Machinery Fault Diagnosis and Signal Processing
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Lecture - 30
Overview of Transducers For CBM

We will conclude this week on an overview of transducers used in condition-based monitoring or CBM. So, what I am going to do is, you know there are many transducers, which are used in CBM.

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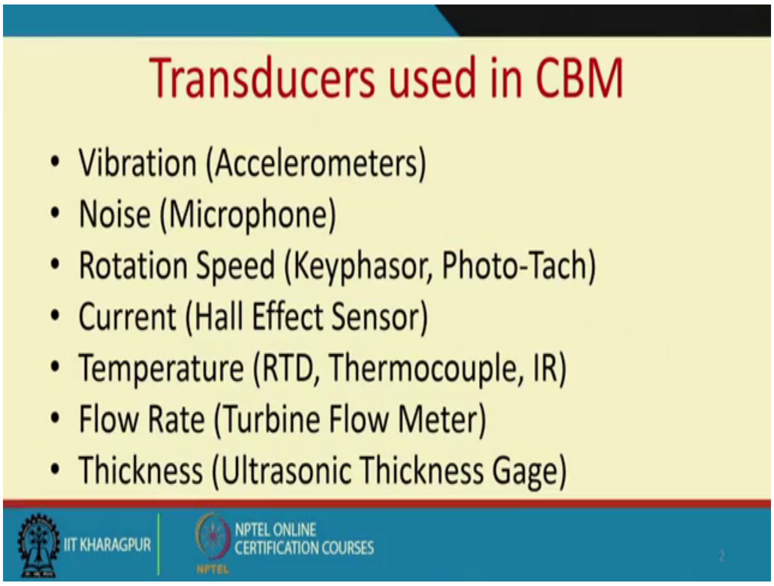

The mechanical parameters here are listed, followed within brackets. The typical or transducers, the name of the transducers which are used for a certain of these measurements. And some more I will discuss while we go ahead on this class so, as you know by now in CBM almost 70 percent of the monitoring is actually done by vibration. And vibrations are actually measured by transducers which are known as accelerometers. There is the sensing element in this accelerometer; which earlier used to be strain gauge, but today throughout the world. Usually, piezoelectric accelerometers are used where the sensing element is the piezoelectric material. For radiated noise or the sound, we use microphones. Microphones again the there are different types of microphones, but for the industrial CBM microphones there could be piezoelectric microphones or the condenser type or the capacitive type microphones. Because of the fact, they have wide frequency response unlike the carbon granule microphones. Rotation speed is a very, very important mechanical parameter, I would say which is measured a other than vibration monitoring, my vibration in rotating machines.

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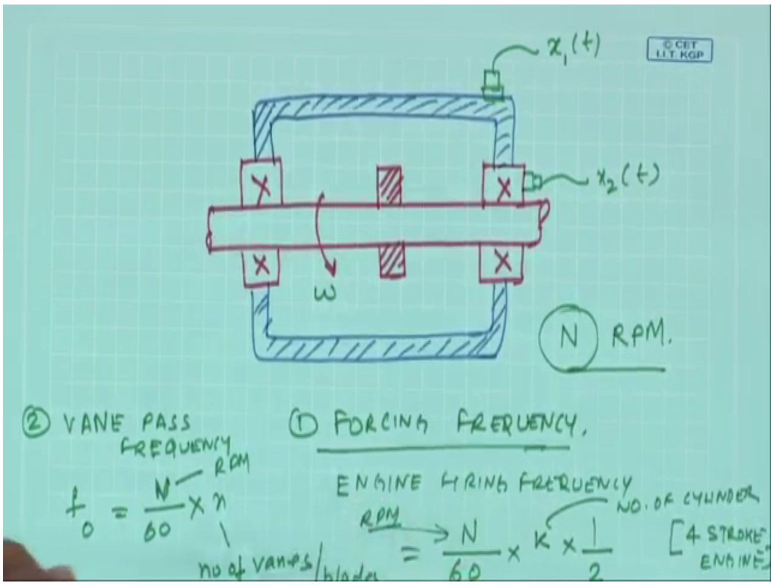

Because you will realize that when I have a Machine just to recap, every machine actually maybe having one or 2 rotating shafts supported on bearings which are rotating and this could be put in a casing and they could be carrying some fully gear etcetera and then I could be having a casing here so, this is the typical scenario of any machine. Now, I will put a transducer either here is a different color pen here, I could use the transistor here, I could put a transducer here and so on I could be measuring some x1t some x2t, but I need to measure the rotational speed omega or n RPM. Because, as you realized the forcing frequency that is the frequency at which signals are being generated are usually related to the rotational speed an RPM or sometimes given an omega. So, I need to measure rotational speed and of course, we will talk about different speeds because suppose engine firing frequencies engine firing frequency is nothing but an RPM. So, N by 60 into k is the number of cylinders into 1 by 2 if it is a 4-stroke engine where k is the number of firing cylinders.

You see this engine firing frequency is related to the rotational speed another quantity is the vane pass frequency vane pass frequency. F say 0 is nothing but N times 60 times number of number of vanes or blades. Again, N is the RPM here am of course, a so, to identify force in frequency one has to always use what is known as the rotational speed of the machine. And we will spend some time trying to see what the different methods to measure rotational speed. Current we can measure by hall effect sensors temperature by resistance temperature detector thermocouple or even infrared cameras flow rate by a turbine flow meter and thickness by an ultrasonic thickness gauge. So, what am going to do is pictorially go you go to you.

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And show you some of these transducer. So, that you get a feel of what is how they look like an order? So, this is a typical piezoelectric accelerometer if you will see this here, and you will see one of my technical staff is holding this in his hand just to get a relative feel of the dimensions of this accelerometer and you see these, this is a sealed unit the sensing element is actually inside it and we will discuss more about the accelerometers in particular in the subsequent class, but you will see that there is a connector here wherein we put this cable. So, that whatever charge is being generated because of the motion of this base can be converted to a charge to voltage. Voltage through a charge to voltage amplifier and once I have a voltage, it is an dynamic electrical signal which could be conveyed over cables to a signal conditioner.

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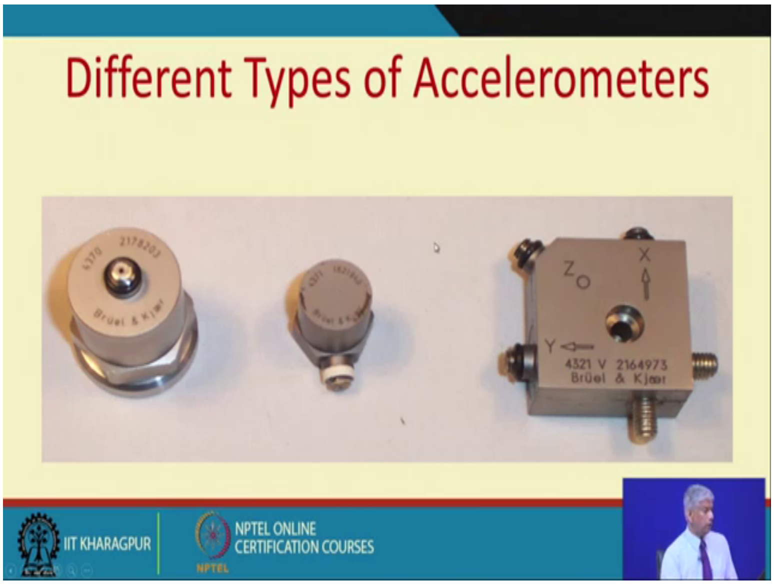

So, as you know vibration is very directional. So, the sensing element the piezoelectric crystal which is put inside this different accelerometers her also have direction to which they are most sensitive. And this is an uniaxial accelerometer and by the way this is this is about you know this diameter is about around 15 mm in size about a 50-paisa coin size.

So, there is a connector on the top. This is a little smaller accelerometer and then the connector is in the side where you put the cable and there is a mechanism there is a tap in the bottom of the accelerometer by which it could be tapped on to a surface. Now, as you will see now all of you can say that this has a higher sensitivity, this has a lower sensitivity, this being of a smaller mass, has a high frequency response and this has a lower frequency response, but now if I put 3 piezoelectric crystal in 1 unit in 3 mutually perpendicular directions this is known as a tri axial accelerometers.

The transducer this transducer is mounted on a surface any vibration which is measured along this direction in one of the X direction will come out of this cable any vibration, measured along this direction on the plane of this projection is in Y direction and now Z with a circle, here means the direction is perpendicular to the plane of the projection. So, I am able to measure at any point this if where this transducer is mounted in 3 mutually perpendicular directions and these are certain studs which are used to mount such 3-axis accelerometer are known as tri-axial accelerometers or sometimes they are known as tri ax.

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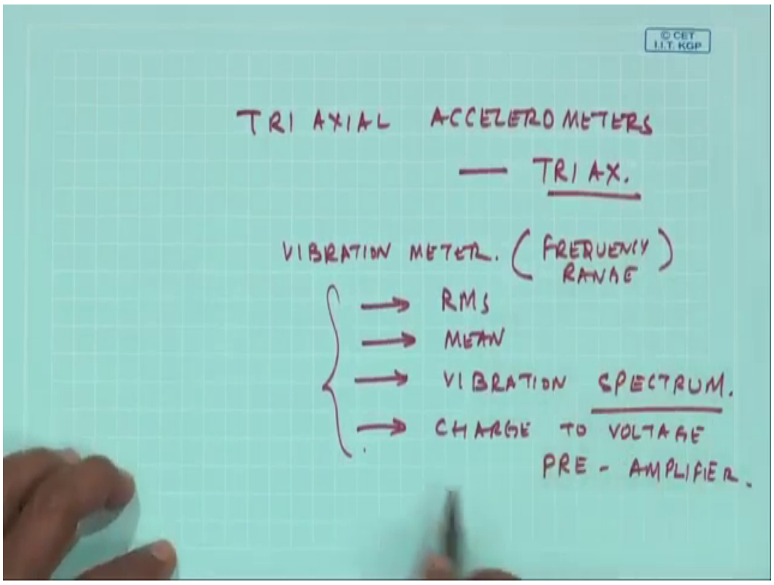

So, tri axial accelerometers are known as tri ax. Now, once we have the signal out of this accelerometers.

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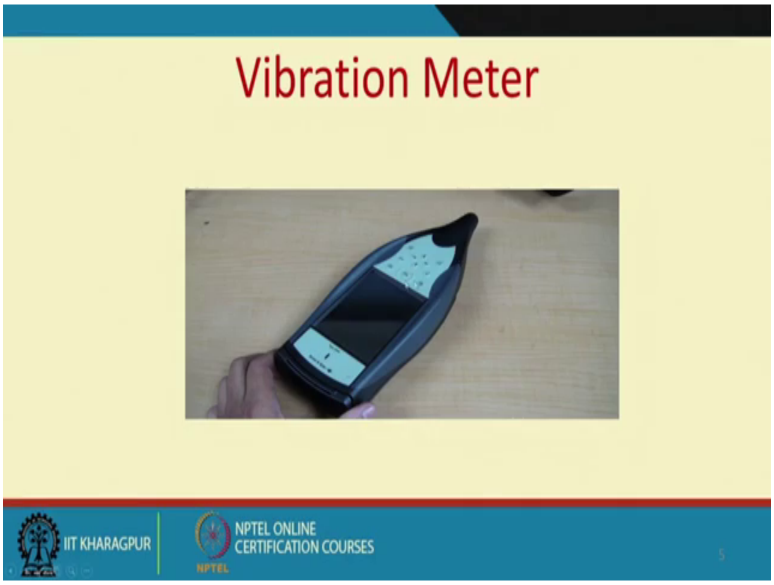

I can get either the velocity spectrum or the displacement, we could put it in a vibration meter. So, that either I can see the vibration spectrum in a vibration meter. I could see the RMS value, I can see the mean value or even I can see the vibration spectra a spectrum.

So, this is a vibration digital vibration meter where it once you mount the transducer and we can see the spectrum. Actually, this also has a built-in charge to voltage pre-amplifier all these functionalities are available in the vibration meter of course, here you can change select the frequency response frequency range also. And nowadays in digital vibration meters you will recall that when I measured the vibrations.

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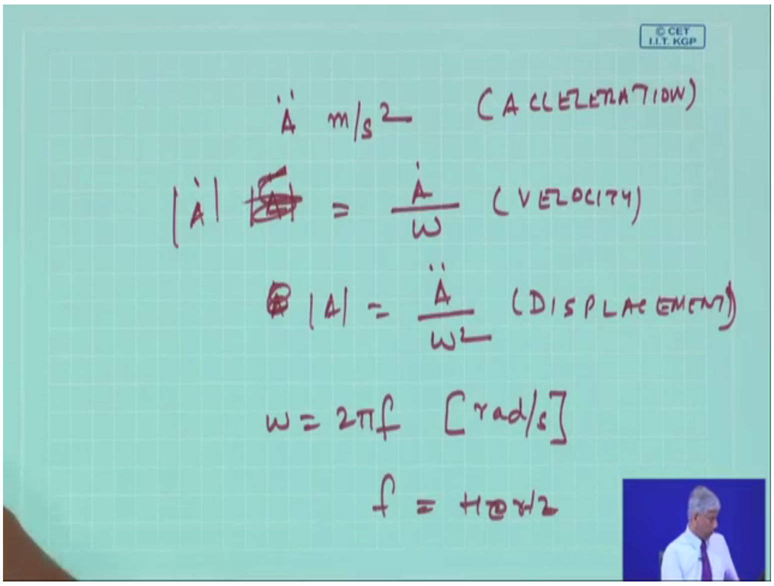

Some a meters per second square I can get the velocity amplitude nothing but a by omega and the displaced sorry of course, I should have named it A. So, and then the displacement is nothing but.

So, this is my acceleration, this is my velocity this is my displacement. So, you see in such vibration meter if I see the vibration spectrum in acceleration I can just at every frequency I can divide it by omega where omega is nothing but 2 pi f.

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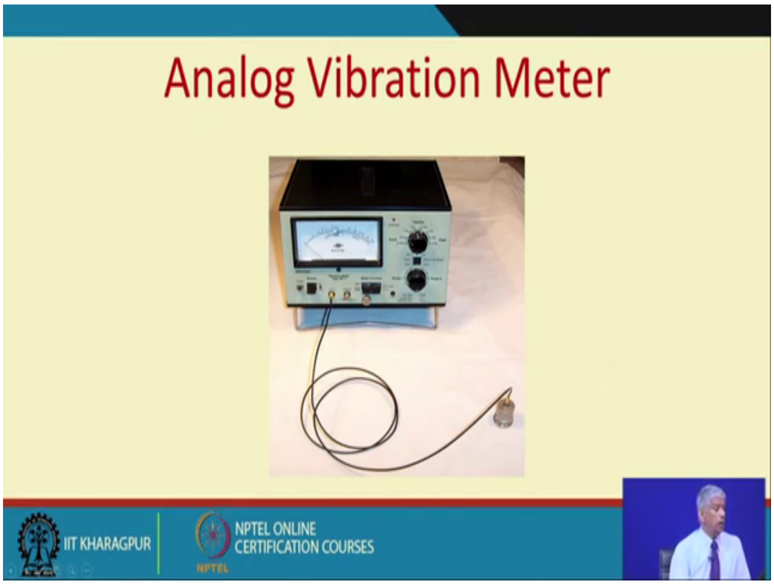

This is in radians per second and f is in hertz spectrum earlier when digital vibration meters were not available people were using analog vibration meter and we have a couple of them in our labs you know which are still working maybe 30 40 years old. So, you will see the piezoelectric accelerometer connected with a very low tribe electric noise cable to a vibration meter. Where any of the option of choosing either velocity displacement and acceleration. We can measure the RMS value mean value and then we have such an meter you also have an option to take the analog.

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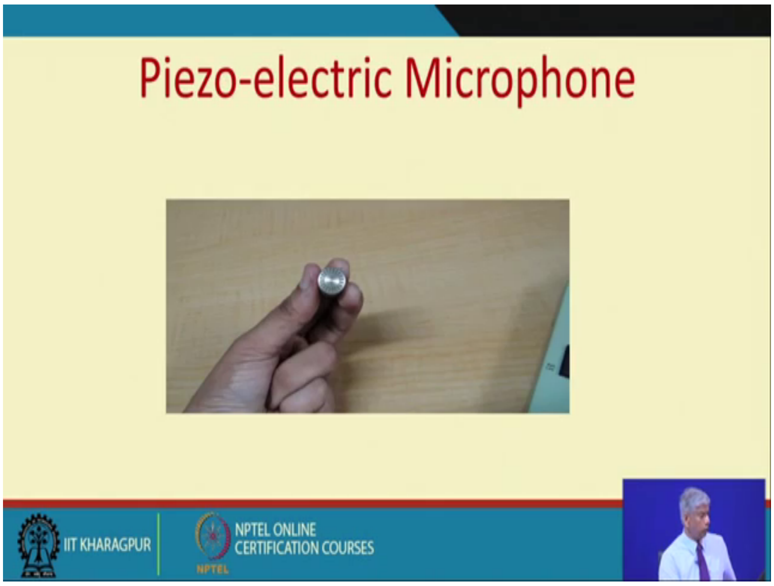

Output from this is a typical piezoelectric microphone this microphones usually have a thin membrane.

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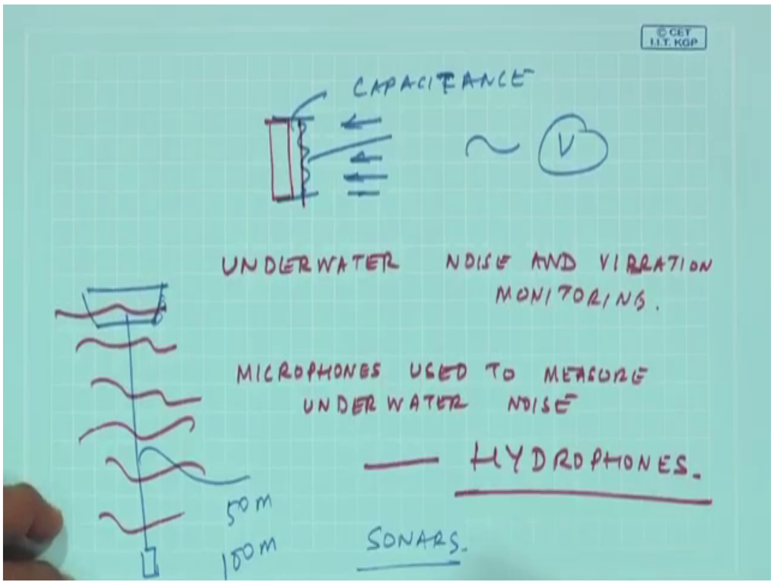

So, this membrane would vibrate because of the sound pressure. So, the capacitance would change and then we will have a corresponding voltage and then of course, in piezoelectric microphones we have a piezoelectric layer put here and such.

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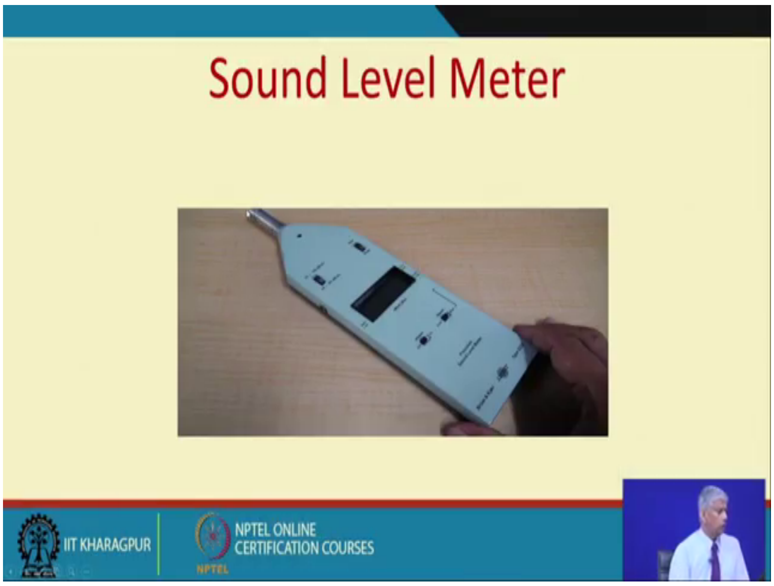

A microphone is put in a sound level meter wherein we can measure, there you can get a digital display or the sound level being measured.

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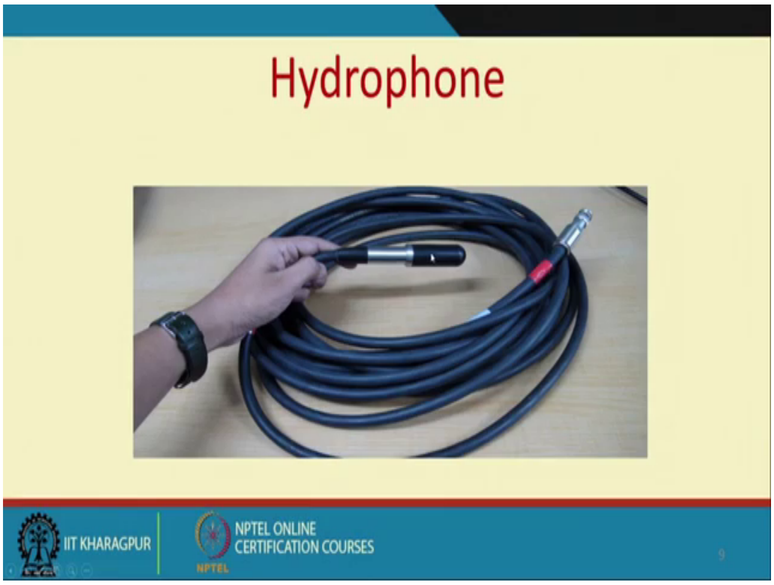

Similar to microphones which we have used in air there are cases wherein we have to do in many cases underwater noise and vibration monitoring. So, microphones which are used for underwater use to measure underwater noise known as hydrophones. So, this hydrophone also has a piezoelectric sensing element here of course, there are a lot of things related to the coupling of the energy. So, that the all the energy which is coming in gets transmitted into the hydrophone and there is a sensitivity and these are long cables sometimes the cables are. So, long you know if you are going to measure you know in an ocean you can you can suspend from a boat you can suspend a hydrophone down to the bed of the ocean this cables could be known maybe 50 meter or even 100 meter.

So, you can see underwater noise you know to understand marine features to understand popular noise to understand enemy ships sonars are nothing but hydrophones mounted on a hull of a ship. So, you can measure such underwater vibrations or underwater noise by using hydrophones the principle is the same, but then they also have different frequency range etcetera.

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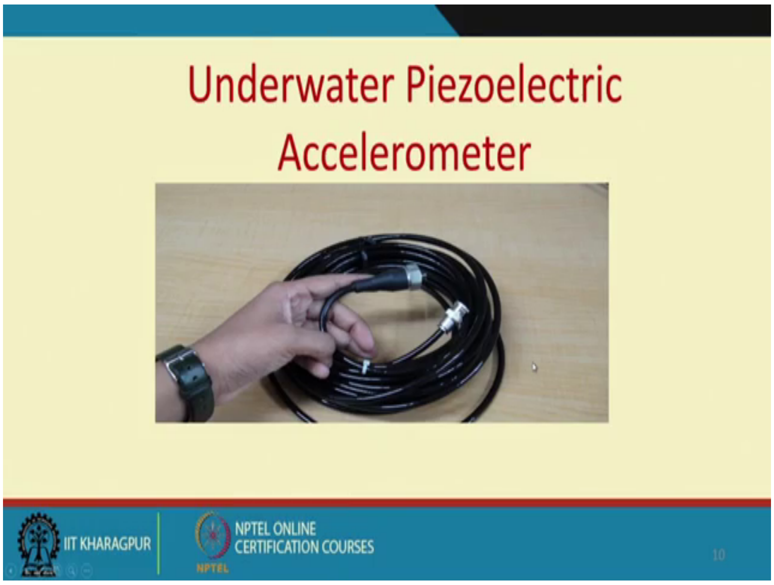

So, to measure the underwater vibrations we also have underwater accelerometers you will see this is the accelerometer here and again they have long cables integral with the accelerometer and then will it have an output which are used. So, today CBM does not mean only measuring machines you know which you see in a in a shop floor underwater measurements are being done to find out the impact of you know underwater piling noise.

A movement of ships in an channel which could affect the marine life you know sometimes because of lot of underwater movement of ship of vessels of fishing vessels of trawler noise the motor outboard motor noise of such boats does it affect the life of the marine animals. Do marine animals migrate away from ports or from areas where the noise has increased. So, this kind of monitoring are also being done many times when you know bridges or you know are being built over you know water bodies large long flyovers. So, they need to do a lot of piling because.

You know CBM always does not mean health of machines you know environmental.

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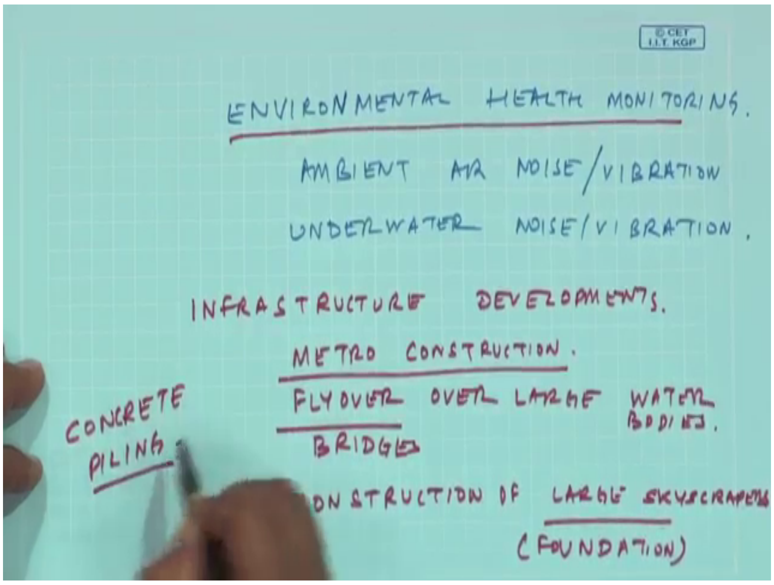

Environmental health monitoring be it ambient air noise underwater even vibration underwater noise and vibration I will give some ideas for you know people who are appearing in this online course today in our country because infrastructure developments we are having metro constructions fly over fly over or bridges over large water bodies construction of large skyscrapers; that means, you can imagine the foundation we need to have a strong foundation of you know rock bed foundation. So, if you soil conditions are very, very important you cannot have a large skyscraper built on a soft soil or we you know this. So, metro construction so, they do what is known as concrete piling to have a solid anchorage point.

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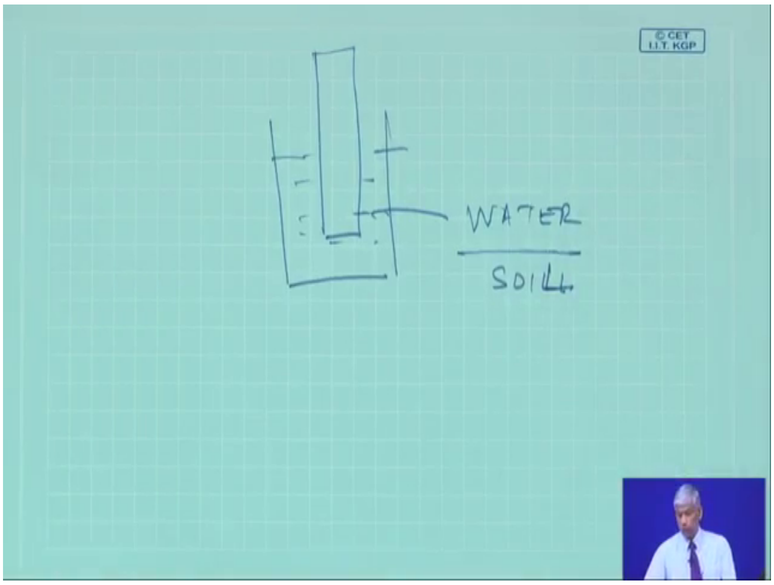

So, that piles could be put whether it is you know in water or whether it is in soil. So, all this will lead to lot of underwater noise vibration and you know buildings could get damaged because of large piling and so on. So, one has to monitor using such equipment.

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Now, will specifically focus on the speed measurements. So, if you see a shaft this is a cross.

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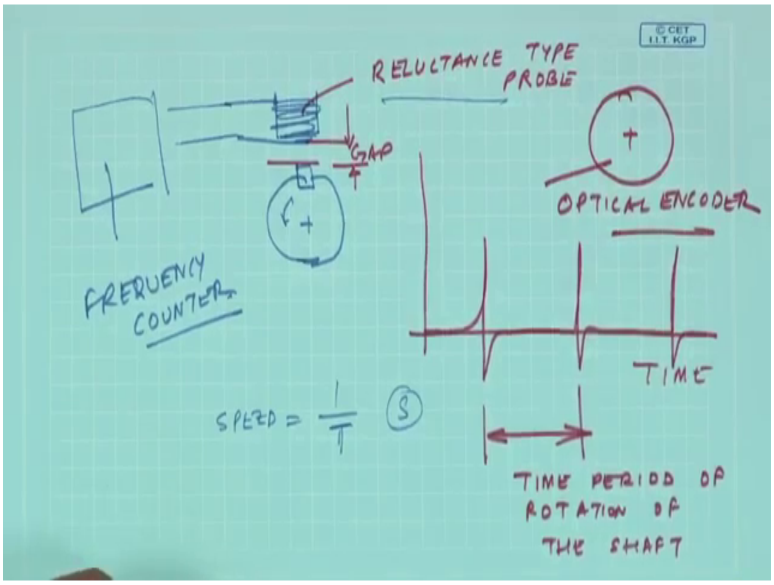

Sectional view of a shaft with a key which is rotating now suppose I put a simple electromagnet and every rotation what happens this gap is going to change. Now, this is an electromagnet or a reluctance type probe. So, what happens in time every rotation? Once the keyway just comes below the reluctance type probe the gap is going to reduce. So, I will get a voltage so, the time interval between 2 consecutive gap is the time period of rotation of the shaft.

So, if I connect this signal to a frequency counter such frequency counters are available, I will get the RPM speed, this is nothing but 1 by t seconds or in proper units either in RPM and so on. So, this is a very convenient type of pickup which is used for measuring rotational speed. And you can very easily get this it is very literally very cheap. So, every in fact, today in the industry every rotating machine, be it a palm, weighted fan, be it gearbox, they have at one of it is end such a key phasor mount such a reluctance type mount and which is connected to a frequency counter wherein you will get a digital display of the RPM, but know the accuracy of this depends.

Because I cannot vary you know this gives a mean value over a period of time, but if I want to see the change in rotational speed over one rotational that calls for a higher accuracy and that we do not what is known as in an optical encoder. Of course, another method of measuring the rotational speed is just having a tacho generator you know, you measure the frequency of the voltage which is being generated by the tacho generator which is meant connected to the output shaft.

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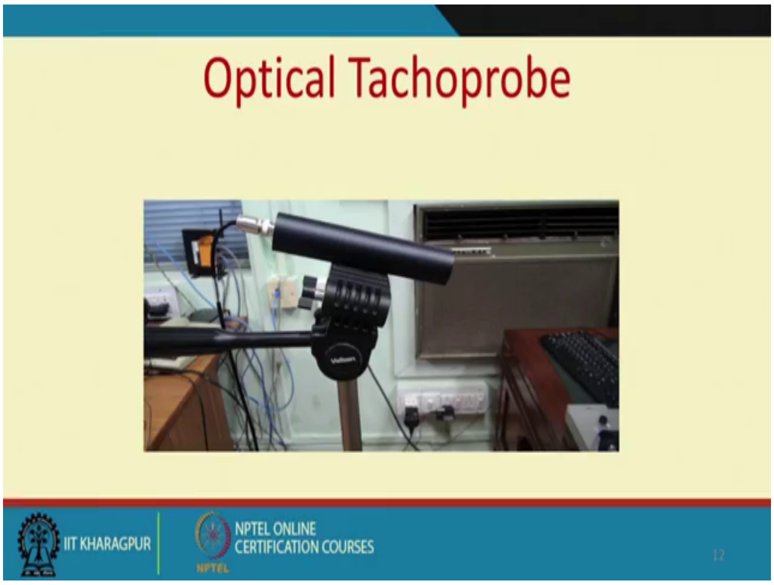

Because lot of optical tacho probes are also being used wherein we have a surface which is rotating.

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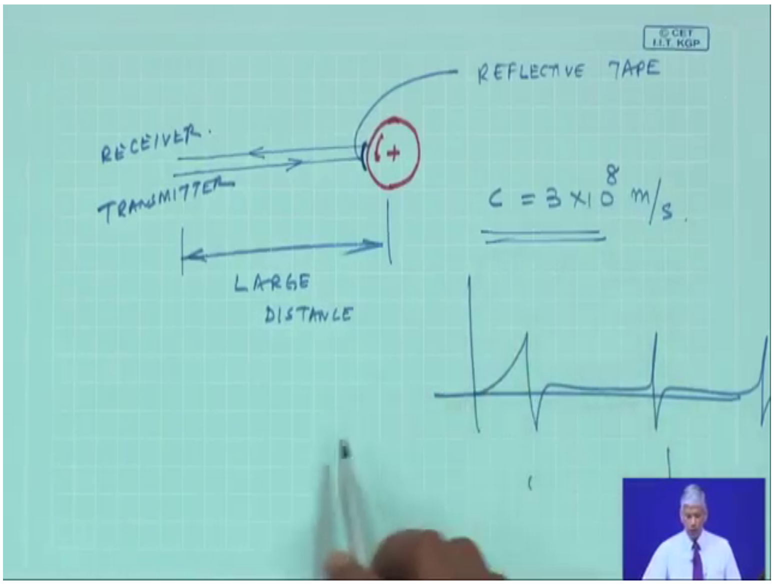

So, we will put a reflective tape so, if there is a beam which is going on same instance I will get a beam back. So, again so, the problem with the advantage of optical probe is they can be from a large distance. So, it takes only a fraction of a second because you know speed of light is 3 into 10 to the power 8 meters per second. Because of such high-speed light, we are able to use in a simple optical tacho probe. So, one is the transmitter and other is a receiver. So, again we will get a similar pulse and the we can measure.

So, optical only because of this reason a large and the advantage of our reluctance type probe is no, we can shoot optical type of probe from a large distance and then you can get the measure. For example, something is rotating high up and we are not able to access it only things that we need to have a reflective tape. So, that the light which is incident on the shaft gets reflected and such an optical tachoprobe you see, we being used in our lab.

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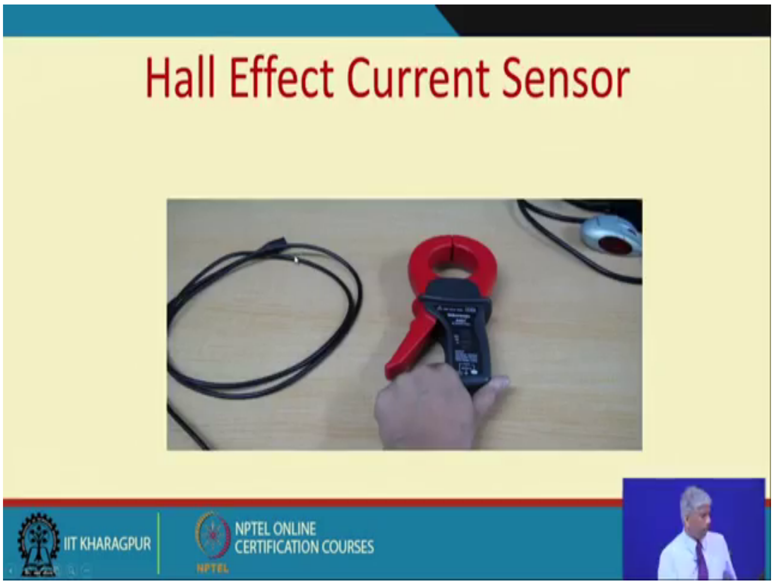

Of course, many of the electrical phenomena you will see.

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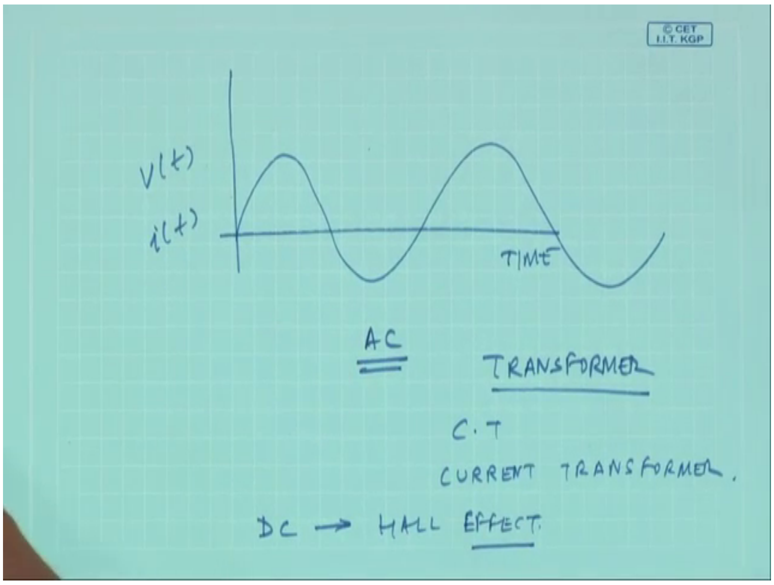

Relate to the voltage or the current, if the voltage is varying you see I can have a transformer either by a step down or a step up. So, this is known as CT coil current transformer coils and then we can measure the voltage, but even if the signal is DC.

We can have sensor built on the hall effect which can be used to measure either the current or the voltage sensor.

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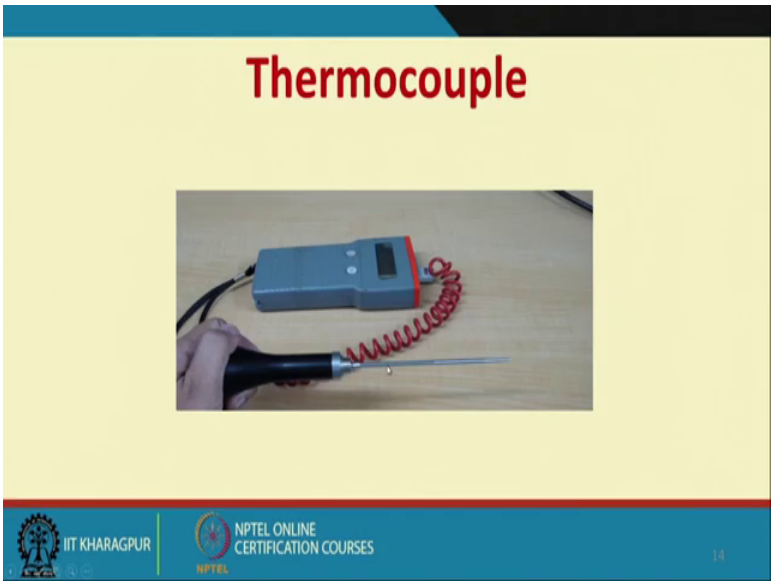

We will discuss this when we talk about electrical machines such transducers are also available thermocouple. Because of 2 metals kept at a different junction. Because they have different materials and we can by knowing one end we can measure the other hand such industrial thermocouples are there for different ranges and they can be used for different temperature ranges and so on and such thermocouple these devices are also used.

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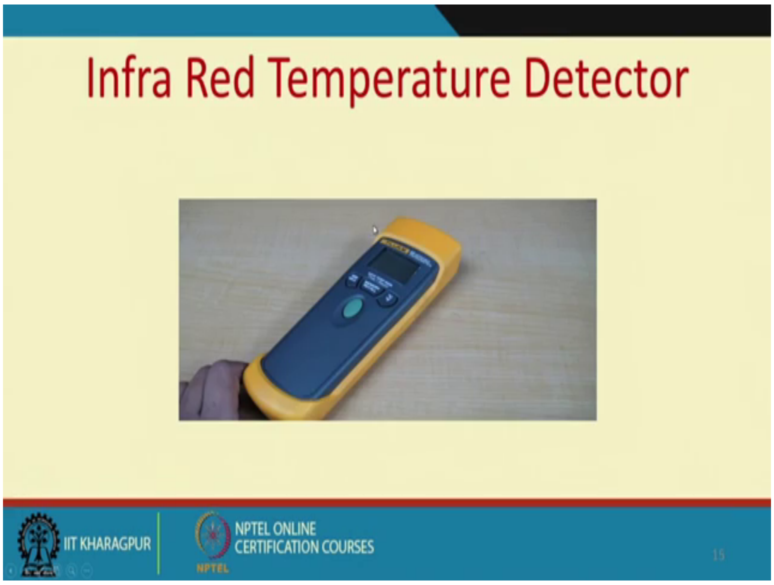

We have also infrared temperature detectors where you talk about thermal graphic. We will see how the infrared energy emitted by a surface can be measured as function of it is absolute temperature to the power 4. And then we can measure the temperature of the surface which is radiating this infrared energy.

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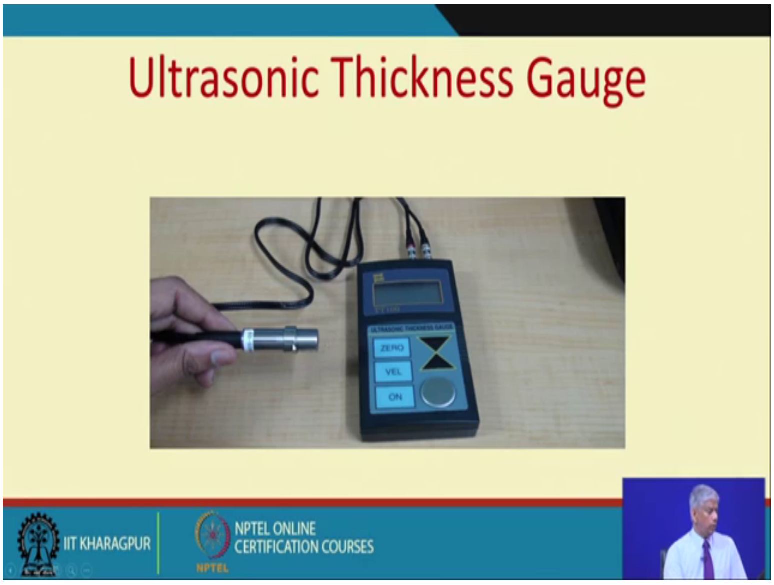

Ultrasonic thickness gauge; we will discuss this similar only things that similar to the optical case, but the variant we give a very high frequency signal.

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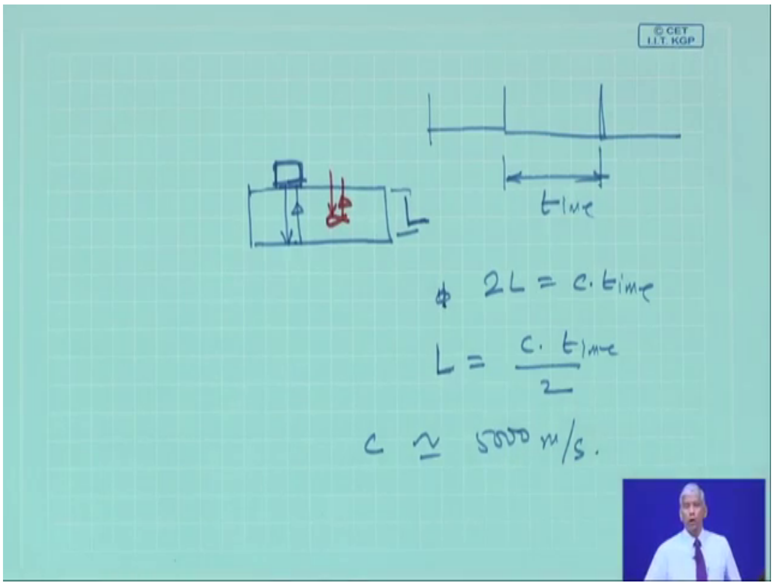

From and because of the impedance variation between surface there will be reflection back. So, the time taken between the incident and reflected back this is the time. So, and this distance is l. So, I know l because it is going and coming twice l is equal to C by t. So, I can find out L is C t times 2 and C for ultrasonic.

For example, for steel it is 5 thousand meters per second. So, I can just find out the thickness of this is the time of course, and this time is detected by an detector here we measure the time. So, we can measure such thicknesses of surfaces using such ultrasonic thickness gauge ultrasonic thickness gauges. Later on, we will see are used to detect cracks in a surface because this would reflect back from some locations. So, by as proper scanning through using ultrasonic gauges we can find out the occurrence of the crack in a surface.

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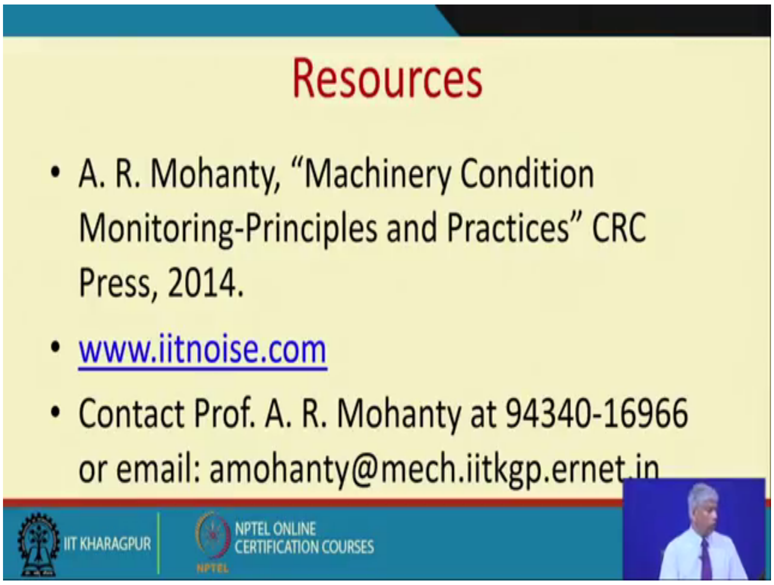

So, more of these; some of these transducers you will find in my book.

Thank you.