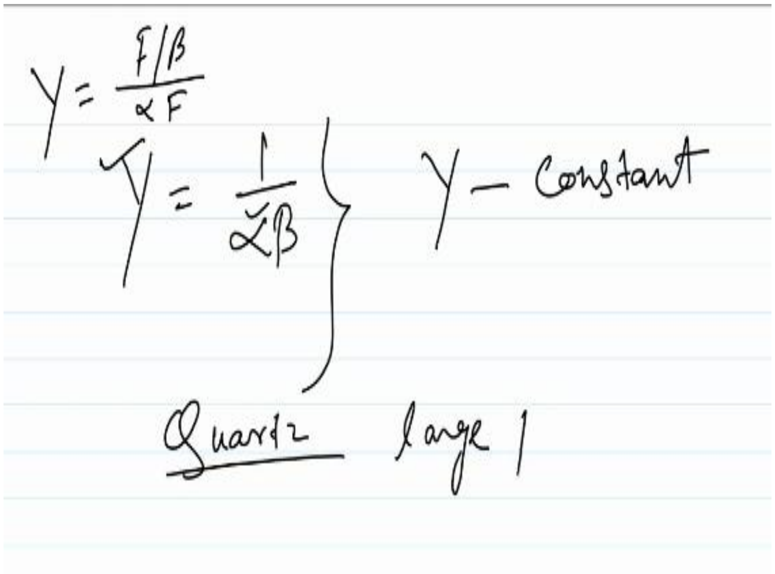

This okay as we could see from here let us write that okay so now we could see their related to this young's modulus in this fashion and since young's modulus is a constant it is a material constant you cannot optimize both alpha and beta simultaneously okay so if you increase alpha for example then beta has to be reduced because this has to be kept constant okay so that is why it is not possible to optimize both alpha and beta together simultaneously one transducer.

So you either have two compromise with the reasoning ability or you have to compromise with the transmission ability but for the commonly use materials for the commonly used piezoelectric materials the values that you have for alpha and beta are enough for both transmitting and receiving okay, for example if you look at the values that these two materials that you talked about for quartz channel PZT.

Quartz has a large beta value around 58 vm^{-1} pa^{-1} okay but alpha for which is low which is around 2.3 m/v okay on the other hand if you talk about PZT it has very high alpha value which is 374 and it also has a beta value which is high enough much higher than compare to or it is not as low like what you have a very low value for alpha it is a 15, okay but a still is more than 10 and at the same time it has a very high value for the alpha.

So that is why this is a very good piezoelectric element for an ultrasonic transducer but Quartz also can be used because we are mostly concerned about receiving the signal which is coming out from the sample in terms of those Eco's coming back from the defects so if you have a good receiver and if you could ensure that you sent enough ultrasonic pulses into the sample then converge also is a good material in fact it is being used in ultrasonic transducer.

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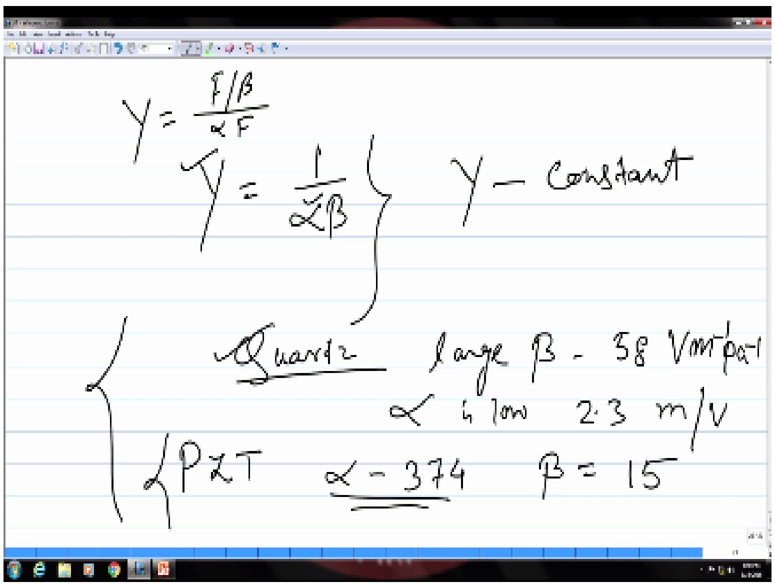

So both of this materials have you know good properties good acrostic properties in terms of this α and β parameters and that is why they are most commonly used piezoelectric materials in ultrasonic transducers.

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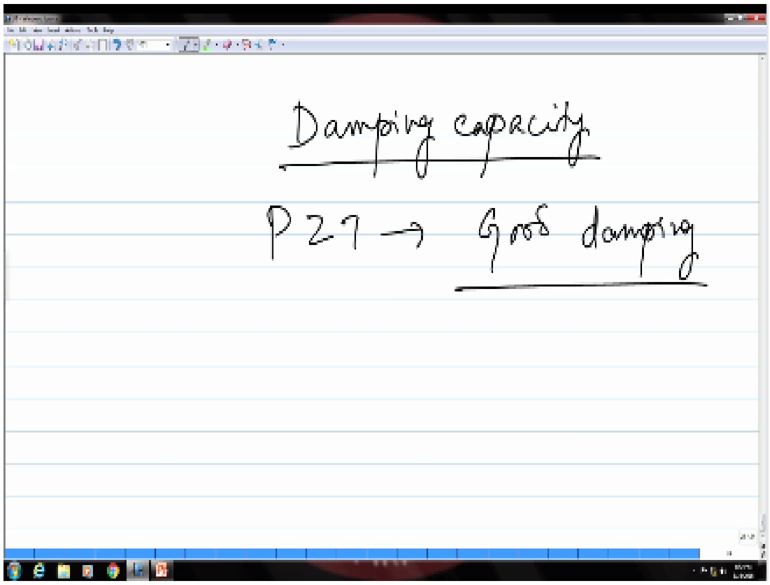

The other property which is needed for an ultrasonic transducer is the damping capacity which is the ability to absorb vibration, okay because as I said before also by the time the eco comes back to the transducers it should be ready to receive them, okay it should not vibrate when the eco comes back to the transducer, right. So that means it should also have good damping capacity so that this vibrations can be quickly absorbed and the probe is ready to receive after the transmission is over, okay so that is why this damping capacity is also important for a ultrasonic transducer.

So PZT is a very good damping material so apart from the piezoelectric property it also has good damping and in most of the cases to enhance this damping, damping background is provided in the housing in which this element is there, so when you talk about the construction of this ultrasonic transducer we will talk about that also in the back ground you provide some material inside that casing where you place this element which has good damping property, so that within this probe within the housing of this probe this vibrations could be quickly absorbed, okay.

So damping back ground can also be provided the damping support or damping back ground into that probe housing to enhance this damping property of the ultrasonic probe as a hole.

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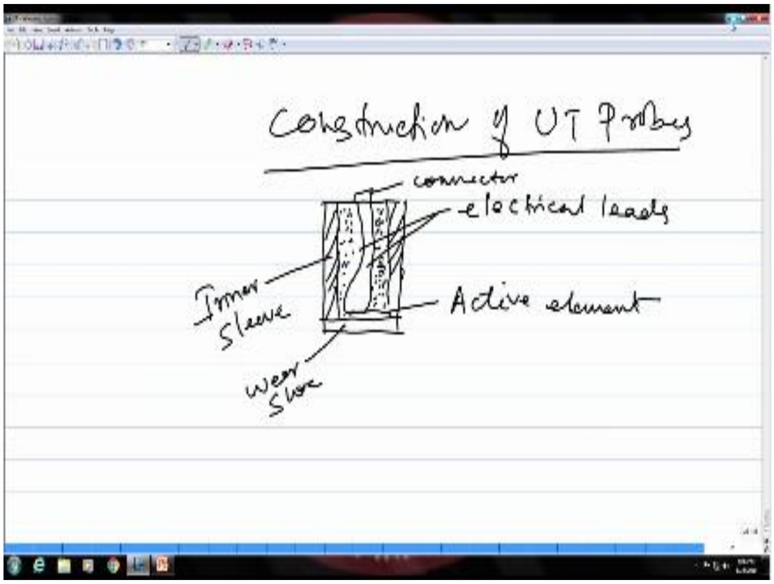

So let us talk about the construction of the probes and then see what are the different elements and components of the UT probes. So this will this comes in different shapes at milli there either cylindrical or some kind of rectangular shape and if you take a cross section for one of these cylindrical transducers for example this is what you will see inside, so the main component as I told is this piezoelectric element so this is the active element to which you have two electrical leads connected like this to supply that electrical signal.

And then you have this inner sleeve and other things to house it properly in place and here the front phase you have some protection for wear sleeve so you have what is called a wear shoe and this is the active element. This are the electrical leads so here on top should have a connector for electrical connection and this back ground as I mentioned should be made of some material which has high damping capacity so a damping a good damping background is provided in this housing so that vibrations can be quickly absorbed after the transmission as happen, so that the transducer is ready for receiving okay so this is a sciatic let me show you how do they look like.

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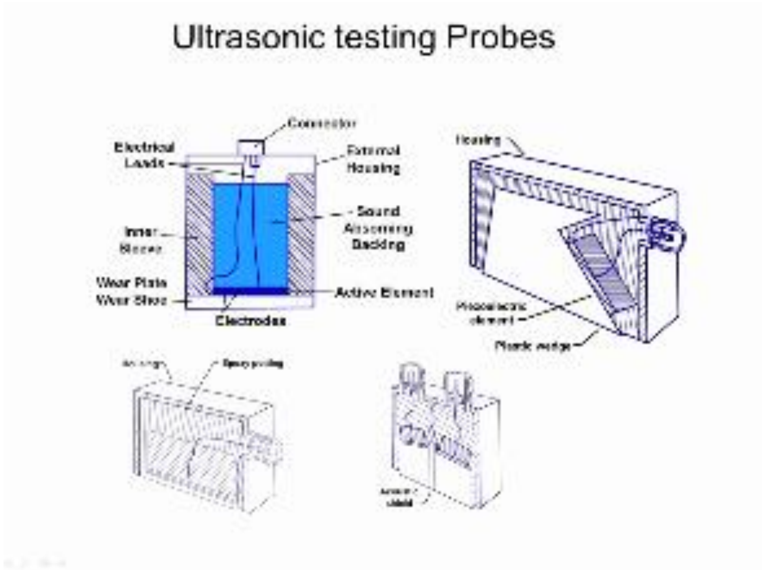

So this is part they will look like if you see this diagrams so this is the one that just now we have drawn so you can see the similar parts the main components of course is the active element which is now housed inside a casing like this, this is a small cylindrical casing in which you have all the support and dialectical lead this blue area indicated that it has sound absorbing high damping background as I mention before and it comes in different kind of says like you could have this kind of cylindrical save or you could have this kind of rectangular shape and so on.

And the other aspect of this is that it also comes in a particular angle okay so the ultrasonic beam can be sent normally or perpendicular to the surface to the sample or it can also be sent at some angle because in many cases as we are going to discuss later an incidents had a particular angle is also needed because your defects and flaws can lie ion different orientations they have not be exactly perpendicular or they may not be parallel to the front face of the sample they can lye at an angle also.

Sop that is one scenario where you may need and incidents had a particular angle then you have this parallel joints wielded plats where ion you have a well to inspect so there again if you have a V joint kind of thing it is always had an angle so in those case again you have to use an angle probe okay. Sop in order to provide that angle as you could see this kind of wedge is provided here so the piezoelectric element is now sitting on this wedge and this way just cutout the particular angle that is needed so this is the this will be the incidents angle for this particular probe okay.

So this is how an angle probe is built and in this case we could see there are two elements okay her it is only one element here also it is a single element but in this case we could see there are two elements and for this two elements there are two separate connectors and two separate leads. So this is the duel element probe that I talk about sometime back while talking about date zone.

So this kind of probes can be used when you do close surface analyze or close surface inspection because in that case since the reflector is very close to the surface or very close to the probe this date zone effects will be prominent so in order to avoid that this kind of duel element probe can be used where in you have two separate elements one for transmitting and another for receiving so this is what is been shown over here okay so that is how the construction is for this ultrasonic probes.

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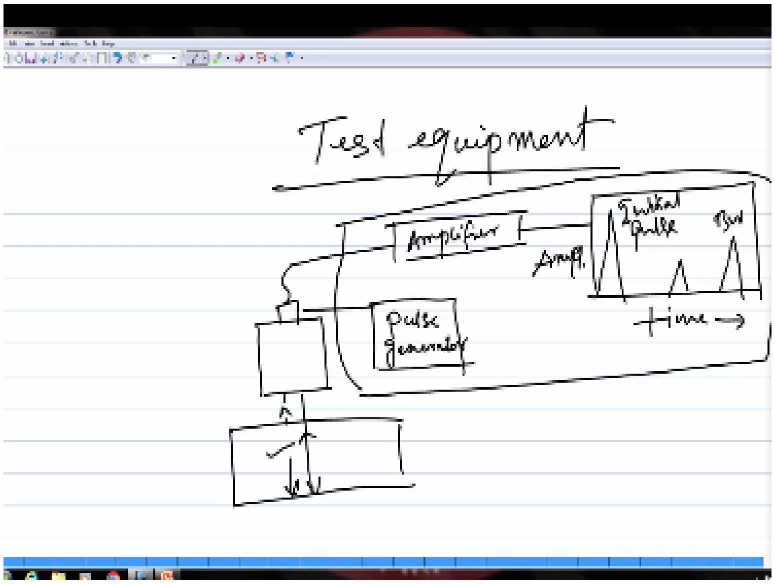

And if you talk about the test equipments so apart from the probe is also have the display in which we can see that signal the defect signal and you should also have a power source to power this probe all those things is build into a compact small equipment and if you see the major components of that piece of equipment this is what we will have this probe we already talked about okay so this has to be connected to that small box which will contain all other elements including electronic circuit.

And the power source and it will also have amplifiers and things like that to amplify the signal so that it can be properly displayed in into the display by the equipment has okay so this probe will be connected that to a pulse generator and this has to be connected to the system to first amplify the signal so it will have an amplifier and then you will have the display.

Which can show the display in terms of amplitude and the time base and this we have seen we will have an initial pulse and then the back one and then you have sample over here okay and if there is anything in the in between we will see that defection coming in between say pulse and the back one signal okay right so all these thing apart from this probe or all this pulse generator display and everything will be build into small compact box.

Which will have everything like I said it will have the electronic circuit it will have the display and it will have also the power source this box itself will be connected to a power source which will intern power the probe okay so this is how the system is major component of the system and in the next lecture we are going to see how this equipment is used to do alternate testing so we will see the test method and different process parameter and so on. So today I will stop here and I will see you next time thank you.

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