Machinery Fault Diagnosis and Signal Processing

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Lecture – 31
Accelerometers

Hi, in this week you know we are going to focus particularly on vibration measurements and monitoring, and towards the last two lectures will be discussing about basics of noise of sound acoustics, and a little bit about noise control. Last week I had given you an overview of the transducers used in condition based maintenance or monitoring. And in this class today we will be focusing mostly on accelerometers.

As you all know by now accelerometers are a transducer which is used to measure vibration.

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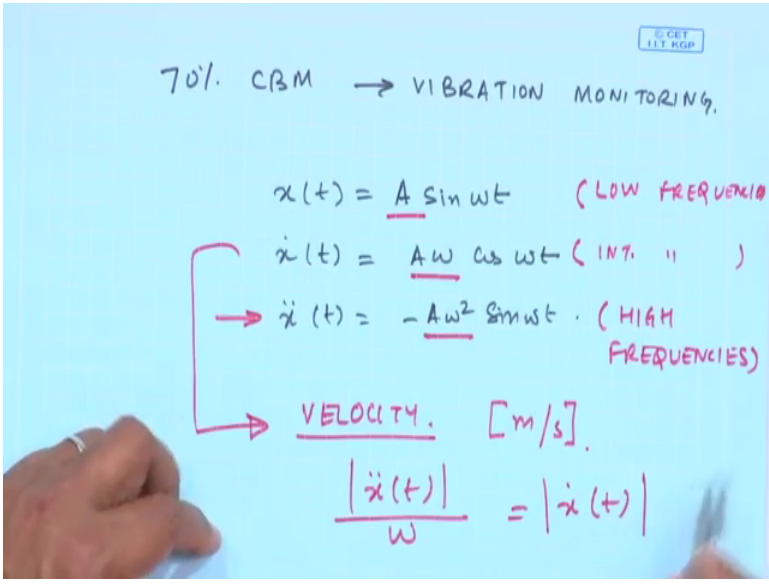

And by now we know that 70 percent of CBM is actually through vibration monitoring. But fundamentally you know vibration can be represented either as displacement or velocity or acceleration, ok.

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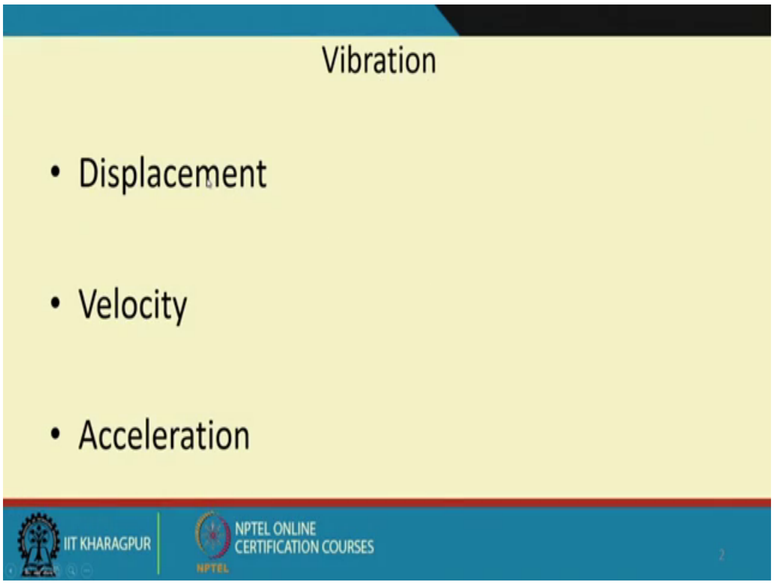

But then a fundamental question always which has been asked to me is you know; what should I measure. When I am asked to measure vibration should I measure displacement should I measure velocity, should I measure acceleration? I will give you a simple reason why and how. Imagine our displacement x t given as A sin omega t the velocity x dot t is nothing but A omega cosine omega t and the acceleration is nothing but e minus A omega square sine omega t.

So, if you look at the amplitudes of these three quantities, as the frequency increases the magnitude of acceleration is very very high omega square. And the displacement is particular practically independent of frequency amplitude A. So, definitely at high frequencies we need to measure acceleration and at low frequencies we need to measure displacements, and intermediate it is intermediate frequencies we need to measure velocity.

Now, there are many standards which exist which use velocity as a parameter. So, many of the measurements have to be reported in velocity. However, if I measure a quantity by acceleration, you already know about now if I divided by omega I get the velocity amplitude. So, by measuring acceleration and dividing it by the frequency omega, I can get the displacement the velocity amplitude x dot t, ok. So, if I was to measure vibrations either at high frequencies or intermediate frequencies, in terms of acceleration I can get either acceleration or velocity as the case may be.

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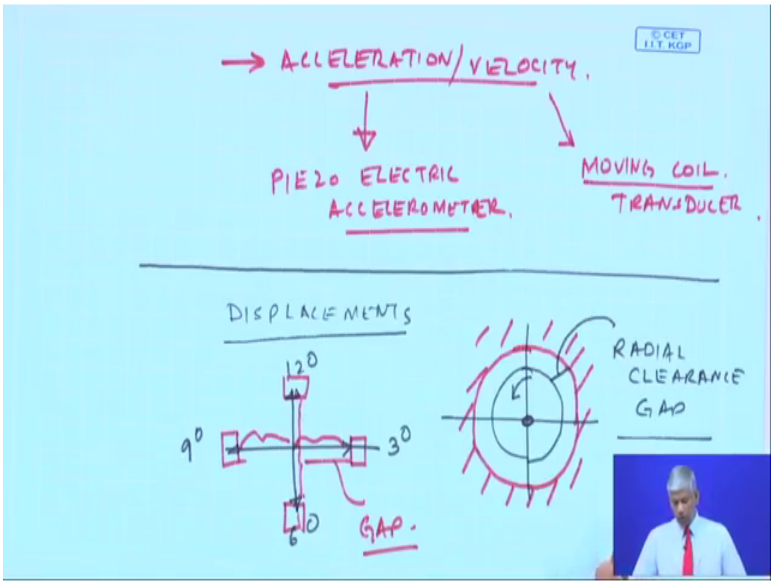

So, there are transducers to measure acceleration and velocity, this is what we will be discussing; and mostly for measuring accelerometers it is the Piezo electric accelerometer and for velocity there is this moving coil transducer, but then when I am talking about accelerometers, I must also tell you how to measure displacements. You recall that I just mentioned that for low frequencies or for imagine this is the shaft which is rotating and it is supported on bearings; imagine this was the end of a large turbine.

So, if this turbine shaft is concentric in the casing, this distance which is known as the radial clearance or the gap has to be a constant at all the positions, 12 o clock, 3 o clock, 6 o clock, 9 o clock ok. So, imagine if you are installing such a turbine at one end if you are to measure these displacements this has to be a constant value. So, how can you measure that? I can put a sensor here displacement sensor, which will just measure this gap. So, usually if it was a small movement even you know if this clearance is very very small, you are talking about a very very precision measurement.

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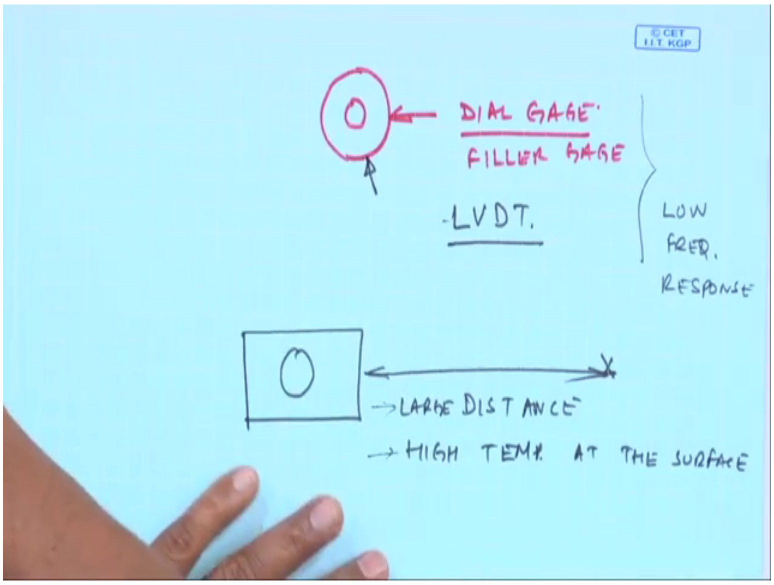

Like say the displacement in the race of a ball bearing ok. I could be having what is known as a dial gauge or a filler gauge to measure the displacement.

So, all you do is you measure in all the radial directions and they has to be same. We can do this because the event is slow imagine if you think of a mechanical device or like an LVDT is another device ok. So, all these devices are have low frequency response. So, the phenomena itself is slowly moving, I can use such transducers beta dial gauge or an LVDT to measure the displacement and they has to be equal.

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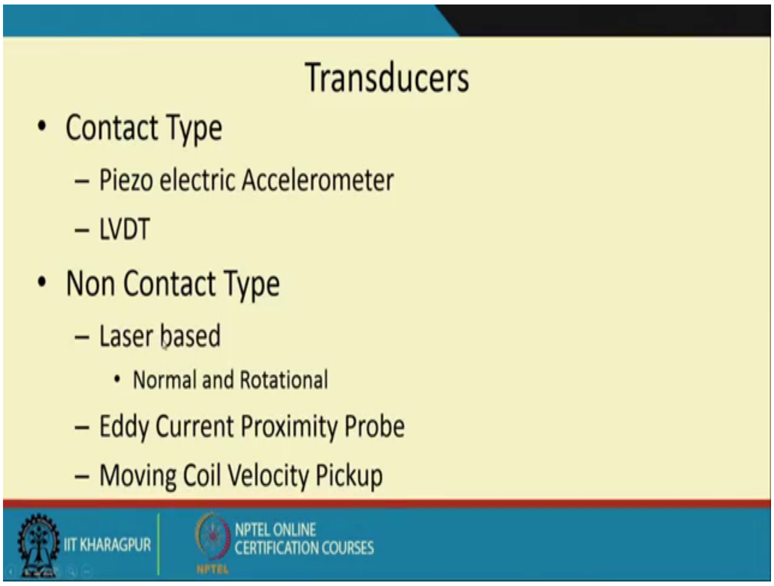

So, if I was to give you an overview some of the contact type processes which are used are the piezoelectric accelerometers. So, I can measure the acceleration, I can divide it by omega and get the velocity if it is necessary; and they require the displacement I can measure is in an LVDT. But we will come across many cases wherein I need not because in if you see LVDT it will make a it has to make a contact stylus as to make a contact. But there will be scenarios wherein you are at a distance from the machine large distance, another is high temperature on the surface. So, these are scenarios where in the contact type displacement or acceleration transducers cannot be used.

So, there are certain laser based techniques like normal or rotational this is something which we will talk about and then of course, the eddy current project proximity probe or the moving coil velocity pickup, which are used to measure the velocities.

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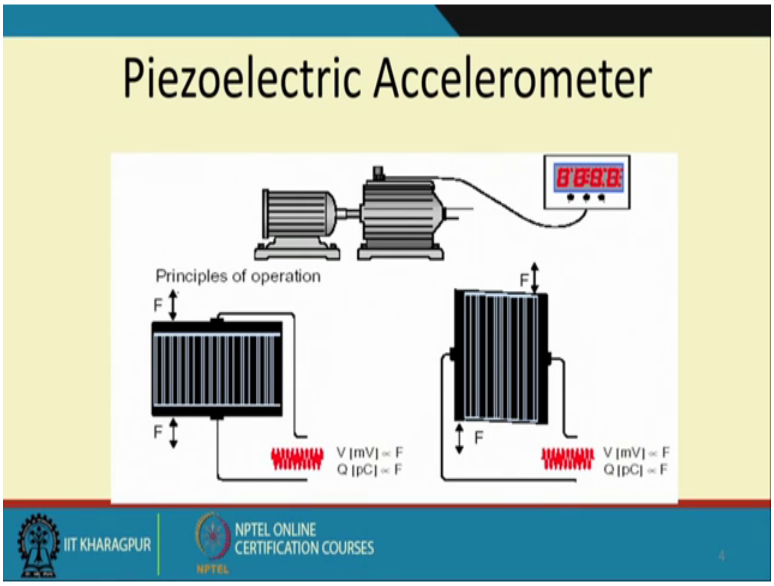

So, coming specifically to the accelerometer piezoelectric accelerometer, you will see here that in this piezoelectric accelerometer we have put a piezoelectric material or crystal, which when is having a mechanical displacement or force is applied it will produce a charge, ok so either this piezoelectric crystal.

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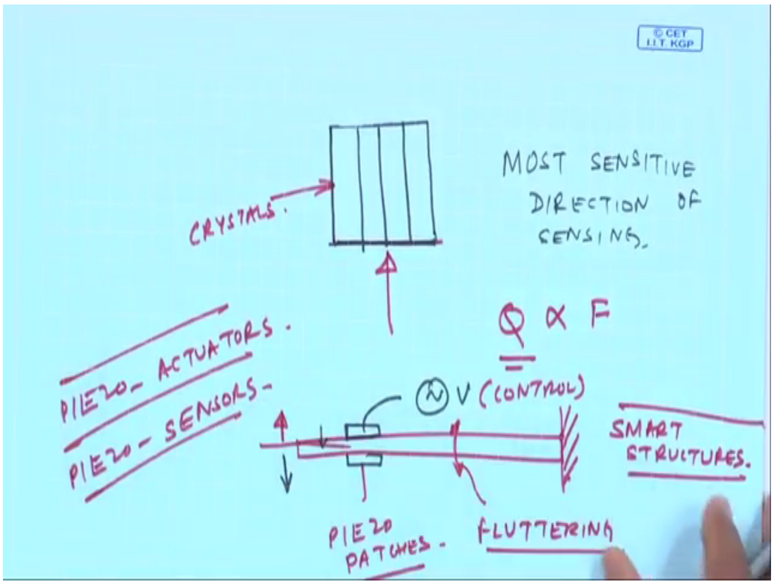

See piezoelectric crystals are found in nature or they then we artificially made also. They have the most sensitive direction of sensing as you know vibration is directional ok. So, if I have a vibration coming in this direction, I have to align this piezoelectric crystals in their most sensitive direction and then of course, you know put them in a housing like this wherein they will give a charge which is proportional to the force which is being applied or even the displacement which is occurring because of the motion ok. Now I will come to this charge a little bit later.

Another thing I must tell you when am talking about this accelerometers the vice versa also works in the case of piezoelectric crystals. So, if I give them an electrical voltage, they will also have a mechanical deflection and that is what is used in what is known as this smart structures. Suppose I put a piezoelectric crystal and give an electrical voltage some voltage V.

So, it is going to have a deflection, imagine if this beam was vibrating or what is known as fluttering I could put some piece of patches and give a proportional control voltage which would suppose the deflection was in this direction, I will give a voltage which will give a force in this direction and thus reduce the fluttering.

So, this is what is used in smart structures, this is something of course, we are not going to talk, but then there is a whole domain of research, which goes on and using piezoelectric crystal for developing smart structures; wherein I can control the movement of the mechanical structure like the Piezo actuators ok. But in accelerometers which we are using which are basically Piezo sensors ok. So, this is Piezo sensors or Piezo crystals are put in a housing I will just go to the next slide and you will see.

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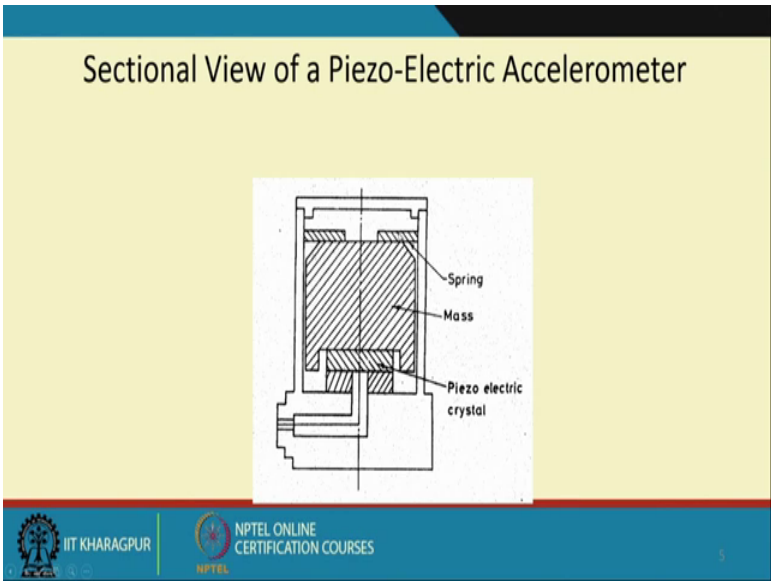

So, this is where the piezoelectric crystal is put this is a mass spring system wherein a Piezo electric crystal is embedded here, and this is the surface which is flush or mounted or attached; to the surface, where I am going to measure the vibration suppose this is my surface whose vibration needs to be measured.

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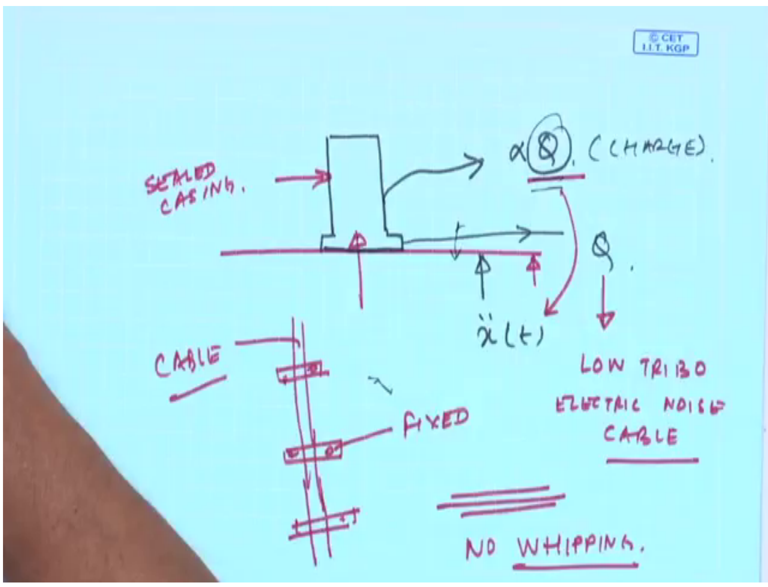

I can put a piezoelectric crystal type accelerometer, and then all this is going to give is a proportional charge which is proportional to the displacement x dot t. So, these piezoelectric crystals which are here can be subjected and this is a very hermetically sealed unit. So, the accelerometers which we see have actually this kind of sensing elements inside them and these are sealed while at manufacturing. So, all we will have is a cable; now as you know even if a cable moves around if a cable oscillates or vibrates it will generate charge. So, one has to be very very careful while using accelerometers to measure vibration.

So, this cables. So, the cables were if they are moving, they do not pick up the noise these are known as low tribo electric noise cable. They are special cable wherein the conductor is actually an co anchored with lot of reinforcements. So, the cable itself does not whip around no whipping. So, it is always a good practice when you lay an cable from an accelerometer.

So, that to get less noise it is basically good to you know strap, it with some fixed and this is the cable. Because my objective is to measure vibration in this direction and this charge should be only because of x double dot t, and not because of any other extraneous noise because of the cable moving around and so on.

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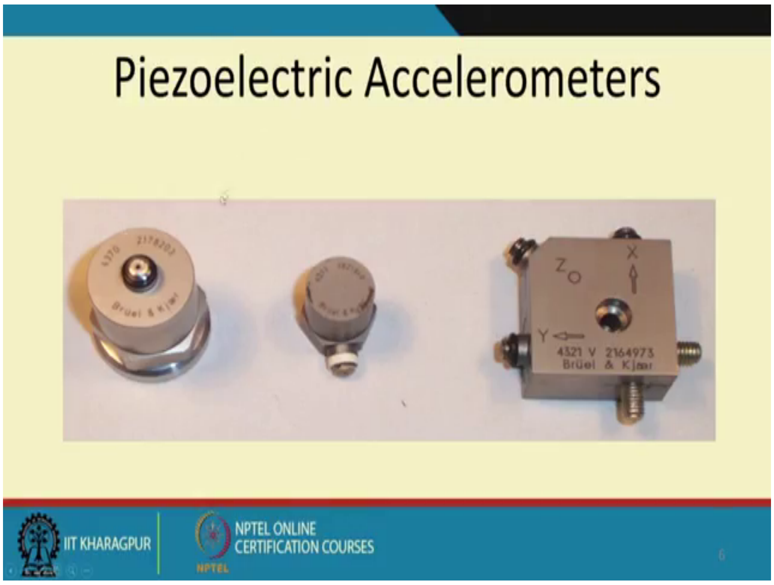

So, as I told you in the last class, these are the typical views of a uniaxial piezoelectric accelerometer sensing in one direction with the top connector, this is a side connector and this is a tri axial accelerometer with three piezoelectric crystals, aligned in three of the most sensitive in directions.

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So, you get an idea of how big or how small this piezoelectric accelerometer is, but something regarding this charge as you know this charge which has been produced by this accelerometer will decay with time.

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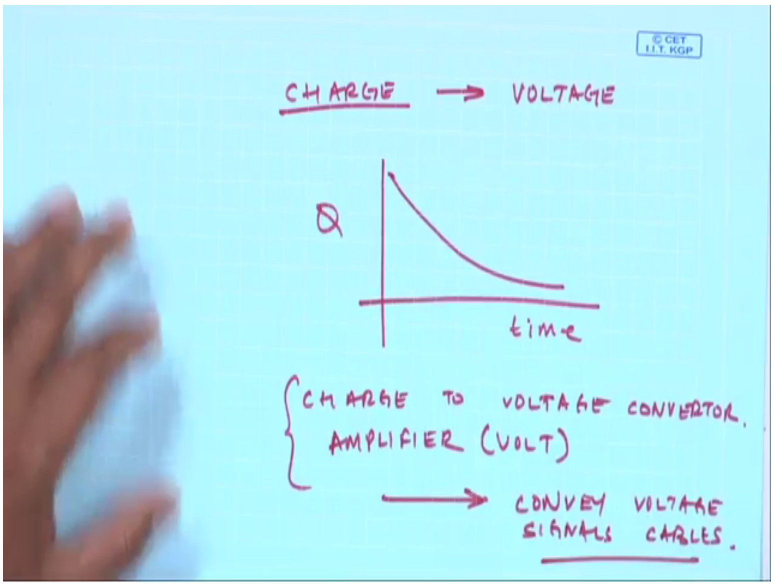

So, immediately this charge has to be converted to voltage.

So, these accelerometers require a charge to voltage converter and of course, you can then have an amplifier this is of course, the voltage amplifier and then you can convey voltage signals over cables. So, the requirement of this piezoelectric accelerometer is, that we need to have a charge to voltage converter sometimes this charge to voltage converter is actually placed inside the casing ok.

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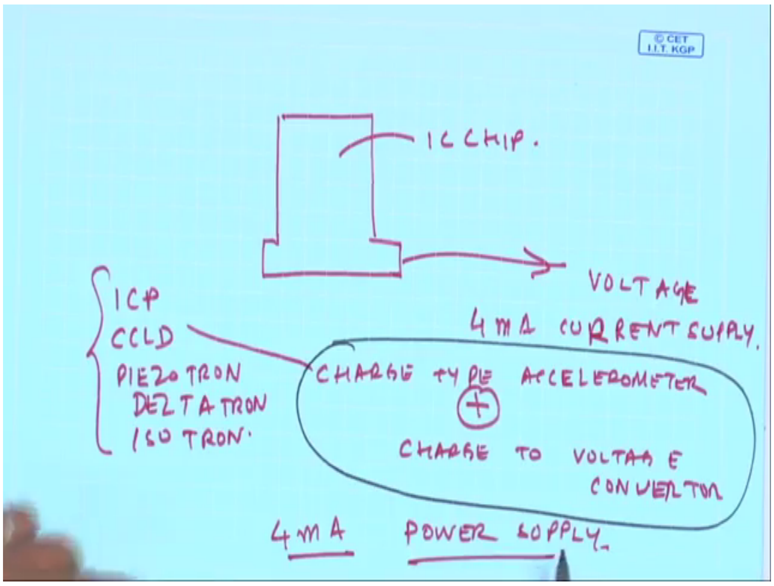

So, there is a small IC chip, which is the converter and then the output here is actually voltage. Such converters are such accelerometers require a four mille ampere current supply. So, the traditional name of some of this charge type accelerometers with an plus and charge to voltage converter inside them, this a single unit have some traditional trade names like ICP, CCLD, Piezo tron, Delta tron ISO tron. So, in the market if you go to accelerometers which already have this IC chip built in all you require is just a current supply. So, many of the signal conditioners today give you four ampere a mille ampere power supply supply power current and the advantage of this is you do not have to carry a separate.

Charge to voltage preamplifier or power supply now what happens is this voltage which we have got can be straight away connected to a signal recording unit and then stored, but there is a limitation because this IC chip is inside it there is a.

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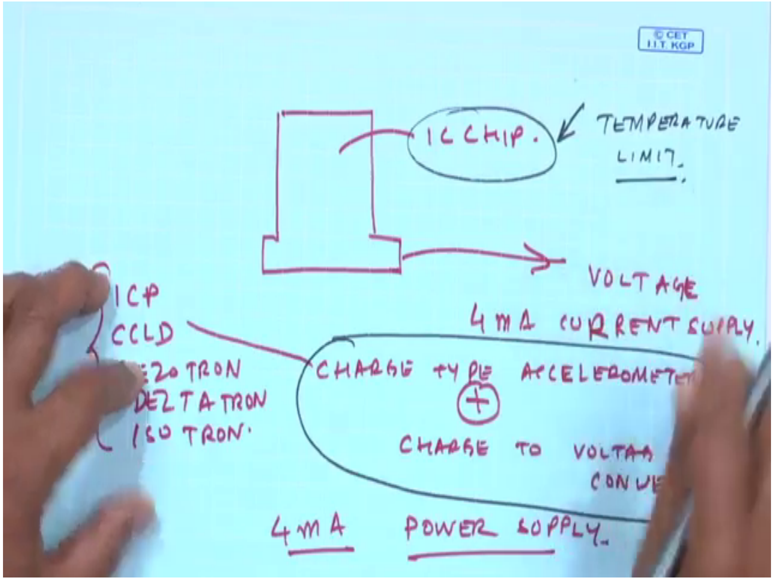

Temperature limit this temperature limit can be high.

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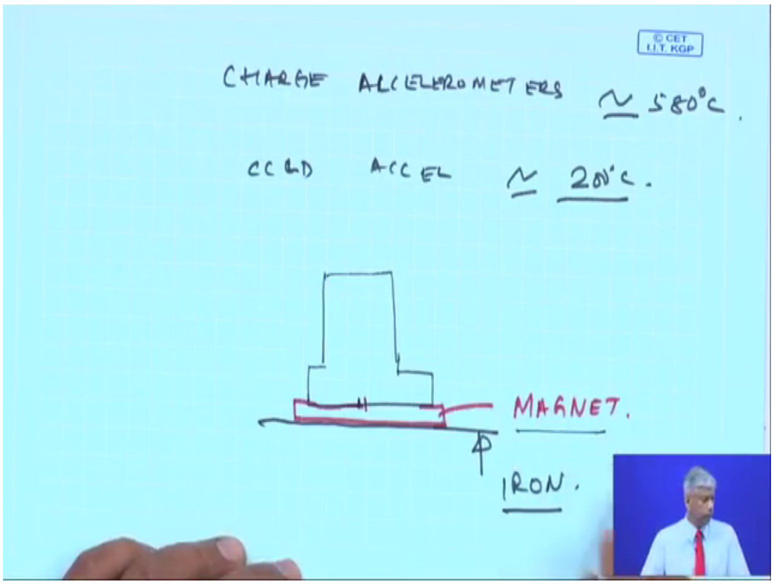

For charge type accelerometers today in the market they may go somewhere around 580 degree Celsius, but the CCLD accelerometers can go only at 200 degrees Celsius.

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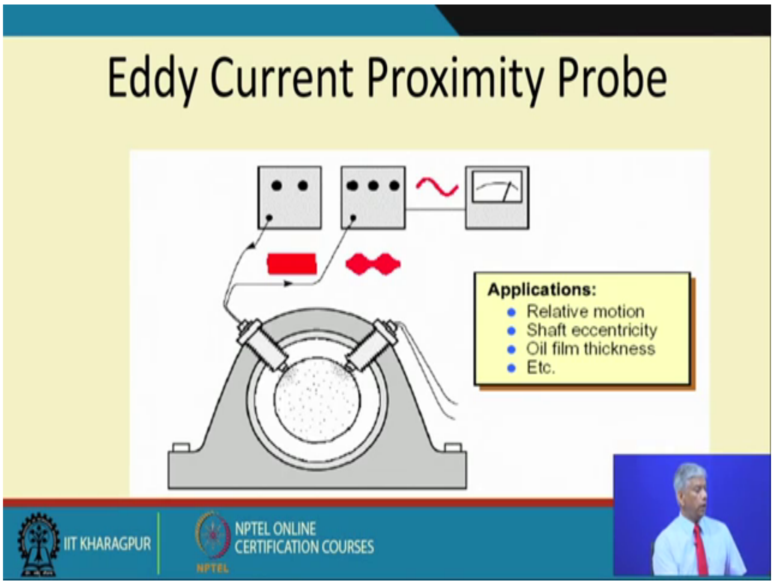

So, for high temperature applications, we require charge type accelerometers. Now coming to the displacement type measurements we can have an eddy current proximity probe, wherein we give a primary excitation voltage and because of this air gap or a gap ok. There will be a secondary voltage induced; only thing that this has to be metallic and then we will get a proportional voltage which is because of this air gap and such, eddy current proximity probes are used in tub turbines wherein we can use the relative gap at different radial distances.

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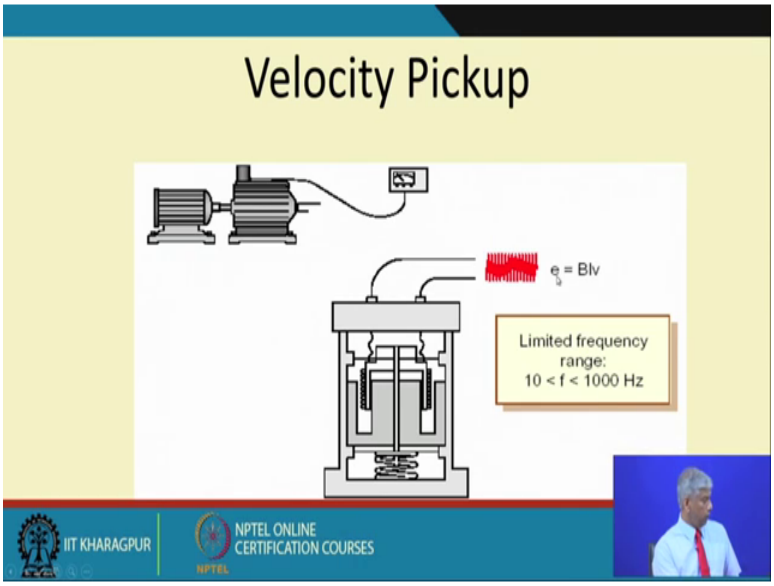

Velocity pickup which is used to measure low-frequency vibrations, but they have a frequency limit from 10 to 1000 hertz nothing but an electromagnetic coil and because of this velocity here I will get a proportional voltage.

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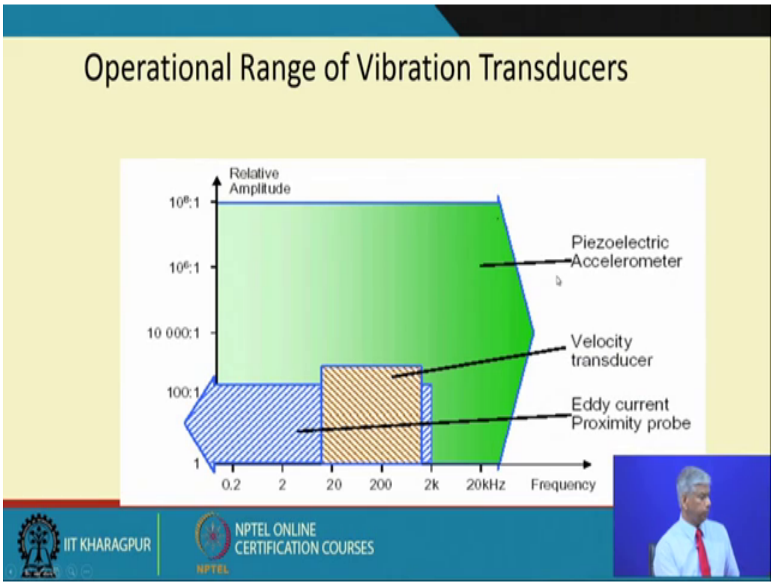

So, if you look at all the operational range of vibration transducers, if you look at the frequency re response here frequency range and the dynamic range. The piezoelectric accelerometer in fact, cover the entire domain of measurements, where in the low frequency measurements are done by ad current proximity probe, which again has a very low dynamic range and the velocity type transducers which have somewhere between 1000 to 2000 a little less than 2000 hertz of frequency response.

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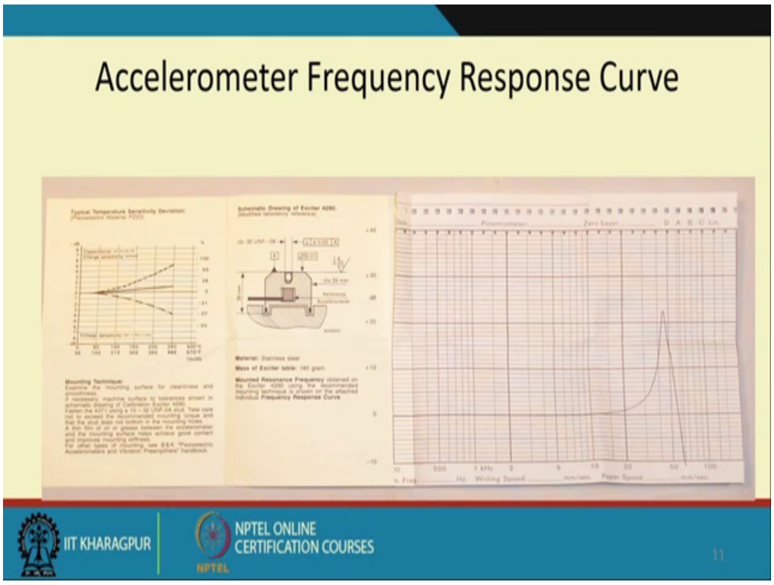

Now, if you go to the market to buy this accelerometers, you will see such charts where this gives the frequency response of the accelerometers and some of the mounting methods by which the accelerometer can be adapted.

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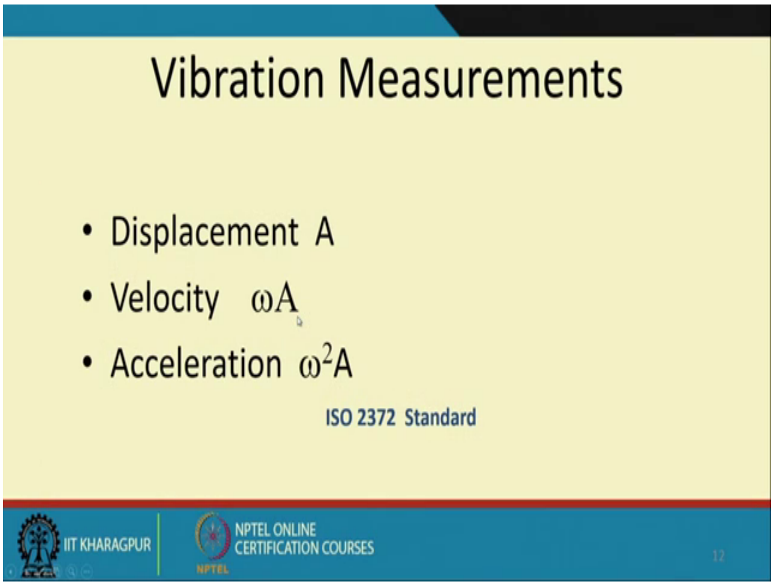

And of course, there is an SO 2372 standard which we will discuss in the next class when you talk about vibration monitoring that how this is to be done.

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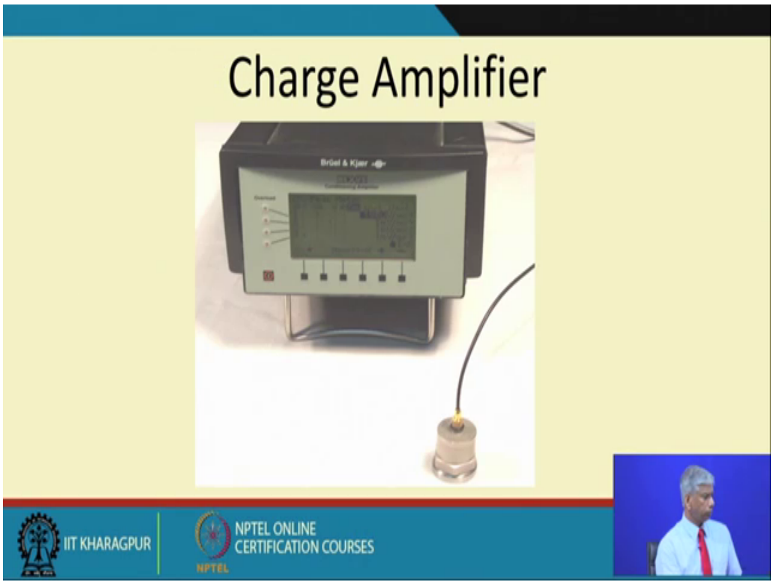

And this is a view of the charge type amplifier wherein this is the accelerometer and this is the low noise triboelectric cable, and where in this charge amplifier actually has a charge to voltage converter and then an amplifier where I can amplify the voltage signal to transfer to long distances.

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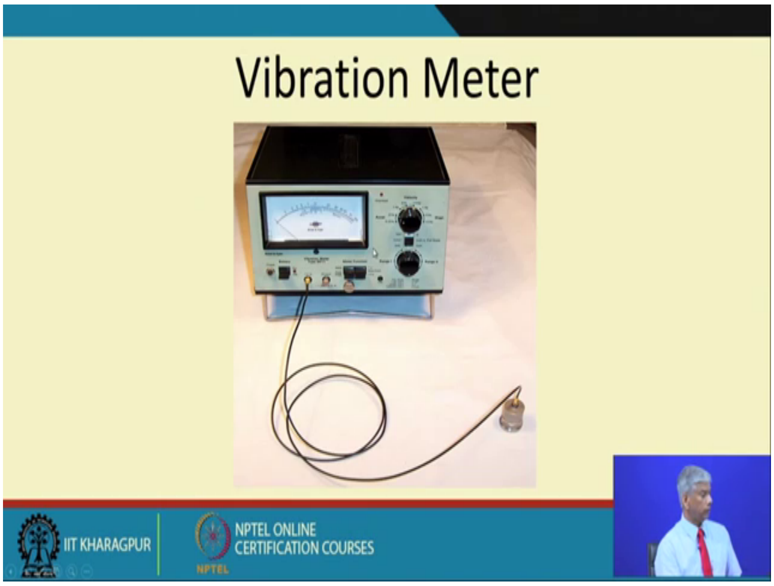

And this is the vibration meter which you know by now.

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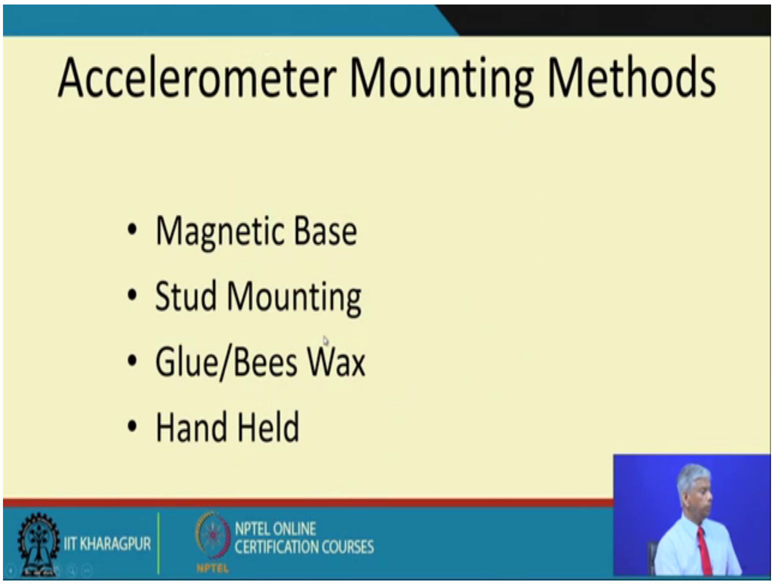

So, some of the methods by which this accelerometers can be mount, we can have a magnetic base to the accelerometer for example. If you have this accelerometer, I can screw a magnet onto it, but then this surface has to be of iron, which would attract magnet. So this is not possible on all surfaces another is I could tap a hole onto a surface and put a stud.

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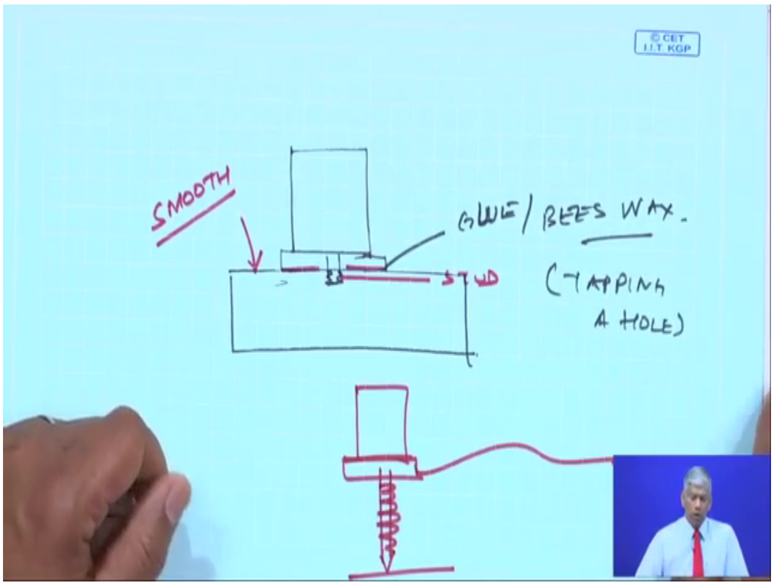

So, tapping a hole; but mind if this surface has to be smooth; so that this surface makes a nice contact with the base; so easily a good idea is to always you know clean the grease by some acetone and then, I have a sandpaper and then polish it and then you can put either a magnet or put a stud and sometimes even a thin layer of glue or wax or these wax can be applied to stick this accelerometer on to the surface, and sometimes you can also have a handhold probe and then you can be attaching it to any surface which you are measuring. So, this gives you a good idea and very quickly we can measure the locations.

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So, this is a typical accelerometer kit, which is available when you buy from the market.

So, this is the accelerometer with a side connector, this is the low noise triboelectric cable this is the magnet, this is the beeswax, and here if you see there will be some studs, some washers, sometimes to ensure that there is no electrical grounding of the signal I am passing of the cur electrical current; we put a micro washer and this is the probe which can be attached to the accelerometer, which is known as the handheld probe, and they have given a tap to tap a hole after you drill it the surface tap it and then put a then screw the start and then amount the accelerometer. So, you will get typically a different type and of course, this is the, this is known as a microdot to b and c.

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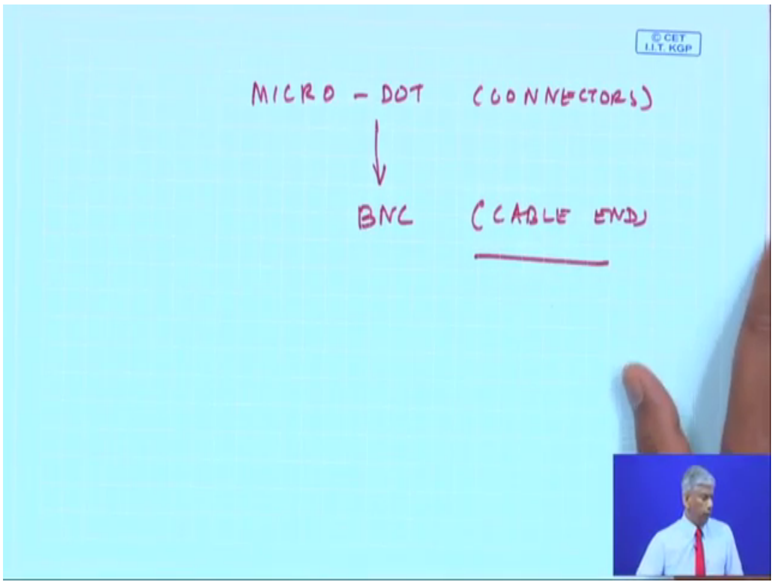

So, usually the accelerometer cable connector are known as the microdot connectors ok. And then the typical BNC connector is the cable and. So, a microdot at one end and BNC male at another end would be used to connect to any of your signal conditioning devices, and once you have the signal conditional where there is a voltage signal you can amplify it and go ahead and.

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This is the calibrator which we know about, now this gives an acceleration of ten meters per second at thousand radians per second ok.

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So, this is a typical view of a natural air meter being used to measure the vibration of a bearing rig.

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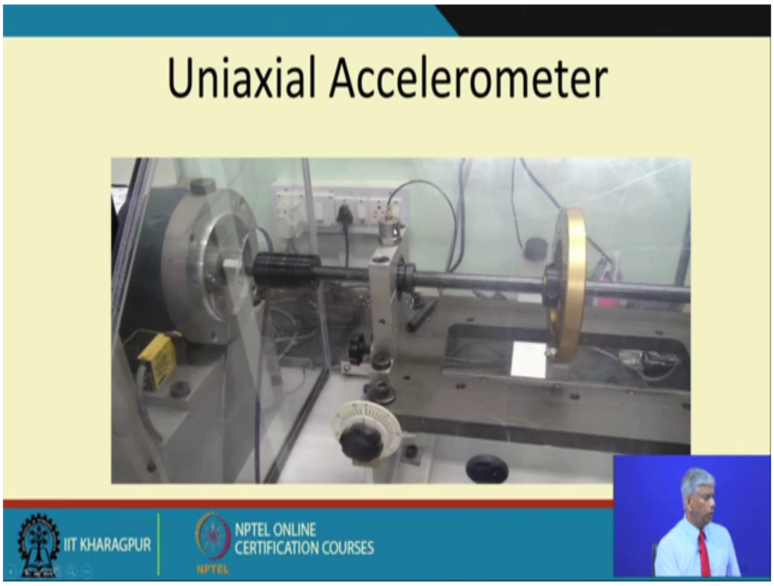

This here you can see an uniaxial accelerometer, being put in a rig to measure the vibration.

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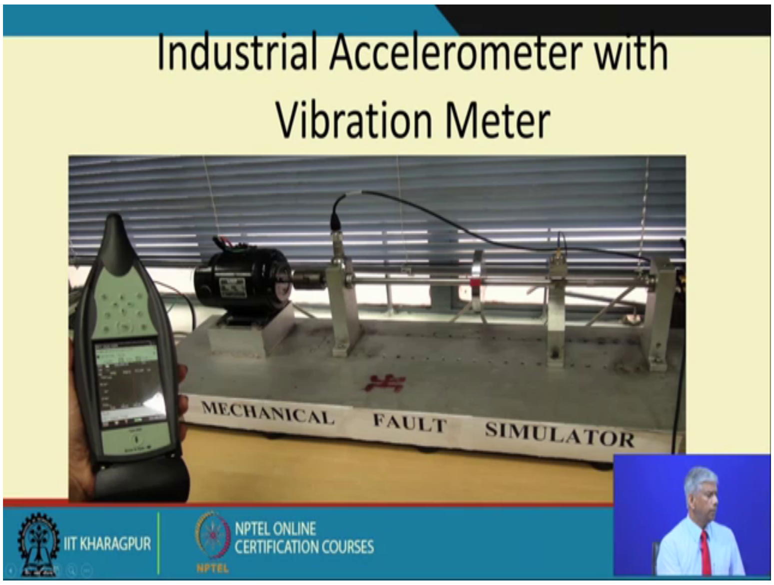

And this is again and industrial accelerometer which is heavy duty this strong magnet along with a vibration meter.

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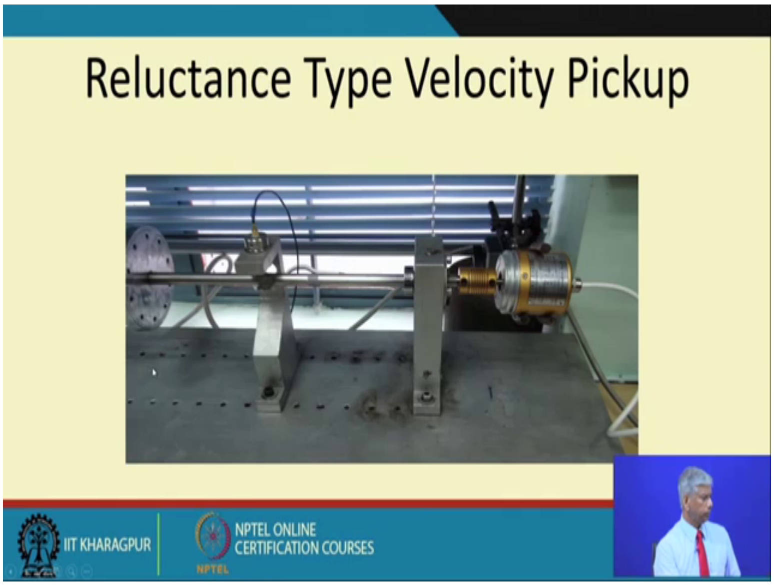

This is another type of velocity pickup, which will come when you talk about the rotational speed measurements.

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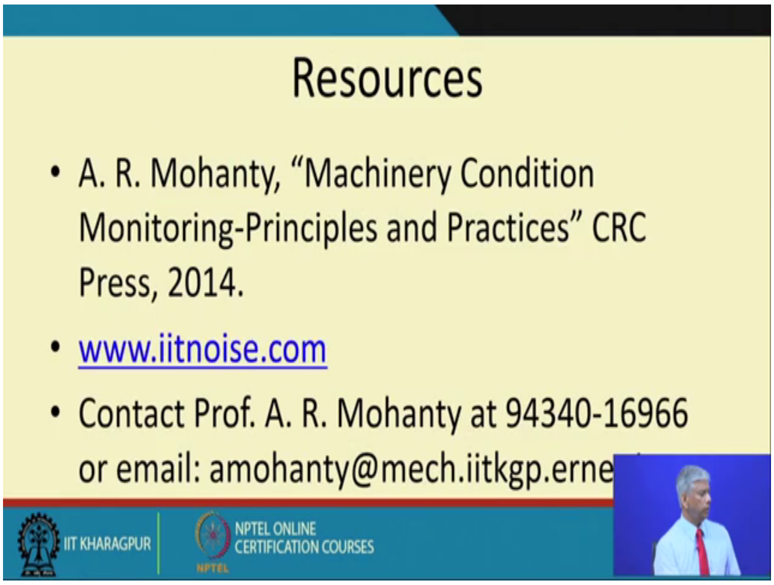

I will discuss about laser vibrometers in the subsequent classes regarding laser based vibration measurements and both for normal and rotational vibration measurements in the next class.

Thank you.