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Theory and Practice of Non Destructive Testing

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Ultrasonic Testing - 3

Okay so in the last class we started this topic on ultrasonic testing and then we learned about the basic principle first and then we also saw the beam shape and the pulse shape.

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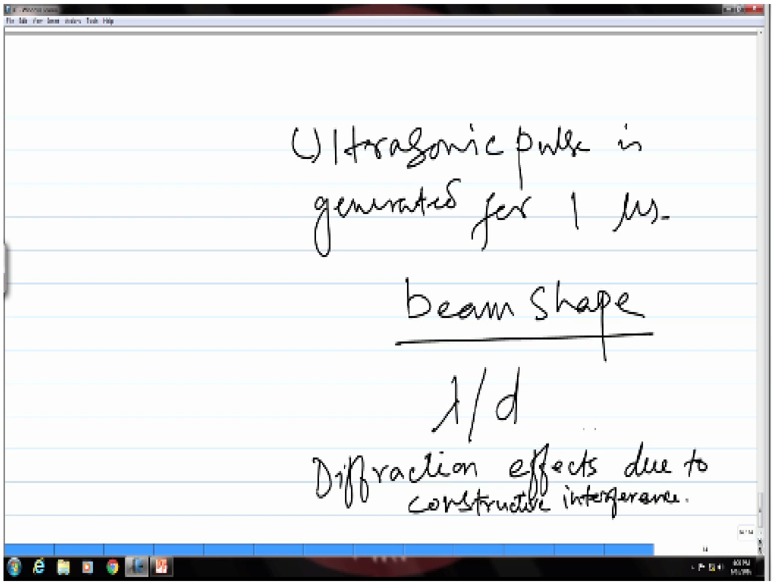

Ultrasonic pulse is generated for 1 μs.

beam shape

λ/d

Diffraction effects due to constructive interferance.

So we saw first that an ultrasonic pulse is generated for about one microsecond so you use this kind of short pulses to make that ultrasonic beam which goes into the sample. And you have also seen that these pulses are a mix of several frequencies which is little above or little below the actual frequency and when you take the resultant of all this frequency you get the chosen frequency okay.

And then you talked about the beam shape and then we saw that it primarily depends on this ratio lambda by D where lambda is the wavelength of the sound waves and D is the diameter of the ultrasonic pulse okay. So as you keep increasing the diameter with respect to the wavelength the beam becomes more and more directional and as we discussed that is because what is known as diffraction effects coming out due to constructive interference of the sound waves which are coming out from different points of the same transducer. So these are known as diffraction effects due to constructive interference.

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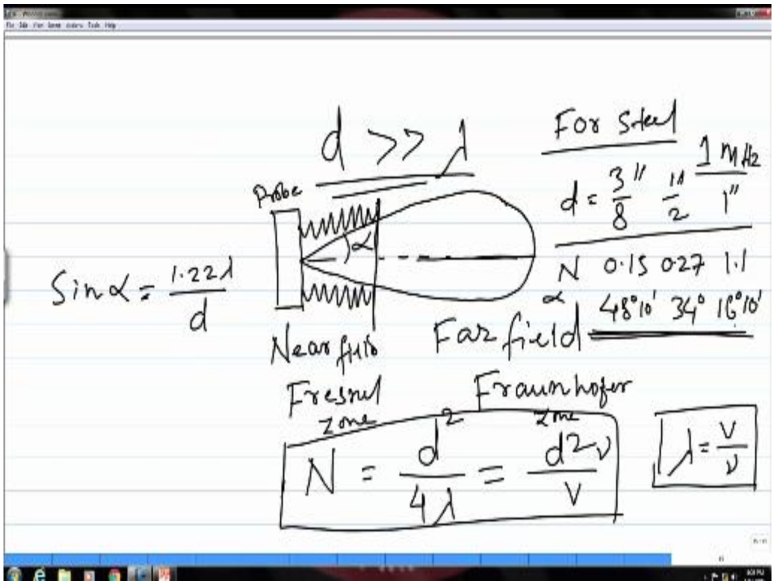

And then we saw that finally when d is much larger than lambda which is actually the case in real scenarios and we use this transducer to do NDT. So then we saw that it takes off a shape like this which is radiating out like a search light okay, so it becomes directional like this. So this is the scenario for this okay, so in this case you can see that the beam is divergent so it has a divergence angle α okay.

So today we will talk about this a little bit more and then we will see what are the different characteristics this kind of beam has and after that we will go on to see the ultrasonic system the inspection system the transducers different kinds of transducers and then if time permits will also see in today's class how the test is done okay.

Okay so let us talk about this first so it has a divergence angle and if you talk about the intensities across this beam you will see that there will be lot of fluctuations near to the transducer okay. So this is the probe rather transducer and this is how the beam is coming out of it so close to the transducer there will be a lot of fluctuations in the intensity and as it goes away from the transducer then the beam kind of becomes more uniform these fluctuations will die down and the beam will take up a more uniform form.

So there are two regions based upon that depending on whether you have fluctuations or not so in the region where you have lot of fluctuations near the transducer that is called as near field and the region away from the transducer where the beam becomes more uniform that is called far field this near-field is also known as Fresnel zone and the other name for the far field is Frawnhofer zone okay.

So these are the two different regions you have in the beam and if you want to see them and express them in terms of some parameters on which the extent of each of these fields will depend, so the near-field if we call that as n it will depend on the size or the diameter of the transducer in this fashion and it would also depend on the wavelength lambda okay. So this is the extent of the near-field which depends on the size of the transducer d and the wavelength lambda.

And if new be the frequency this can be expressed in terms of the frequency also, so then this will become because we have seen before that lambda = V/ν by the frequency if the frequency is called by ν so this is lambda in terms of the velocity V and the frequency. So if you replace that over here you get this near-field in terms of the frequency of the sound waves and the velocity V okay. And if you see the far field, far field is characterized by this divergence angle α so this α depends on again the same two parameters but this time it is in a different way.

So now in this case this is directly proportional to the wavelength unlike the near-field which was inversely proportional. So this divergence angle α is given by this particular relationship so this is again dependent on the wavelength of the sound, and the dimension or the size of the probe and of course it would depend on the medium through which the sound waves are travelling.

So let us say for steel if you see these values at a particular frequency of let us say 1mhz okay, so when you vary d to this sizes 3’’/8 inch half a inch and 1 inch okay. So for this three sizes three different values of D N would be 0.15, 0.27 and 1.1 inches and the value of α would be 48º 10 minute then 34º and 16º 10 minutes okay. So this is how for a particular material as you vary the size of the probe at a particular frequency this is how the near field and the far field would change.

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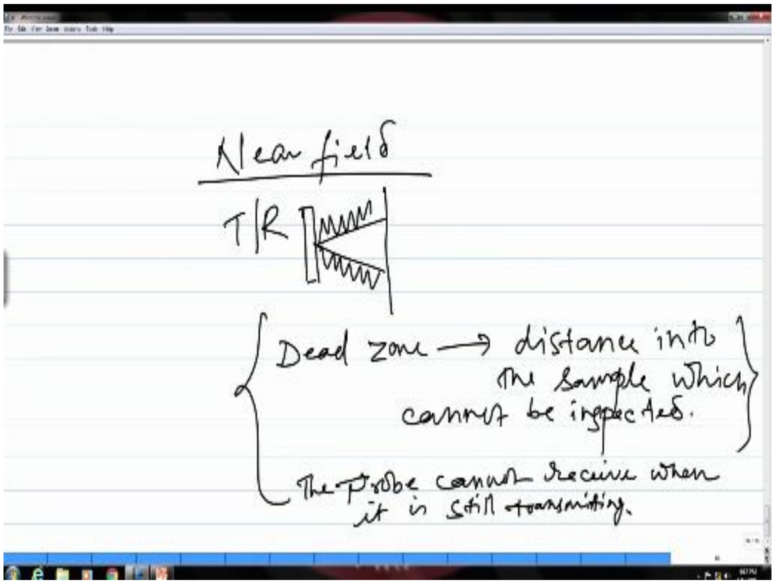

Dead zone → distance into the sample which cannot be inspected.

The probe cannot receive when it is still transmitting.

Now this near field the fluctuations it has some implications on the ultrasonic testing okay. So due to this high fluctuations even after the sound beam is transmitted into the sample this portion this near field would steal vibrate okay and it will take some time for the vibrations to die down completely.

And if you are using a transmission receiving system that means the same transducer is acting as both as a transmitter and as a receiver also, so in that case a transmitter or a probe cannot receive until the transmission is completely stopped okay. So in this case in the near field if it is still vibrating that means it is still transmitting so if an echo comes back within that time when it is still vibrating then it would not be able to receive that echo okay.

And that can happen if that eco comes back very fast if it comes back quickly that means if something is very close to the surface of the sample that is if something a defect or a reflecting interface is very close to the probe then there is a chance that, that particular defect will be missed because the echo coming out from that defect will not be received by the transducer because it will still be vibrating since the echo is coming back very fast okay.

So that particular distance is known as dead zone, so this is a distance into the sample which cannot be inspected due to the near field fluctuations okay. So this is the direct effect of the near field fluctuations because as I said a probe cannot receive when it is still transmitting and due to that fact the near surface defects or near surface echoes may be missed so that particular distance which cannot be inspected due to this fluctuations as I said is known as the dead zone okay.

But there are some ways some means and ways by which this dead zone can be avoided or at least can be minimized.

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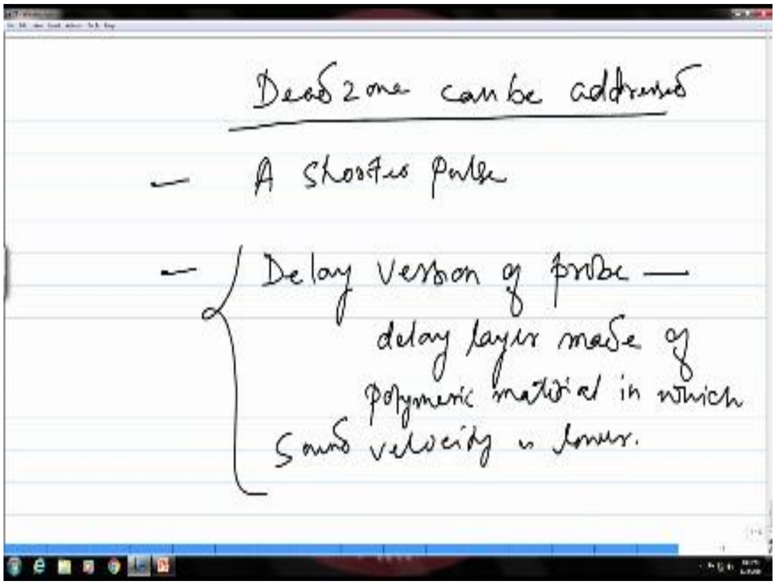

Dead zone can be addressed

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

So this problem of dead zone can be addressed by using a shorter pulse or high frequency, then you can use something called a delay probe or a delay version of probe so in this kind of delay probe there is a delay layer which is made of a different material like for example, a polymeric material in which the velocity of sound is lower, okay so since the velocity in this layer is lower it will delay the sound wave when it comes back to the probe, okay.

So then the probe will have enough time for these fluctuations to dye down completely and by the time the eco comes back to the probe it will be ready for a CV okay, so due to that delay which is provided by this delay layer the probe will be ready for receiving by the time the eco comes back even if it is from a near surface discontinuity.

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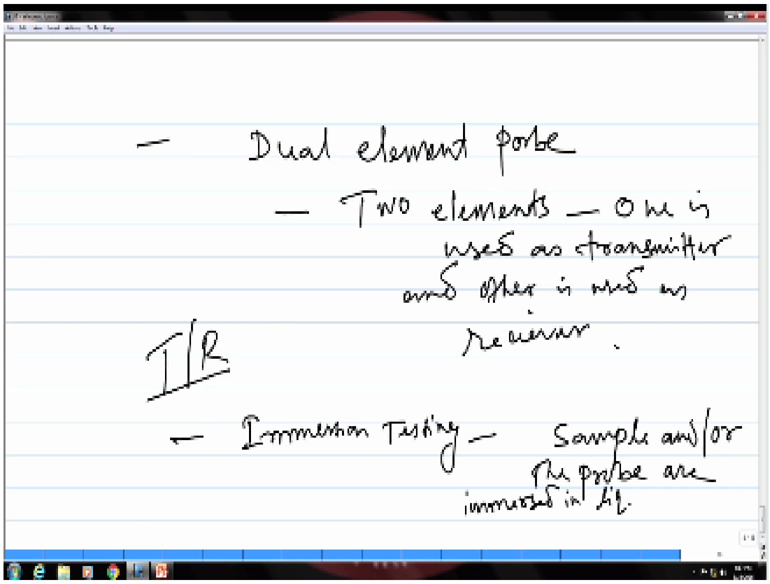

- Dual element porbe
  - Two elements – One is used as transmitter and other is used as receiver.

T/R

- Immersion Testing – Sample and/or the probe are immersed in liq.

And then the other way of avoiding dead zone is to use what is called a dual element probe, so in this case as the name suggests it has two elements to active elements which generates these ultrasonic pulses so these are actually piezoelectric elements which we will talk about little later in more detail so in rest of the cases what we discussed before when you say that the same probe is used for both transmission and receiving.

In those cases it is only one element but in this case in case of dual element probes there are two elements one is used as transmitter and the other is used as a receiver, okay. So in this case since the same element is not transmitting and receiving you do not have the problem that you have in single element transducer, so one probe will transmit the ultrasonic pulses into the sample and the other one will receive so there will be no problem in receiving it because the fluctuations are not in picture in this case.

Because a different element is receiving the eco which is coming out from the sample, okay. So this is another way of addressing the dead zone effect and there is one more way there is one more method by which you can address dead zone that is by immersion testing, okay so in this case the sample or the probe is immersed in a liquid like water and it is well known that the velocity of sound in water is much lower compared to that in metals okay, so if you have a metallic sample which is the case most of the time.

Then you can immerse the sample inside water so when the ecos come out from the sample they have to travel through this water path and since the velocity of sound in water is much lower it will delay these sound waves coming out from the sample by the time they reach the probe which is at the top surface of the water or the liquid by the time it will have enough time due to this delay for all the fluctuations to come down or die down completely and the transducer will be ready to receive.

So this water path again is introduced to delay this so this is again serving the same purpose like what the delay layer does in the delay version of the probe, so here also due to that delay the probe will be having enough time for all the fluctuations to die down and by the time any eco comes back to it, it will be ready to receive, okay. So these are different ways by which the dead zone effect can be addressed.

So now let us talk about the ultrasonic probes and let us see what kind of probes we have what are the different constituents are elements inside of row and what are the different types of probes and then we will finally see how these probes are used and how do you get the defect signal by doing ultrasonic testing.

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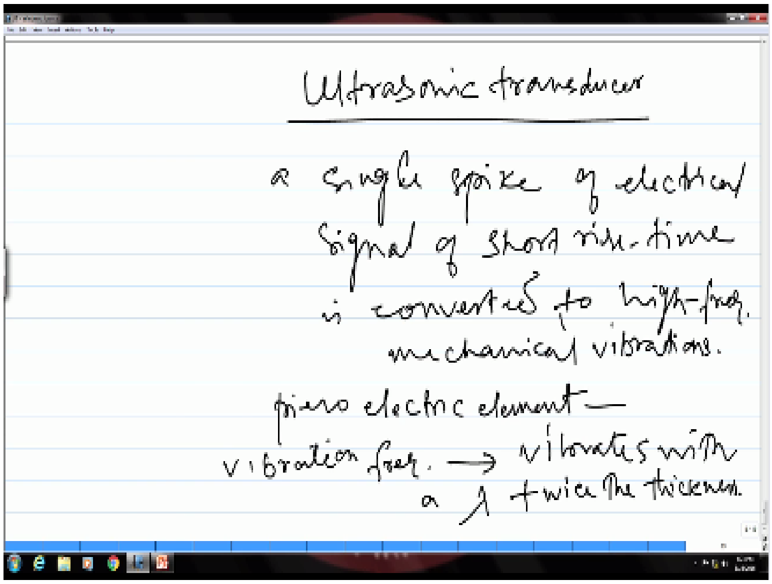

Ultrasonic transducer

a single spike of electrical signal of short rise-time is converted to high-freq. mechanical vibrations.

piezo electric element —

vibration freq. → vibrates with a λ twice the thickness.

So in an ultrasonic transducer a single spike of electrical signal of short rise time is converted to high frequency mechanical vibration so this is the device which converts an electrical signal into mechanical vibrations and that is as you may all know is called piezoelectricity, right. So the main element or the main component of an ultrasonic transducer is a piezoelectric element which converts an electrical signal into mechanical vibration or ultrasonic waves, okay. So that means all you have is a small piezoelectric element which vibrates at a particular frequency when you supply an electrical signal.

And the vibration frequency would depend on the thickness of the element, okay so it vibrates with a wavelength which is twice the thickness of the element, okay. So that means for higher frequency the thickness has to be lower, okay so lower the thickness higher will be the frequency so that means the elements have to be cut out into a thin wafers, because we are talking about frequencies in the range of 20 KHz 25 MHz or10 MHz so these are very high frequency vibrations and that is why the element has to be very thin, okay.

And it has to be constructed in a proper housing in a proper encasing wherein you can provide the electrical leads to supply that electrical signal, okay. So let us see how is the construction for these ultrasonic transducers, but before that let us talk about what is the material of these piezoelectric element and what are those parameters which control the transmitting and the receiving ability of this element or the transducer.

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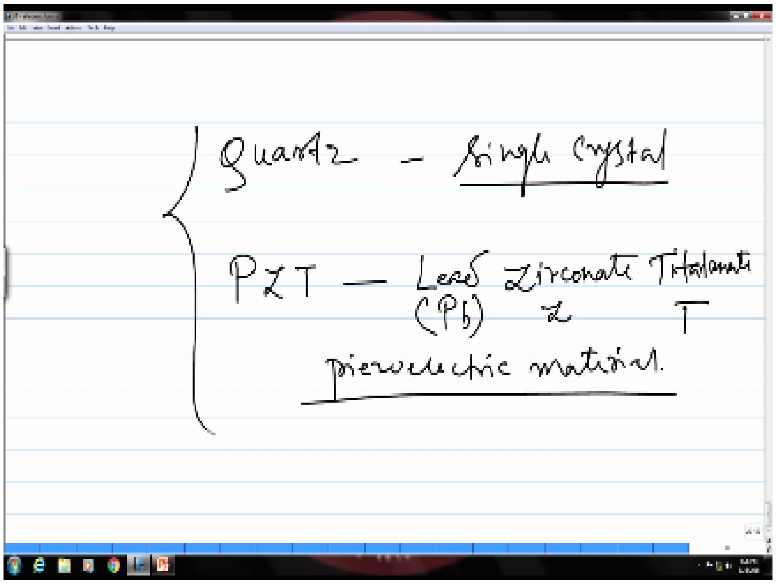

Quartz – Single Crystal

PZT — Lead Zirconate Titanate
(Pb) Z T
piezoelectric material.

So the most commonly known piezoelectric material as you might all know is quartz so single crystal quartz can be used for making these elements for ultrasonic probes there is one more material which shows very good piezoelectric property and that is known as PZT which stands for lead that is PB so that where the PB comes from zirconate that is the Z titanate that is the T, so this lead zirconia titanate, poly crystalline lead zirconate titanate is again a very good piezoelectric material shows very good piezoelectric property and this can be used in the ultrasonic probes, okay.

So let us see in terms of their properties what is the level of these parameters which control this vibrations or these ultrasonic waves in terms of transmitting and receiving for these two particular materials, okay. So when you talk about the parameters which control the transmission and receiving properties then you have to see how these waves are generated by the elements, so a piezoelectric or piezoelectricity as you all know when you supply an electrical signal.

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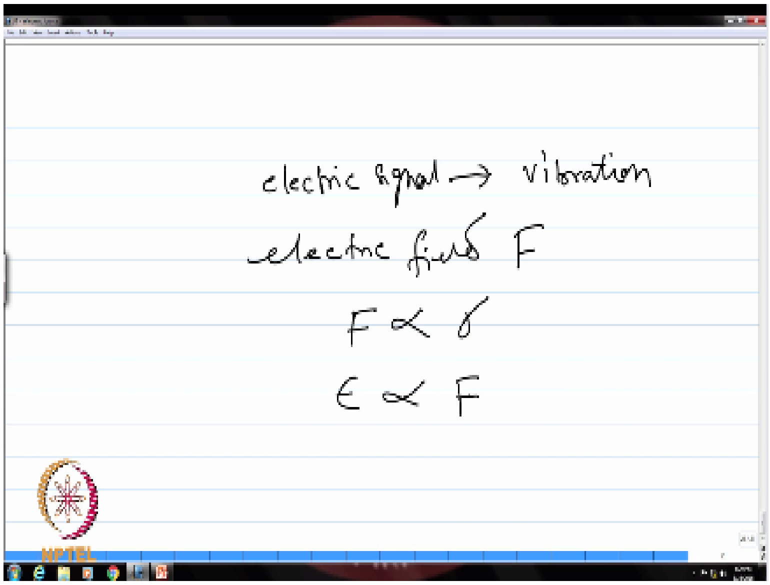

electric signal → vibration

electric field F

$F \propto \sigma$

$\epsilon \propto F$

You get vibrations on the other hand if you have mechanical strength that can also be converted to an electrical signal, okay. So let us say an electric field f is supplied so with respect to this electric field mechanical stresses will be generated and if the mechanical stress is a σ then it will be proportional to the electric field being applied, okay. Similarly, if you have a mechanical vibration or a mechanical strain that will also generate an electrical signal so if ε be the mechanical strength then it will generate this electrical signal f sothese two again will be proportional.

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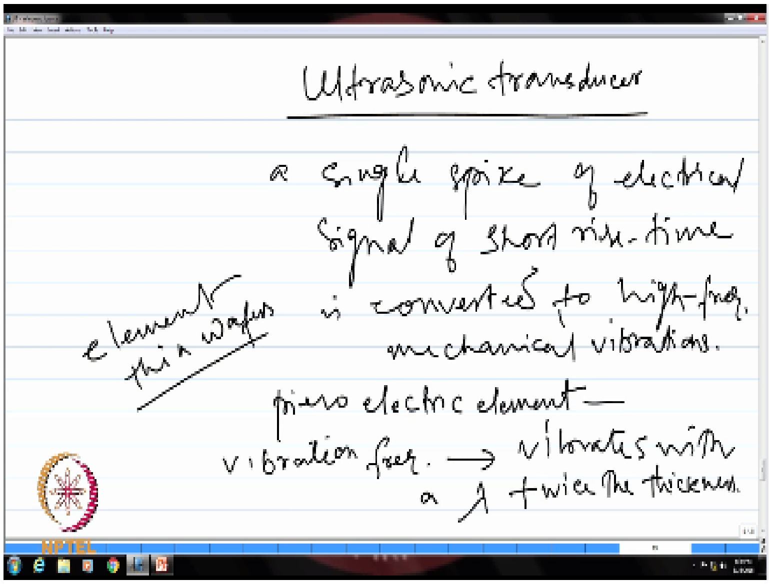

Ultrasonic transducer

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element
thin wafer

piezo electric element —
vibration freq. → vibrates with
a λ twice the thickness.

So the main component as we just now saw of the ultrasonic transducer is a thin wafer of a piezoelectric element which when excited by an electrical signal will generate the ultrasonic vibrations, okay and then this element has to be housed properly inside some kind of encasing where you can provide all the electrical leads and other things to supply the electrical signal first of all and then you have to also shield it from other mechanical vibrations so that there is enough damping at the background of this element.

So all those construction aspects for an ultrasonic transducer we will discuss in little more detail, but today I will not have time to discuss that so for today this is all I have so I will stop here today. In the next class we are going to discuss more about the ultrasonic transducers what is the construction of a transducer and you know what are the parameters which control this and then we will see how a transducer is used to do ultrasonic testing, okay so I will stop here today I will see you next time, thank you.

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