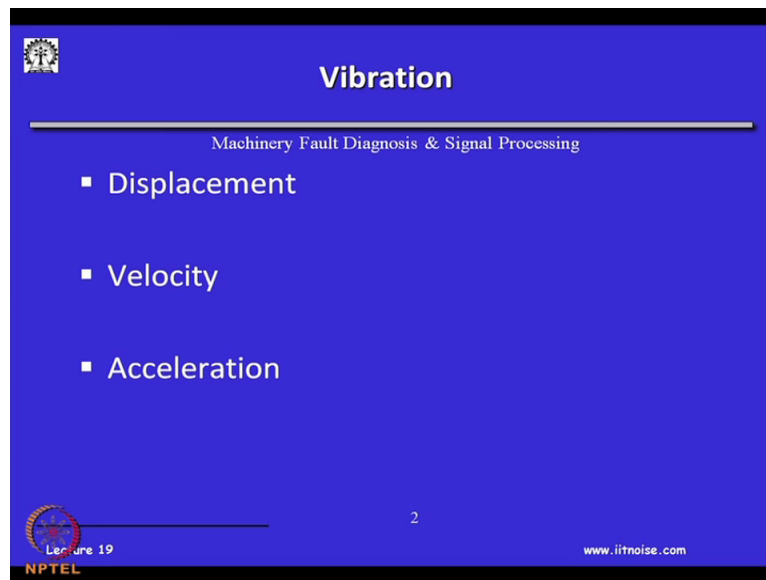


Machinery Fault Diagnosis and Signal Processing
Prof. A R Mohanty
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Indian Institute of Technology-Kharagpur

Lecture -19
Vibration Transducers

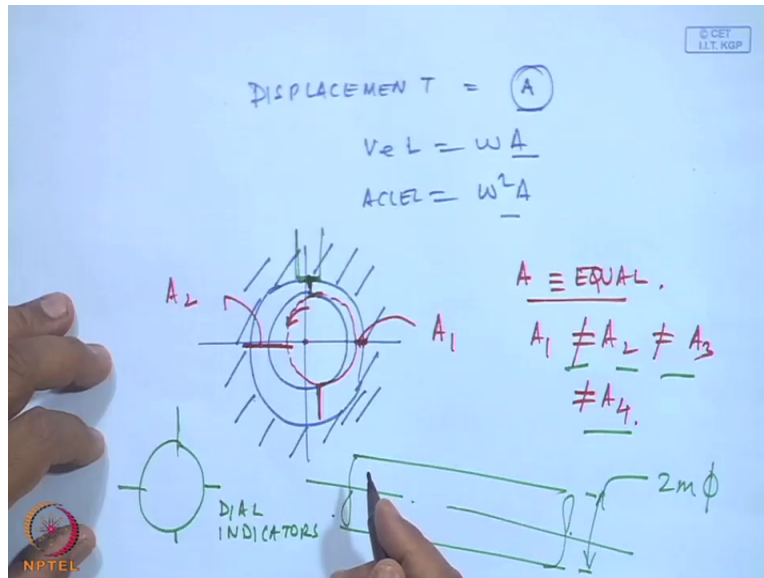
This is a lecture on vibration transducers as you know and condition based maintenance about 70% of the cases of machinery health monitoring is done usually through vibration. So, in this class we thought that we should look into the merits and demerits of the available vibrations and transducers. And what are the different types of vibration and transducers used in industrial health monitoring. And in the subsequent classes will be talking in details regarding how actually why vibration monitoring is done.

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So, as you know oh no what is vibration you all know vibration can be represented either as a displacement, velocity or acceleration?

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Well if displacement is denoted the amplitude is denoted as the A, you know velocity is omega A and acceleration is omega squared A. So, you see there is always a strong relationship between the amplitude of the quantities measured and the frequencies. So, in one way at high frequencies you will see because of this Omega square A term the acceleration is going to have an high magnitude compared to displacement.

Displacement is actually a frequency independent phenomenon okay. And it is actually a low frequency phenomena okay. I always, I am asked this question you know what is the best parametric measure okay. You will see as we go through this class sometimes our low frequencies it is actually the displacement.

For example if you think of a shaft okay which is there in a casing, this is the casing of the shaft or a housing. What could happen is this shaft while rotating if it is not on the rotating at its center there may be a subtle slight eccentricity okay and because of this at any of the points you will see the displacement at one location is A1 another location is A2.

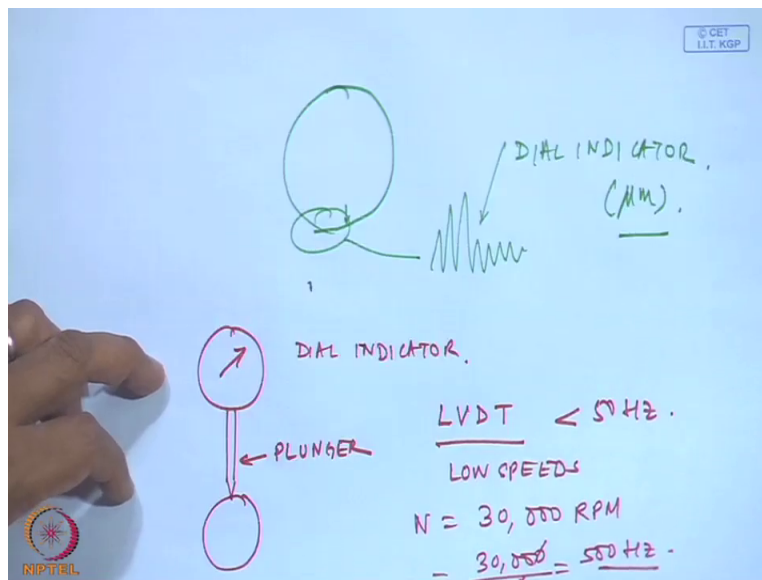
For the shaft to be uniformly or concentric to the center all these A's should be equal to measure in the four quadrants or four or four directions at 90 degrees to each other. But if you will see A1 is not equal to A2 is not equal to A3 etcetera ok. Then what happens is we know there is some problem ok.

Because of and how can this be detected if I have some sort of a sensor here displacement sensor of some sensor which senses this gap between the rotating shaft and the casing it will tell them there is something wrong with this machine. So, this is where actually displacement sensors are used okay if you could be slowly turning the shaft it may not be powered by a motor.

It could be slowly rotating by some mechanical device think of a large cement plant whether you have the large very long rotary kiln. Kiln could we have the diameter of 2 to 3 meters the diameter of the kiln okay and this could be about 2 to 3 meters in diameter. So, what happens in such a case if there is a slight eccentricity we are going to have problems and the forces are nuclear forces etcetera.

So, this actually you know your assign when they go to install and commission such equipment they actually put a lot of dial indicators okay. These are nothing but mechanical spring-loaded they have a plunger and stylus. So, the plunger is going to move depending on this A1, A2 etc. And then we will have to have a corresponding reading and this dial indicators are very good in the sensor.

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Now if you want to measure the surface roughness in a bearing to out of roundness and a bearing small variation here could be measured by a dial indicator okay. And this could be in the order

of microns okay, so, to measure displacements we have a mechanical device or dial indicator looks something like this spring loaded the plunger.

So, as intuitively see that if the motion is very slow almost close to static I can use a dial indicator to move the name see the displacements. But imagine if the bearing or the rotating shaft was moving at a very, very high speed because of the inertia and the plunger. This plunger is not able to respond to quickly changing stimulus.

So, the need for high frequency measurements arises and that is where our dial indicators or LVDT is another linearly variable differential displacement transducers have a limit in the frequency range as to how much they can measure okay. I mean for low speeds they are good in fact LVDT's are good for less than 50 Hertz okay.

But imagine I want to monitor the vibrations of a gas turbine. Gas turbine could be having the about close to 30,000 RPM. So, 30,000 rpm will become 30000 by 60 there is about 500 Hertz okay and that is will be the fundamental frequency. So, such a high speed the measurements are not possible through mechanical devices like an LVDT or dial indicator and so on.

So, we have to see what are the instruments or transducers available to measure high frequency vibrations okay.

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Transducers

Machinery Fault Diagnosis & Signal Processing

- **Contact Type**
 - Piezo electric Accelerometer
 - LVDT

- **Non Contact Type**
 - Laser based
 - Normal and Rotational
 - Eddy Current Proximity Probe
 - Moving Coil Velocity Pickup

Lecture 19

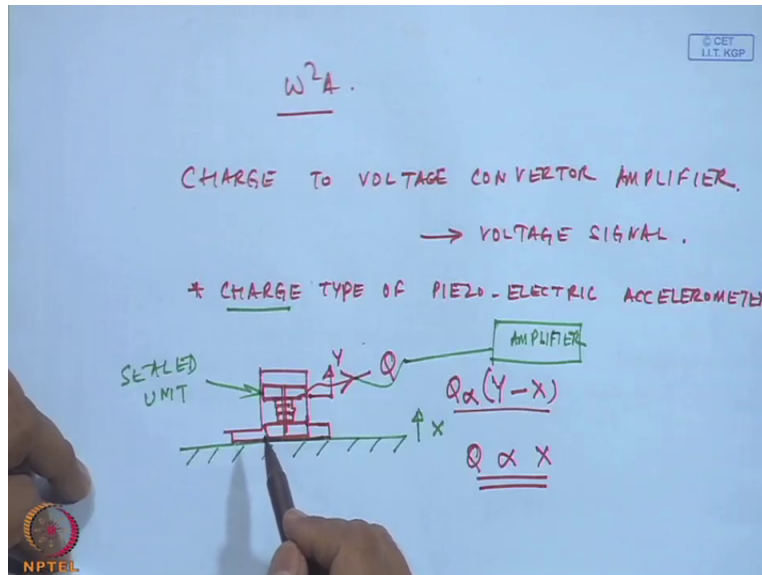
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Before I go into that let me just give you a general overview of what are the different types of vibration transducers available for us. One is the piezo electric accelerometers and we will be discussing in details regarding the piezo electric accelerometers because 99% or 98% or 95% of the vibration transducers are actually piezo electric accelerometers now a days.

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It is because the convenience of measuring Omega square ay which is acceleration is very easy and then once I have this accelerations I can divide it by Omega to get the loss then divided by Omega square to get displacement. So, this covers the entire frequency range from you know 0, all as close to 0 to about 5,000, 10,000 Hertz which is not possible with the LVDT or the dial indicator we just discussed was another one of the LVDT.

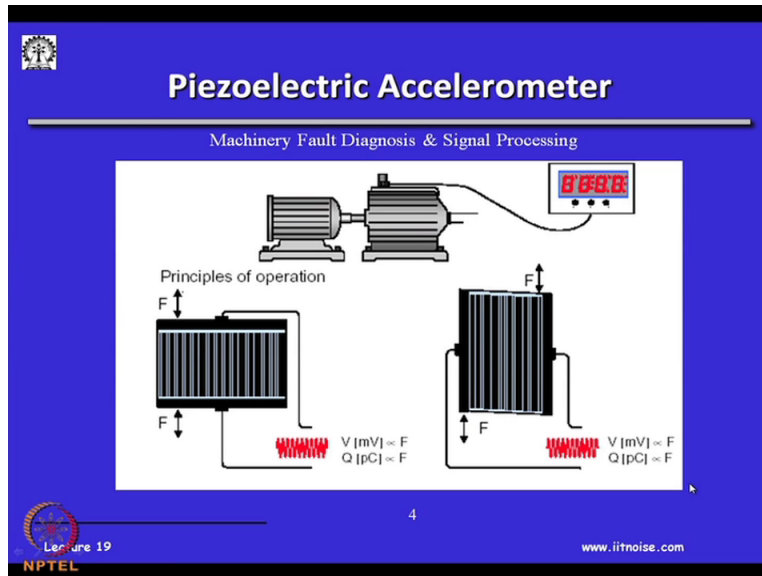
And then one thing you would notice that beat an LVDT or a dial gauge or for that matter an accelerometer they have to be always in contact with the surface at which we are measuring the vibration okay. But there are instances where we cannot touch this surface for example the heater the surface is so soft so surface is so hot temperature is very, very high.

Surface is not accessible okay very minute location in very integrate in the entry great position we cannot use an accelerometer or an LVDT. So, that is where we have to use certain laser based techniques be it to measure the normal version or the rotational vibration because there are some probes like the eddy current proximity probe which can be used to measure the gaps or the measure the; it is like a non contacting type of transducer.

If we can measure the displacement or acceleration in such or velocity in such cases the eddy current proximity probe and Moving Coil Velocity Pickup, they essentially measure the velocities and then they are non contacting in nature. But one again disadvantages of the eddy current proximity probe or the moving coil velocity pickup is that they cannot be measured on surfaces which are non ferreting.

Surfaces have to be ferreting to measure the eddy current or to use the eddy current or the moving coil velocity pickup.

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So, let us come to the various principles of operation of piezoelectric accelerometer essentially what the piezoelectric accelerometer has is basically if I put these crystals piezoelectric crystals either in this form either I compress them or I shear them they are going to develop generative force and this force is responsible for generating the charge Q and this charge could be converted to a voltage with a suitable charge.

To a voltage with a suitable charge to voltage converter amplifier and basically I will get the voltage signal these are known as the charge type of piezoelectric accelerometer. What happens here suppose I make this accelerometer here this is mounted on a surface okay. Where in, it is having a certain motion X . So, essentially in this piezoelectric accelerometer all I have is set of piezoelectric crystals an amount within certain discs and they are bolted okay.

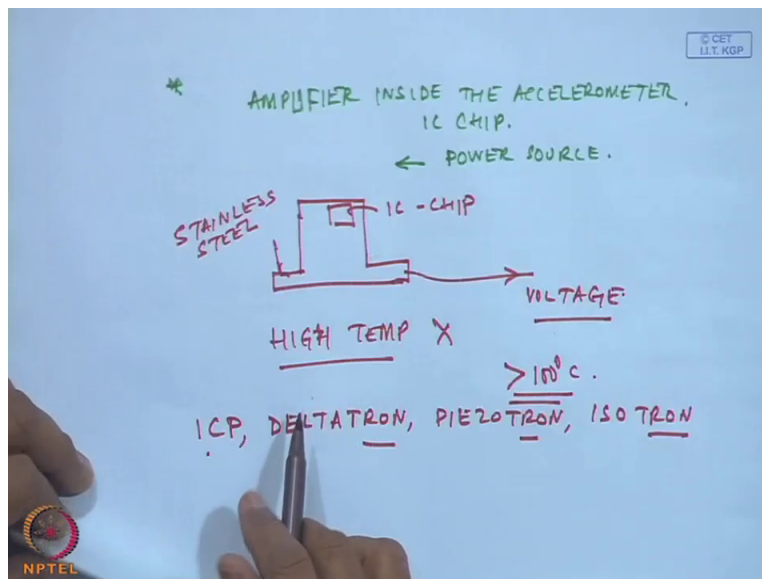
And then I will get a charge Q which is proportional to the displacement of this seismic mass. This Q is proportional to $Y - X$ okay. And with mathematical equations you will see if eventually this Q is proportional to the base motion okay, motion could be in the form of acceleration. So, once I get this charge as you know charge cannot be stored charge has to charge will decay with time.

So, immediately we have to have a circuit wherein this charge has to be converted to voltage okay. So, this is where a piezoelectric charge type accelerometer would require charge to voltage

amplifier. This amplifier is outside the accelerometer okay. The advantage of thus the charge type accelerometer is and this is a sealed unit advantage of such accelerometer is this can be subjected to very, very high temperatures the charge type of accelerometers okay.

But the disadvantage is that you have to carry a charge to voltage preamplifier with this accelerometer.

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So, with the miniaturization of electronics what has happen is people have put the amplifier inside the accelerometer okay in a small IC chip okay. But then to power the accelerometer I have to give it power source it requires a power source okay. So, once such accelerometers are there then what we can do is, so this is the same accelerometer.

But the IC chip is inside installed inside the accelerometer you know all you do is just take a cable and this is a voltage output. Because you have to the same cable could be used another conductor could we use the give the power supply to the IC which is used to convert the charge to the voltage.

But their disadvantage of this is because the IC chips are integral and kept inside the accelerometer housing and usually this housing is you know stainless steel very hard and you can never break it open they are hermetically sealed. So, this accelerometer cannot be subjected to

high temperatures. We cannot subject them to high temperatures because this IC chip will be damaged.

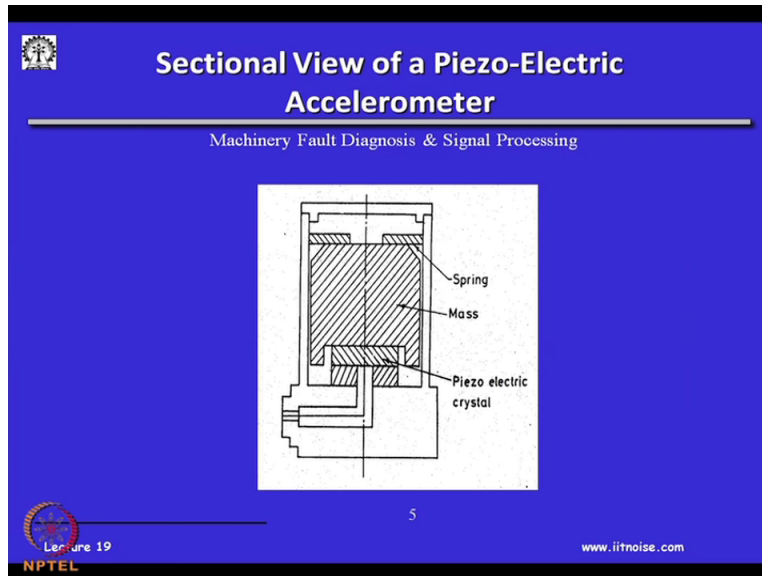
But for simple vibrations and measurements in the room where the ambient temperature is you know 30 to 40 degrees or around 30, 35, 40 degree Celsius is good they are not good beyond 100 degree Celsius the ICP type there are many trade names for this you know. Like you will have the ICP types, the Deltatron, Piezotron, Isotron.

So, these trons comes from the electronics okay and Delta appears Iso, Peizo but these are different trade names the companies used to sell their charge amplifiers which have the IC inside it. So, all you will require is just put the accelerometer give it a power supply and you will straightaway get the voltage so this is very convenient from a vibration monitoring point of view.

Because nowadays many of the signal analyzers have the built in power source which could be used to power such ICP type accelerometers and they are very convenient. But the strongest disadvantage is that they cannot be subjected to high temperatures. In fact while doing experiments on measurements on very high speed gearboxes are lost couple of accelerometers.

Because the technician mistakenly put the ICP type accelerometers on a bearing which is very, very hot and we are monitoring for about 30 to 40 minutes and other day I get no signal and see that the IC chip has got fire enough right okay because the high temperatures. So, we are to be careful when using such ICP type accelerometers ok.

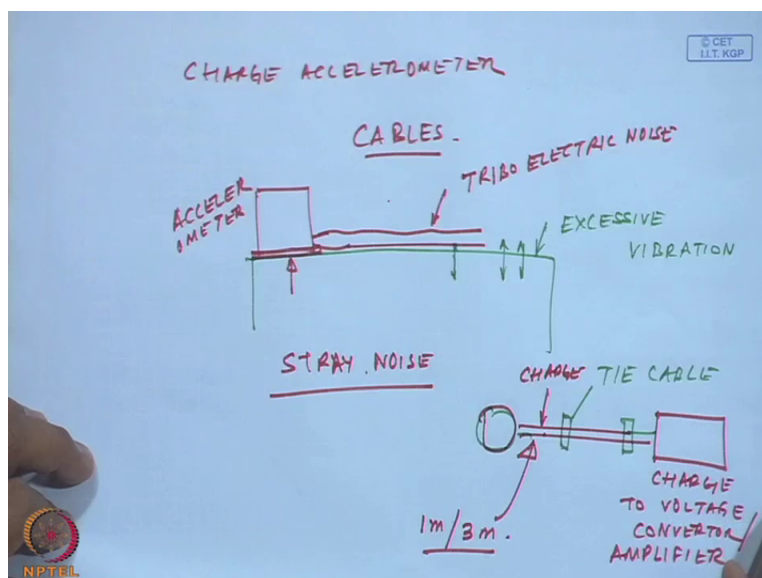
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We will go to the details of the accelerometers later but let me just tell you about the other important accelerometers or vibration transducers. And this is a valve actually in the inside of the accelerometer this is how it looks like. And this is the mass which is loading it and this is the piezoelectric crystal okay, and this is a tightening bolt which goes and this whole unit is sealed this is a ceramic unit there is a steel unit.

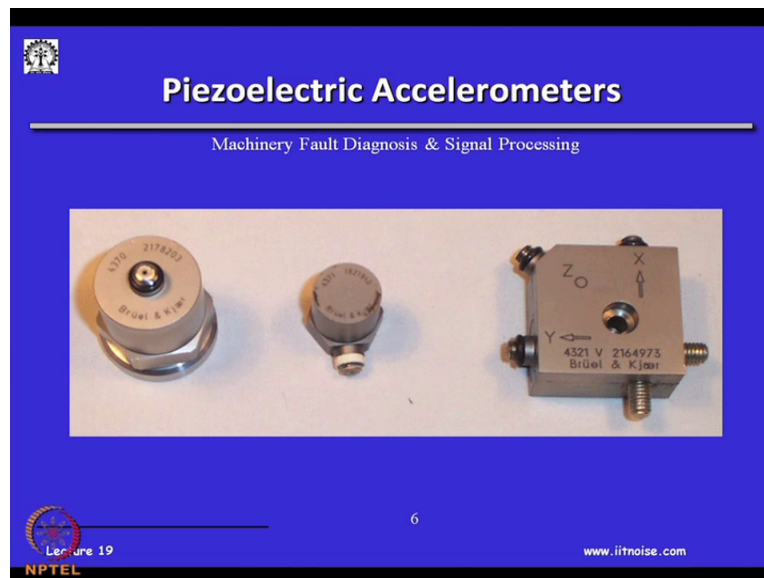
And this is seal and because of the relative displacement here and the preservative mass we will get a charge which is proportional to this displacement or acceleration and then we will see a voltage and this voltage could be measured as the either;

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So, the charge sensitivity could be usually Pico coulombs per meter per second square okay or in the ICB type it will be the voltage sensitivity millivolts usually meter per seconds okay.

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I will move on to the; and this is how the typical piezoelectric accelerometers look like, it will, see this is the size of a 50 paisa coin and this is where you connect the cable to connect the charge to measure the charge which has been generated. And similarly this is the top connector there is a side connector okay.

And this is what is known as the tri-axial accelerometer because of the fact that did not acceleration is highly directional. So, at any one point you would have seen in a machine but we had a measure in the X direction, in the Y direction, in the Z direction. So, rather than putting three uniaxial transducers in one location, the three piezoelectric crystals are put at one location and then we can see you know this means I am measuring in the X direction.

This is perpendicular to X in the Y direction and this Z is out of the plane of the projection and so then I get the 90 degree, three directions which are not in 90 degree perpendicular to each other that are mutually perpendicular. And if you see this hole this is just a hole to mount the accelerometer at the location just by tightening a screw or you could have you could put studs like this on the accelerometer.

And then tap a hole on the surface where you are measuring the acceleration and then we can measure the acceleration. Another very, very important note you have to make while using this charge accelerometers is the cable. Cable plays a very, very important role because you know this conductor which is there and there is a signal wire on the ground where and if there is a relative motion between them they are going to generate a charge okay.

Suppose the cable is violently moving having motion and on this key cable is laying on a surface which is having excessive vibration you are accelerometer here in having this accelerometer here. And then there is excessive vibrations because of this, this cable is going to have a lot of motion and because this motion they will be charged generated which is not actually your charge due to the acceleration but charge due to strange noise.

So, lot of stray noise will occur if I do not take good care of the cables. So, these cables are very, very special cables okay. And they reduce what is known as the Tribo Electric Noise and a good way to do that to reduce tribo electric noise to ensure that the cables do not whip around or slash around or okay. So, what you do is you put this accelerometer here usually you tie the cable some sort of a tape.

So, that the cable does not move okay because if this is the charge type of accelerometer okay lot of charges are going to get generated if the cables are going to move and they are going to interfere with the measurement charges. And the best idea is to best ways to have this amplifier they charge to voltage converter or amplifier very close to the accelerometer okay.

And usually this cables are not very, very long about 1 meter to you know 3meter maximum because beyond that it the cable noise will be so much that you will contaminate the vibration signal. So, this is another precaution you have to take while using the choice of accelerometers for vibration measurements, were some measurements.

But this kind of issues are not there when you take when you have the ICP type of accelerometers wherein we straightaway get a voltage signal and the cable rather than charge. Here we have the charge okay and charge will decay and charge are generating, so you have to

have the charge to voltage amplifier. In fact as soon as the choice is generated you have to convert it and then transmitted over long distances.

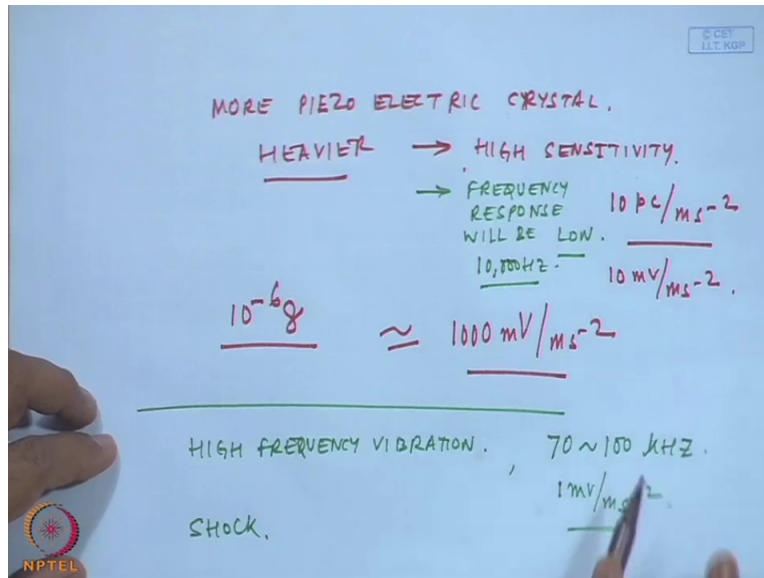
Because sometimes if you have to measure at a one particular location and record at maybe 100 meters away okay. You cannot have a hundred meter tribo electric cable which is slashing or moving around and then generating a lot of noise. So, your or some other ones will be no good and that is where you have to be careful.

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And you can get a feel of how large or how small these accelerometers are obviously to increase the sensitivity of the accelerometers we have to have more piezoelectric crystal.

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So, more piezoelectric crystal means heavier it will be. So, heavier accelerometers will have high sensitivity, easily typically this kind of accelerometer is which you see in the palm of somebody's hand it is about 10 Pico Coulomb meter per second square and if you have the right type of voltage converter this video about 10 millivolts per meter per second squared okay.

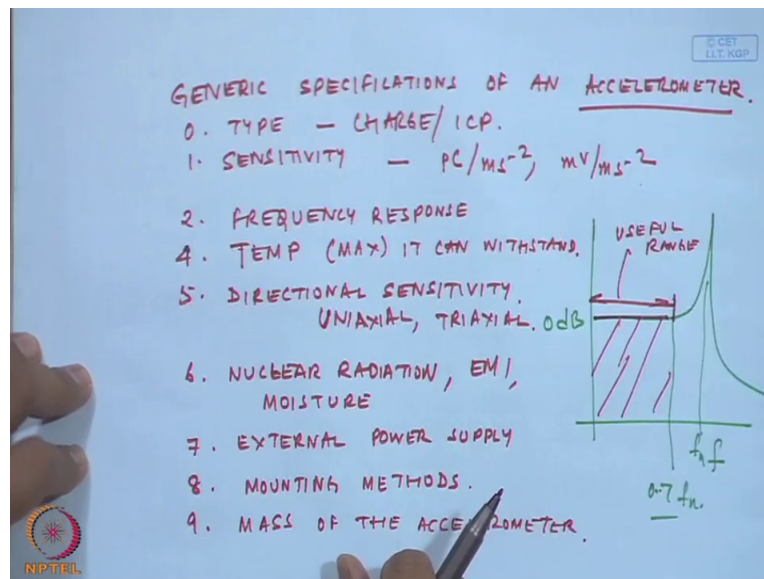
There are actually meters wherein we have to measure very, very low levels of acceleration for example a floor vibration wherein you put an tunnelling electron microscope or a scanning electron microscope. The vibrations level could be about 10 to the power -6g micro g's or no micro gravity levels. For such measurements we have to have maybe transducers having 1000 millivolts or 1 volts per meter per second square.

So, this calls for very, very massive amounts of piezoelectric crystals, so whenever you have high sensitivity requirements the transducer will be big and heavy but you have to pay a price for the transducer being big and heavy. The frequency response will be low. So, you obviously cannot measure very, very high frequencies with high sensitivity accelerometers. You know this could be the frequency of such heavy accelerometers could be up to maybe 10,000 Hertz.

Suppose I want to measure very, very high frequency vibrations, high frequency vibrations to have the high frequency vibrations, my frequency response of the accelerometer has to be very, very high maybe about 72 100 kilo Hertz. So, they have to very, very lightweight, so the

sensitivities are very low maybe, 1 millivolts per meter per second square okay. We want to measure accelerations very, very high accelerations. For example getting a shock generation something fell on the ground so in such a case and shocks are usually very, very high frequencies. So, we have to use light accelerometers so if you go to the catalog of any manufacturer you will see different types of accelerometers made available to you whether so if I was to just specify the generic specifications of an accelerometer.

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By accelerometer I mean piezoelectric accelerometer and that is what we want to discuss. One of course it is sensed sensitivity whether it and of course and before that could be the type of accelerometer my type I mean whether it is charged or ICP type where the electronics inside by sensitivity it could be whether it is in Pico Coulomb per meter per second square if it is the charge type or millivolts per meter per second square.

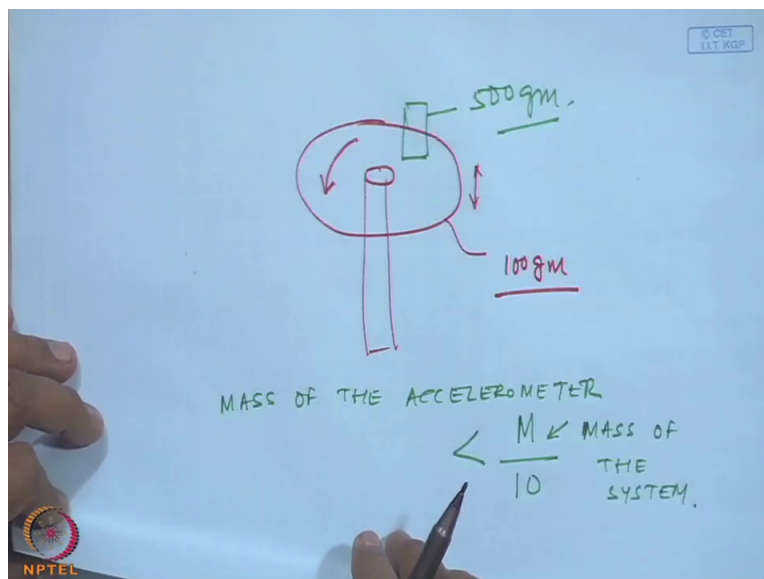
Next important is the frequency response by frequency response I mean that every transducer is also a mechanical system. So, this is also going to have its natural frequency okay maybe so measurements up to this range about an 0.7 times this is natural frequency 0.7 times a frame. So, this is the useful range or this is the useful range wherein you will measure the; so, this accelerometer is good only up to 0.7 of f_n .

Then of course the other maximum temperature it can be subjected to. It can withstand this is very, very important because when you talk about industrial health monitoring they will be gearboxes and bearings which are subjected to very, very high temperature maybe 300, 400 degree Celsius okay, maybe they should know from the manufacturer whether the accelerometer can be sent or subjected to such a high level of actual temperature.

The directional sensitivity; whether the acceleration accelerometer is sensitive to which direction, so we have to mount the transducer in that direction to which it is highly sensitive. It could be uniaxial or tri-axial and then of course where not subject to do which it should not get affected by a nuclear radiation, by EMI, by moisture okay.

Does it require external power supply or not, it is mounting methods okay and so if you and of course the very important is the mass of the accelerometer. Because as you know vibration is a very, very important dynamic property of the system and the dynamics of the system is going to change if the mass of the accelerometer is larger than the mass of the system which you know whose vibration we are measuring, it is going to influence it.

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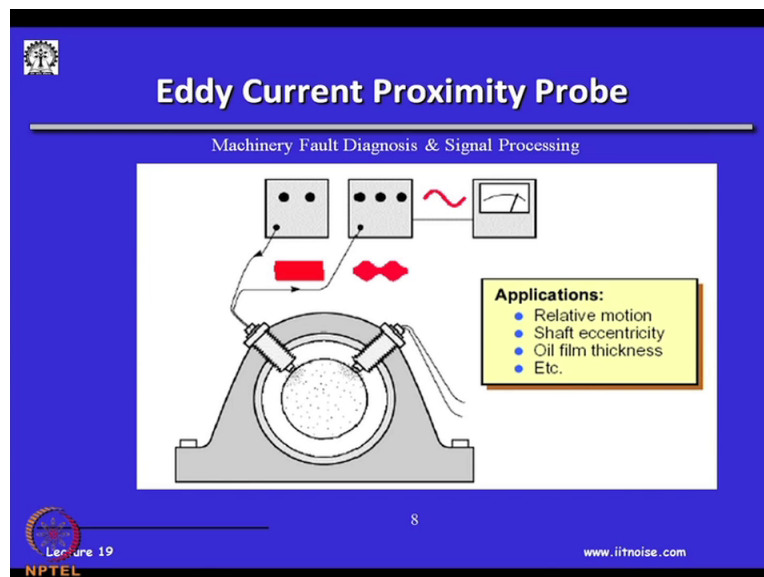


Imagine we have a very, very thin disc okay which is rotating or which is having a motion some sort of transverse motion okay. And this disk may be ways in a 100 gms, I obviously cannot put

an accelerometer on this which is weighing 500 grams okay because the entire dynamics of the system is going to change.

So, one rule of thumb which you have to always keep in mind that mass of the accelerometer has to be less than one tenth of the mass of the system on which you are placing the accelerometer okay otherwise this was what is known as the mass loading effect will occur and then you are not going to get the true reading of the acceleration okay.

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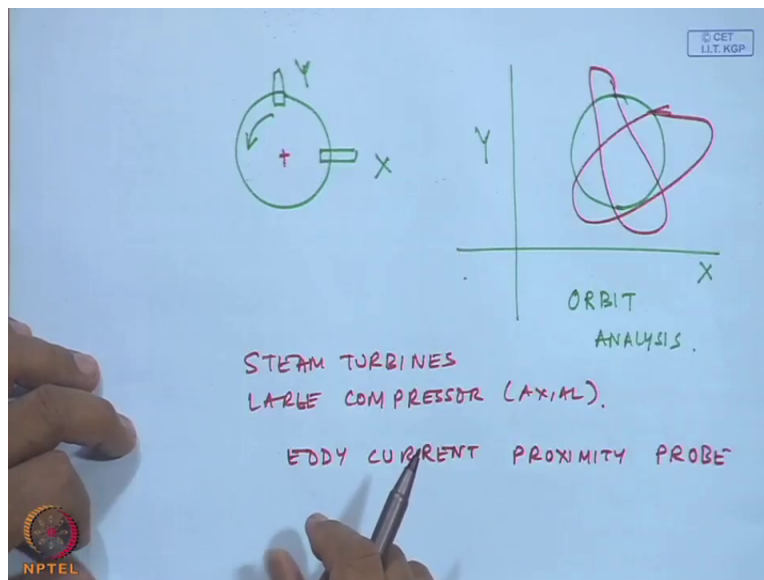
Now before I continue more on the accelerometers I just want to mention you about a couple of two important probes which you also use. And this is essentially an eddy current proximity flow which is a non core non conducting probe. Basically what happens we have a probe here on to which we generate we apply a high frequency signal very, very high frequency signal about few megahertz okay.

And that is there in the primary of this there is a coil here and primary. And because of this high frequency waves which are close to this shaft which is iron shaft eddy currents are going to generate that generated and this eddy current will be generated in this gap. And so the secondary voltage which is sensed by this proximity probe will be proportional or will be a function of this eddy current and this eddy current is a function of the gap.

So, we can measure such eccentricities or gaps which are created between the shaft and its journal of the casing because of an ideal run out eccentricity by putting such eddy current probe okay. They are non contacting type; of course they have a very, very low frequency response compared to the accelerometers. But the advantage is I obviously cannot put an accelerometer here because accelerometer is only going to measure the vibration of the casing here.

I can know way measure the vibration of this shaft because I cannot put the accelerometer in contact with the soft surface. So, the relative displacement can be easily measured by such eddy current proximity probe.

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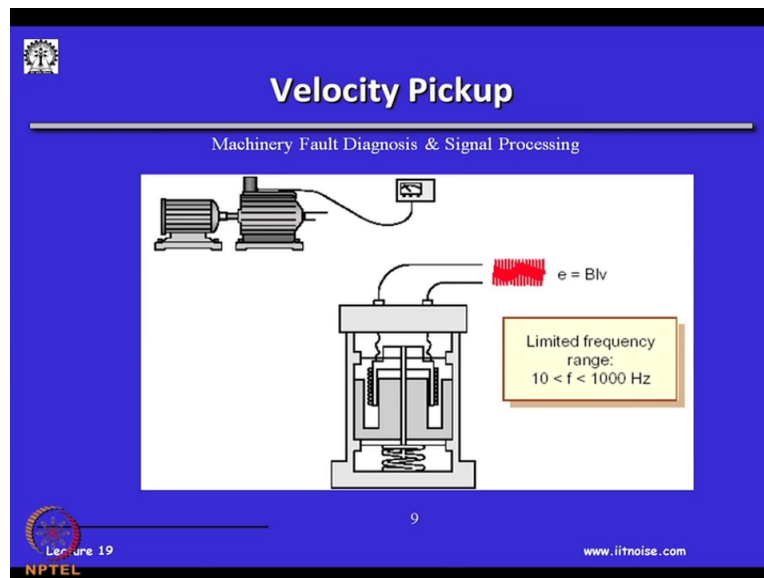


In fact many of the steam turbines etcetera they come up with this pre installed with two or three eddy current probes and if this is your X and this is Y, if you plot them X and Y and if they are identical and of the same frequencies you will get a perfect square okay. So, sorry perfect circle and these are good for what is known as orbit analysis okay. And if there is just looking at a phiso diagram of the X and Y on a two plane system. You will see if it is a perfect circle you know this system is concentric to the casing.

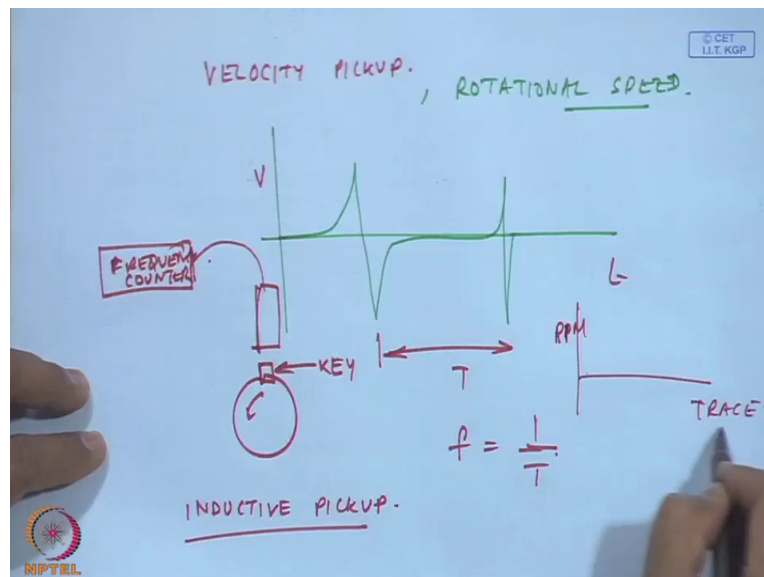
And it is rotating perfectly and which time this may change like this okay this may change like this and then you know that something is wrong with the eccentricity of the shaft. And this is a very good way to report it or record it or observe such an eccentricity by a having an eddy

current proximity probe. So, usually in steam turbines, large compressors axial we can put such a eddy current proximity probe tumours are this relative motion between the shaft and the casing.

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Another non contacting type transducer is this velocity pickup essentially there is a permanent magnet and a moving coil and because of the motion of this system here I am going to get an EMF okay and this motion is because of this is contact; this is in touch with the surface okay. The velocity at I pick up and this will get will get a velocity proportional to this EMF which has been generated.

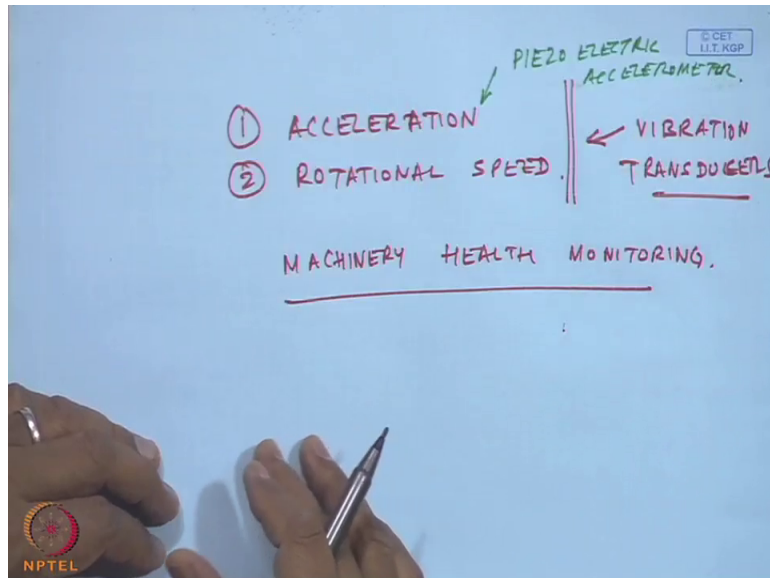
But modification to this is if I have something moving here and this coil is not there and this is variety, we can have a key phaser kind of signal. It will give a signal like this, so this is these are also used to measure rotational speed. Because with my vibration monitoring you know measuring the rotational speed is also very, very important okay.

I cannot obviously put a tachometer always to a rotating shaft when enough inert reading shaft but if I have an arrangement like this wherein I have a shaft on which there is a key way or a key and then if I put such a pickup. So, at every time the keyway comes below the pickup this voltage this gap is going to change. So, they will be in voltage generated with time.

So, just measure in the time period I will know the frequency of rotation as the ones of the time period just by having a frequency counter I can measure the rotational speed. And in the industry all such a rotational speed measurements is done through an inductive pickup okay. And all you and then you can transmit the signal over many, many meters or kilometers for that matter okay and on real time always you will have this RPM trace.

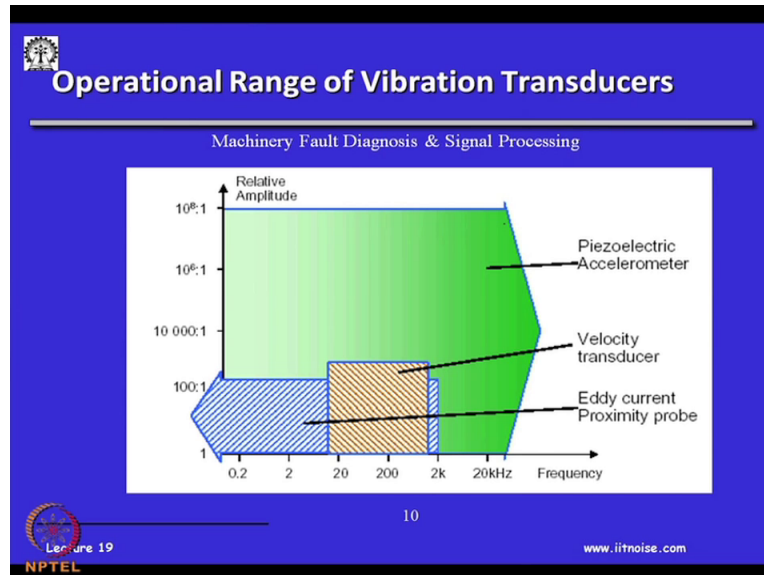
Now earlier days you know when the piezoelectric activities were not developed people were using such moving coil kind of velocity pickups okay and then diagnosis pickups. But nowadays with the piezoelectric accelerometers available we have only two important parameters which you need to measure.

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One is acceleration another is this rotational speed, so these are the two most important vibration the rotational speed is strictly not vibration but I am vibration transducers which we have to use for machinery health monitoring okay. I will now focus on some applications as to how this accelerometer is used and mounted on systems and so on.

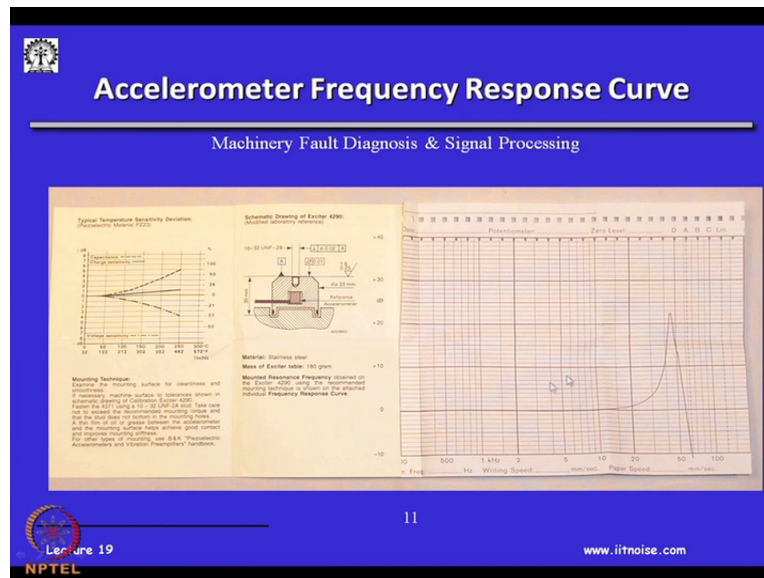
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So, now that we know about the three types of transducers you see this is the eddy current probe, velocity transducer and fidelity accelerometer. If you see their frequency range and the relative amplitude which they can measure the eddy current probe can measure low frequency and the limit is about two kilohertz and the range is not much. Velocity transducer has a low frequency limit of about 10 or 10 Hertz to about know 1000 Hertz.

But the piezoelectric accelerometers can measure all the way from 0 to very, very high you know 70, 80 kilo Hertz and they down the range is also very, very high dynamic range is very high. So, that is what I am telling to measure the acceleration we now will be only talking about piezoelectric accelerometer. Before the piezoelectric sensing elements we are used, people used to you also use strain gauges instead of the piezoelectric crystals to measure the seismic accelerations.

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And this is how a typical chart of an accelerometer will look like this is the frequency response okay and this is the resonant frequencies and then what are the methods to mount the accelerometer and what are the voltage and charge sensitivity as a function of temperature etcetera. And this is typically which you will find in any of the accelerometers which we which purchase.

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Vibration Measurements

Machinery Fault Diagnosis & Signal Processing

- Displacement A
- Velocity ωA
- Acceleration $\omega^2 A$

ISO 2372 Standard



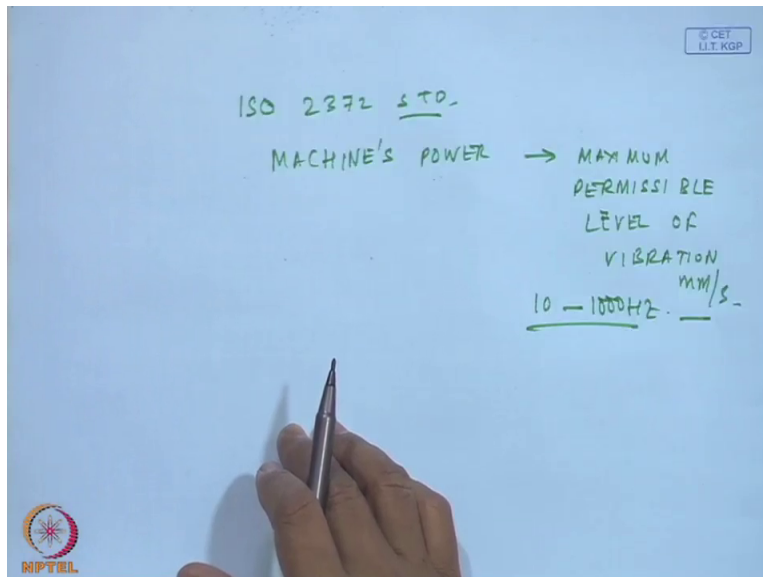
Lecture 19

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The question is we have to use this vibration measurements and question always you would be asking, well how called a certain value is that good is that bad I do not know. So, there is a standard ISO 2372 standard

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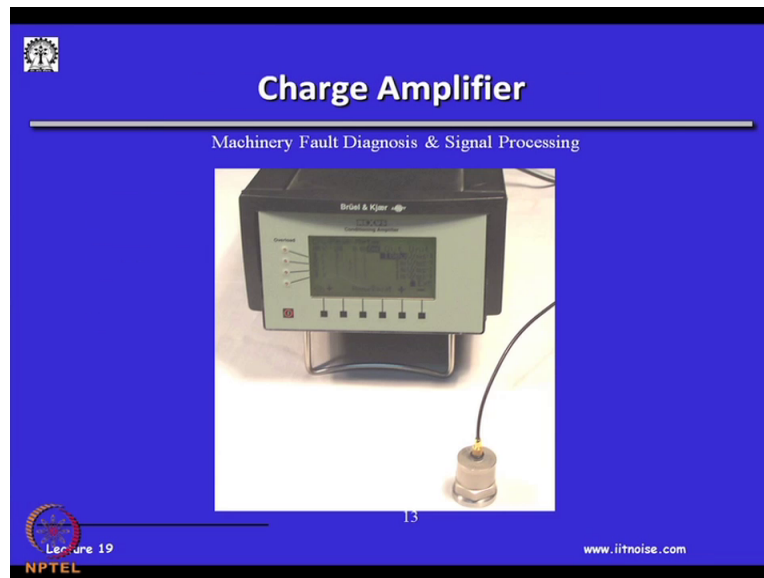
ISO 2372 STD -
MACHINE'S POWER → MAXIMUM
PERMISSIBLE
LEVEL OF
VIBRATION
10 - 1000 Hz mm/s

NPTEL

And recently it has been updated and that is the new standard I will tell you in the next class that tells the machines power as to the maximum permissible level of vibration in a frequency range of 10 mm Hertz okay and this is really in millimeters per second okay. So, if you know a hundred horsepower machine you know it should not be more than three millimeters per second and so on.

So, that gives you a feel like when you are doing by recent measurements on machinery for their health monitoring you know the power of the machine so the maximum acceleration or the maximum RMS level in this 10 mm hertz band should be not beyond a certain level which is given in that standard.

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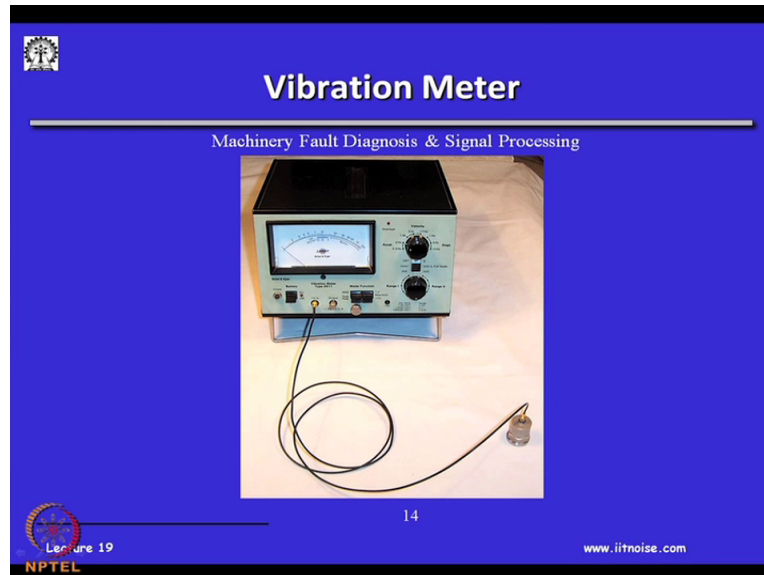
And this is how typically this is a essentially a charge to voltage amplifier and this is the accelerometer here and this is the special cable I was mentioning about which reduces the tribo electric noise. And sometimes you will see the cables are costlier than the accelerometer itself because these cables are beating around.

If they if they move also they are manufactured in such a way that there is so much of reinforcing mechanism in the cable itself. They are actually the copper conductor which is there inside hardly has any motion. It is actually there are multiple sheets of protection in this cable there will be a layer of plastic insulation, steel reinforcement and on top of the copper wire and then there will be a plastic coating sometimes silicon coating.

So, that it can be used underwater etcetera, so these cables are very, very expensive. You know when you are talking about underwater accelerometers or hydrophones this we have accelerometers underwater accelerometers wherein you can measure the vibration of underwater

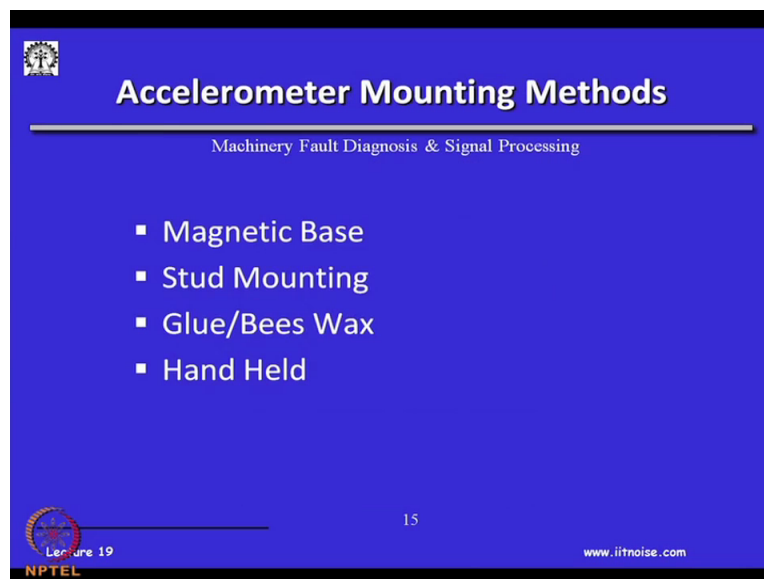
structures. But the cables there are very, very costly they will not allow water to creep into the, or seep into the conductor and contaminate the readings itself.

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And usually when we have this accelerometer, uniaxial accelerometer of the top connector and these are actually a gold-plated connector here to make sure that there is no corrosion etc. And is that cable here and which goes to a vibration meter wherein you can select the knob to see the readings of either acceleration velocity or displacement.

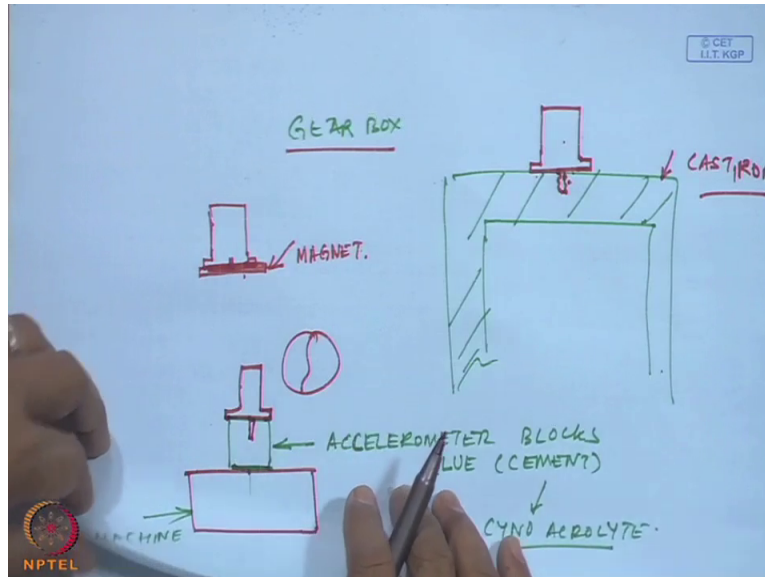
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Now the next question you would be asking yourself is how do, we actually physically fix this accelerometer onto the surface on which we are measuring the vibration okay. Surface could be

as soft as the flapping wings of a bee okay or as delicate as a buzzing bee wings or as robust and heavy and hot as a gearbox casing okay. Everywhere there is vibration how do you how do you measure that okay.

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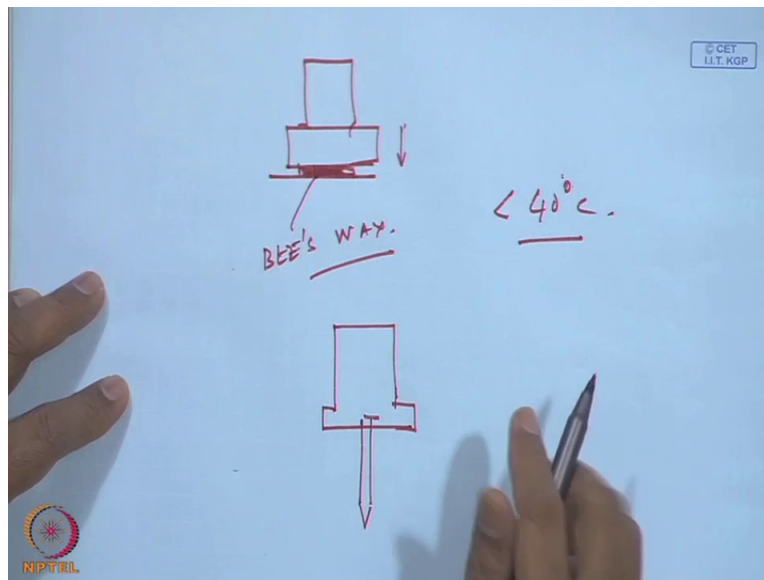
Obviously on a gearbox casing I can mount my accelerometer many ways, one is I could attach if this is usually the gearbox etcetera these are cast iron. So, I can very easily tap and put a stud and screw the accelerometer onto the stud, so one is the stud. Other is I can attach soft magnet to it okay but again out of my experience I am telling you this magnets the soft magnets are very soft.

These magnets cannot be subjected to high temperatures which time suddenly you will see that the magnet has cracked okay. So, usually these magnets cannot withstand high temperatures. So, usually permanent if you have to mount you make a hole and put a stack stud and then you sometimes tap the accelerometer onto it.

Sometimes these surfaces are so hard or some machine the OEM would not allow you to do any tapping which would permanently damage the structure or weaken the structure. How do you do that in such a case what you do is on to the surface you glue a block which could be glued permanently by cement like the cyno acrylyte like you know we talked about this fevy quick type of glues which are available in the market etc.

You can use them to glue the block onto the surface whose vibration you are going to measure. People will not ask you to let you do a drill the hole and do a tapping that is not allowed. So, usually you will use such a device a block. Onto this block you can screw your accelerometer okay. And this actually the start mounting is the best and then comes to lose and magnetic base if it is soft and they have pretty high frequency limits.

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But sometimes even just a layer of bees wax on a surface the honey bee hive bee wax you can just put it here and then stick the accelerometer on to it okay just press it and this is the bee's wax they are very strong okay but the problem is you cannot use them beyond for 40 degrees in room temperature these are good but beyond that they will melt and they cannot be used.

Another type is if you are quickly surveying a surface you can put a handheld probe okay and then move around accelerometer okay.

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Accelerometer Mounting Methods

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- Magnetic Base
- Stud Mounting
- Glue/Bees Wax
- Hand Held



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Now what I am going to do is, I am going to show you some of the mounting methods pictures.
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Accelerometer Kit

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This is how the accelerometer issue by it looks like in a kit okay. This is the accelerometer and this is that special cable I was talking about, this is the magnet, this is the beeswax and a lot of studs, washers etc and this is a tap given to make the tap ok and this is the typical kit to see of an accelerometer.

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 **Accelerometer Calibration**

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10 m/s² at 1000 rad/s

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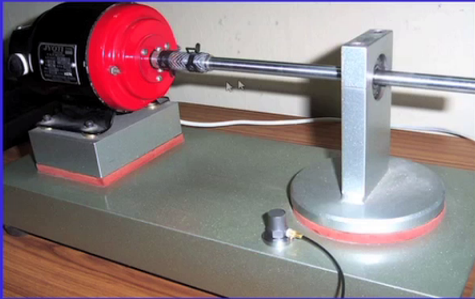
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And then accelerometers always need to be calibrated. So, this is the handheld calibrated we were in you can give an known levels of 10 meters per second square at 1000 radians per second and then you will see the acceleration values whatever voltage it comes it gives you know that it gives 10 meters per second square of acceleration.

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 **Vibration Monitoring**

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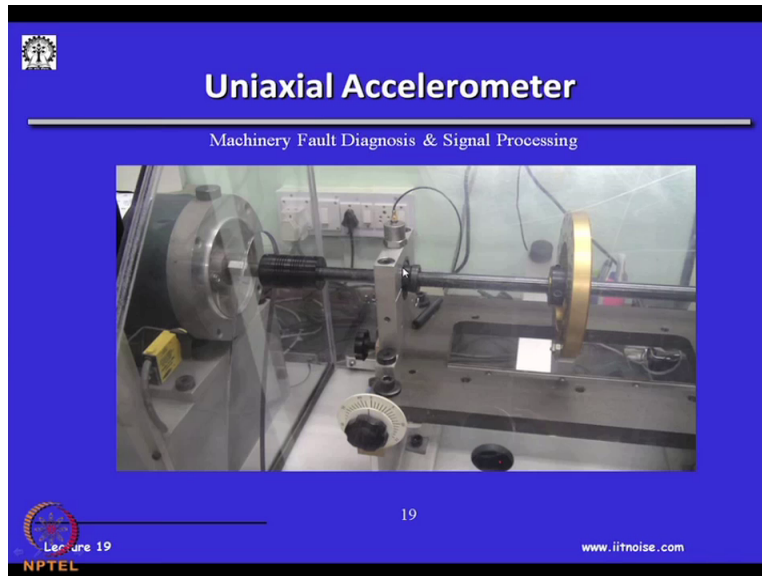


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And this is typically we are measuring using a magnet here the vibration in a test rig.

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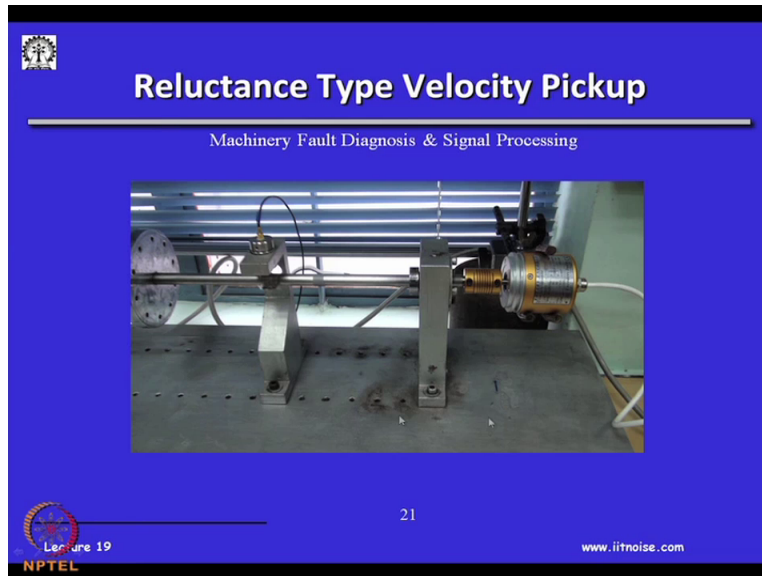
And this is where another test rig we have put an Uniaxial accelerometer and their special cable okay.

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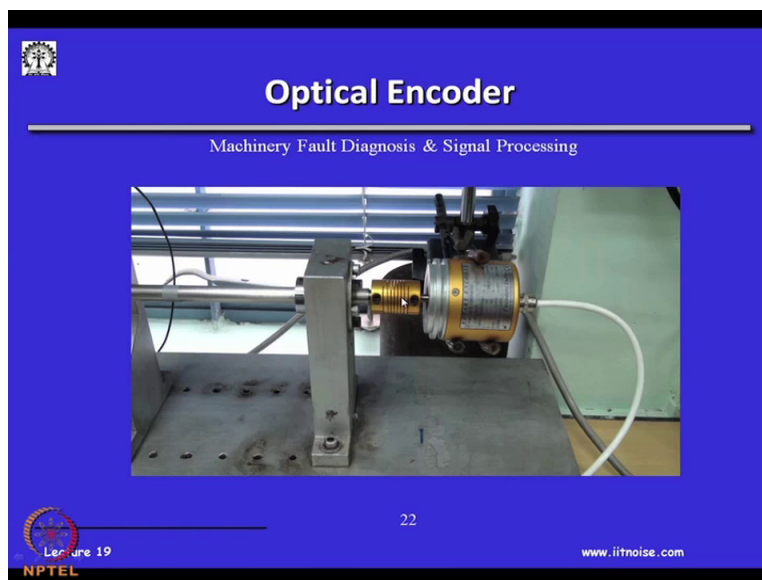
And this is an industrial type of accelerometers which can be subjected to very, very high temperature this cable is special and then we have an meter vibration meter which will actually see the you can see the spectrum okay.

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These are all, there in our lab you can go to this website and see this system as well and this is one of the reluctance type velocity pickup which we have used on the shaft ok.

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We can also use an optical encoder to measure the rotational speed.

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 **Single Point Laser Vibrometer**

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And we can use single point lasers also as an accelerometer to measure the vibration because this is a refrigerator compressor wherein we are measuring can see this spot here, where we have put a laser beam and once we put a known laser beam because of the reflected wave there will be a Doppler shift. And the Doppler shift will be proportional to the velocity of the surface and we can measure the;

For surfaces where when we cannot approach for example here in other case we have a transformer which is there in our lab you can see these points which are shining actually these are the points we have put reflector tapes where and we can measure the velocity which is with which this fins are vibrating.

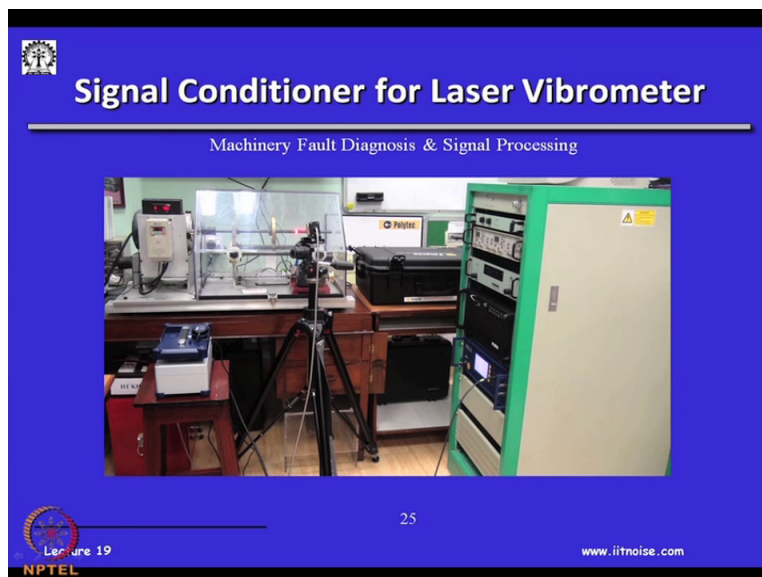
And then we can shoot the same laser by vibrometer to measure the valuations of the surface because here we are measuring the sound and intensity here.

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Another application of this laser based evaluation measurement system is using a rotational a vibrometer okay wherein we shoot two beams if you can see there are two dots you have two laser beams separated by a particular distance if you know V_1 and V_2 F you know ΔR you can find out Ω and that is what we are using this a laser vibrometer to measure the rotational collisions.

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Another real the rational vibrometer and this comes with the signal conditioning system wherein we will straightaway get an Ω as a function of frequency okay.

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Rotational Laser Vibrometer

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And this is another view okay the same rotational laser parameters is a laser head which should shoot two beams okay, thank you.