

Machinery Fault Diagnosis and Signal Processing
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Lecture -20
Vibration Monitoring

In the last class, we discussed about Vibration transducers and with the understanding of par in particular piezoelectric accelerometer. In this class, we will see how in different practical scenarios vibration measurements are actually done using piezoelectric accelerometer and how do you actually monitor the vibrations of a machine be it over the time or be it just for a Diagnostic measurements and so on, ok.

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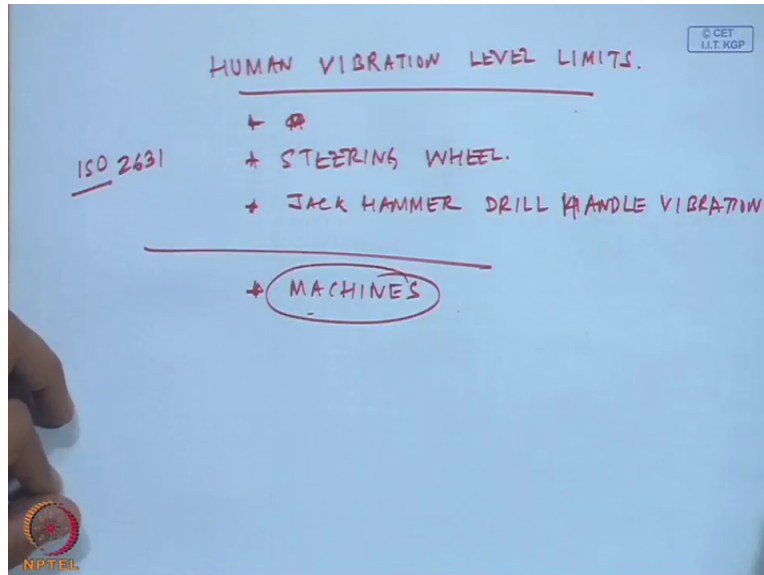


So, typically you will come across many industries, you know, be it a cement plant, Steel Plant, power plant, etcetera. Basically you will be coming across many rotating equipment wherein whose vibrations has to be monitored, measured and recorded and so on. And you see here, this is torsion shaft which is rotating, which is supported on the bearing housings.

And then you will see this couple of few cables coming out here. These are actually, accelerometers which you cannot see here. And then they are installed just to record the vibrations level and then, we can bring back this recording to the lab and do the analysis from a diagnostic point of you.

But another very important aspect of vibration monitoring is, you know, like I had mentioned to you in the last class, regarding a standard wherein the vibration monitoring has to be done so that vibration levels are not above a certain permissible limit.

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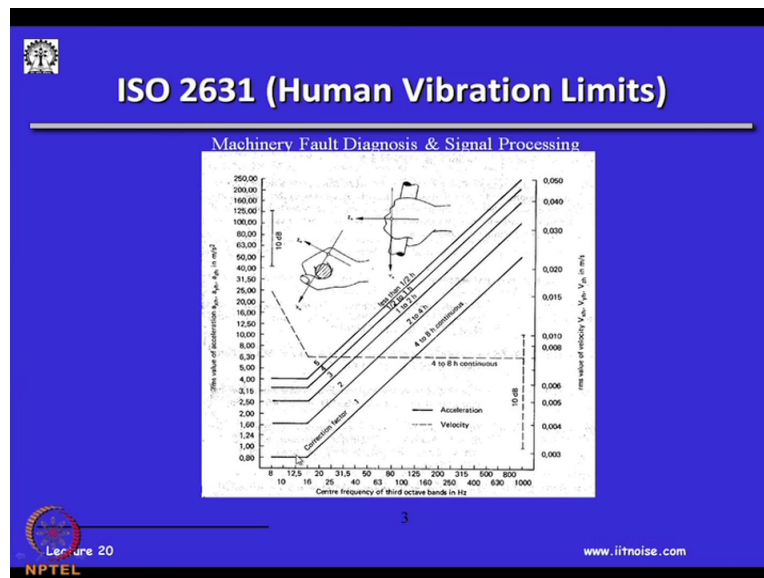
Similarly, because we are talking about vibration monitoring, I think it is important that you should also know that there are limits of a permissible level for human vibration level limits. There are standards to that. In particular, wherever we have human operators, holding on to devices which are vibrating because of their functionality, for example, one is the steering wheel of a vehicle, ok.

One may be the, you know, the jack hammer in the handle. If you go to any construction site, you will see, we will be using Jack hammer drill to break in concrete etcetera. And they produce lot of vibrations when they handle, ok. These are certain scenarios wherein the vibration levels could be harmful and we have to be ensuring that the vibration levels are not beyond a certain level.

Of course, one is the machine level. I will put it here. Another is the machine level, machines. So, we have had some clue as to that standard which has, depending on the power of the machine, what is the permissible limits of the vibration level; similarly for human vibration

levels there ISO standards as to what the permissible level should be; thought, I should mention this, in this class; That is the ISO 2631. So, now look here.

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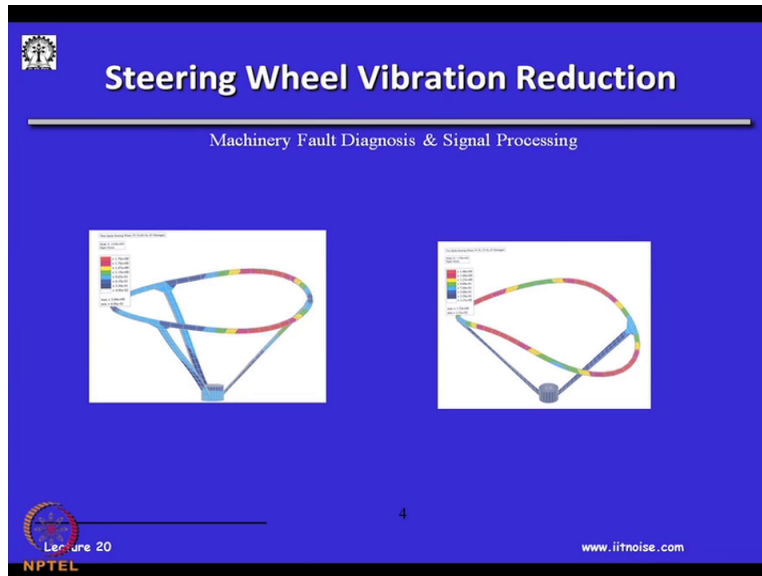


And this is the permission limit also, 2631 human rights and limits subject to different frequency bands active in after one third of till about 1000 hertz in this, in the x-axis. This is the RMS values of the velocity in this curve and the RMS values of the acceleration in the, this line here. And for 4 to 8 hours of continuous holding onto a device, what should be the permissible level is given by this line here for 2 to 4 hours, for less than half an hour.

So, these are the limits as per ISO 2631 standard. So, if I have any operator holding onto a steering wheel for 4 to 8 hours, the maximum RMS level should be in this Band, below this level for these levels are there. We are not of course in a machinery health monitoring. We are not talking about, you know, how to ensure that the levels are less. But I thought you should know in this class that there are also standards for human vibration and levels.

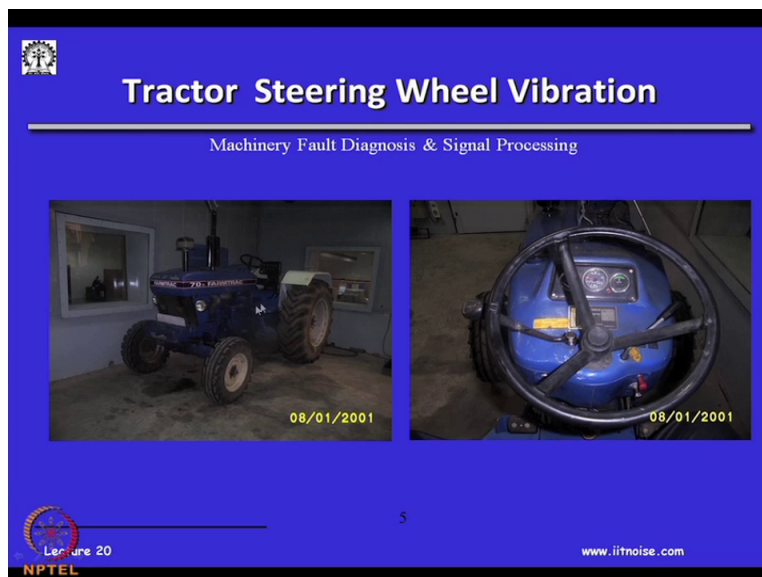
For example, another is the car seat vibrations. The human seat, your body sitting on a platform what should be the maximum allowable level of the vibration to the seat. And that is also there okay. These are for holding hands, for a human body positions; there are different levels also. You can see that in the standards.

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Just I give an example. I will have to go back to this slide first.

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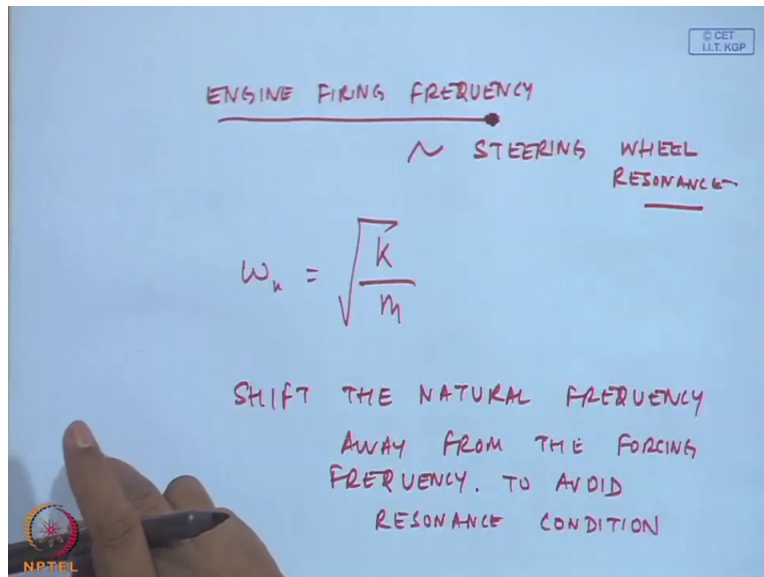


This is a tractor, ok wherein this Steering Wheel was having excessive vibrations, ok. And this relates to a little bit of a diagnostic procedures as well. So, what happens, this level of the steering wheel was much higher than the permissible levels. And as soon as the engine was starting to idle, okay the vibration levels were high. You might have noticed that in many of the particular diesel engines.

You know, not in the modern cars, you should think of the old jeeps etcetera. As soon as the engine is starting, your steering column would rattle and then there will be heavy vibration levels

as per the vibration standards are they acceptable, we do not know, ok. Are our products marketable? No, not; because of the International standards. So, in this particular case, what has happened is the firing frequency generated by the engine.

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The Engine firing frequency was almost close to the steering wheel resonance, ok. No matter how good a steering wheel you design from strength point of view, from a damping point of view, not from damping point of view, from a mass arresting point of view, you will not be able to stop motion of the steering wheel because it is vibrating at its natural frequency, which is, what is the first in frequency; it is the engine firing frequency.

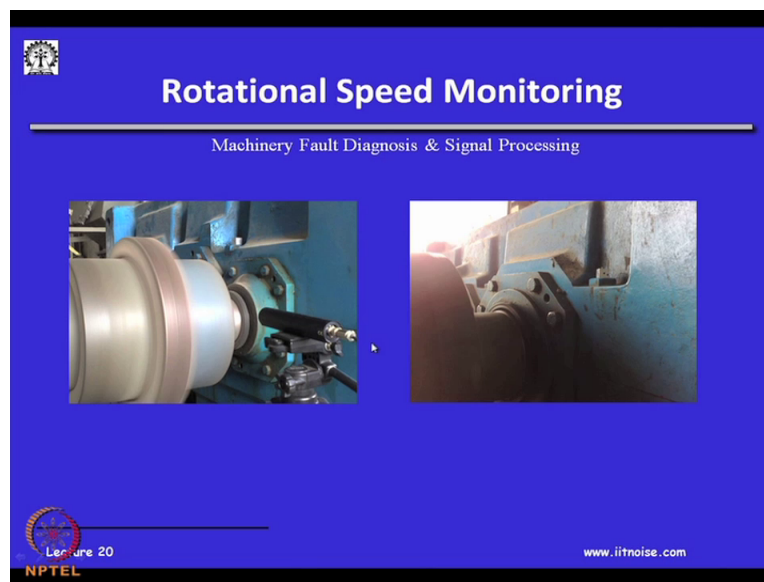
I cannot change the engine firing because that is how my engine is designed to operate at a certain rpm. It has so many cylinders; it is a four stroke engine and so on. So that its idling RPM is fixed, ok. So, the engine firing frequency cannot be changed. All I can do is, change the steering wheels designs and figures.

And that is how it was done using the finite element methods, we can design the attachment locations, ok we can change it the frequency. This is a 3 spokes steering wheel as opposed 2 spokes Steering Wheel. So, just by changing the design of the steering wheel we will change the natural frequency and shift the natural frequency away from the forcing frequency so as to avoid, avoid resonance condition.

So, design we can change that. And then we can shift the natural frequency, now if the engine idles, the steering wheel is going to vibrate, ok. So, now how do we do the vibration monitoring here? Of course, you cannot see this accelerometer here. You can see the clips, there are locations where you can sometimes mount accelerometer clips.

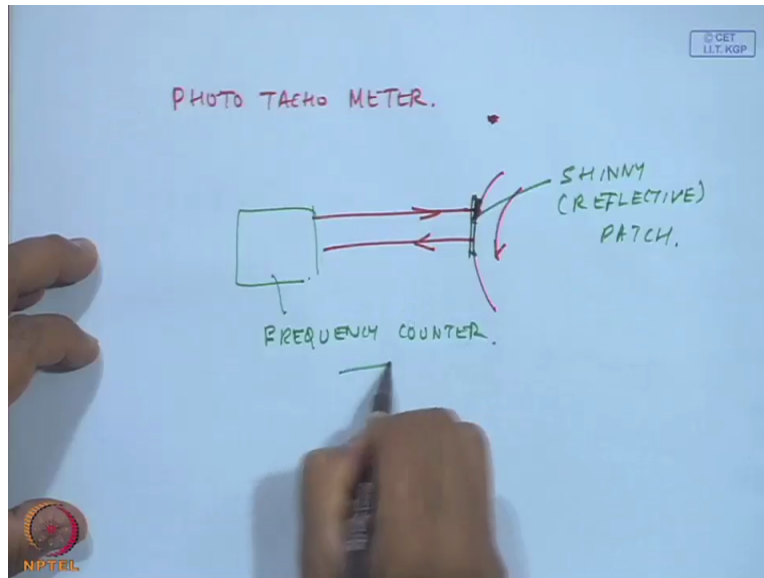
For example, this is a plastic cover on the steering wheel skeleton; there is a moulded plastic wherein you can put a clip. On the clip you can mount the accelerometer, ok.

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Now, how do we do the rotational speed monitoring, ok? And sometimes, we can use the reluctant static or pick up.

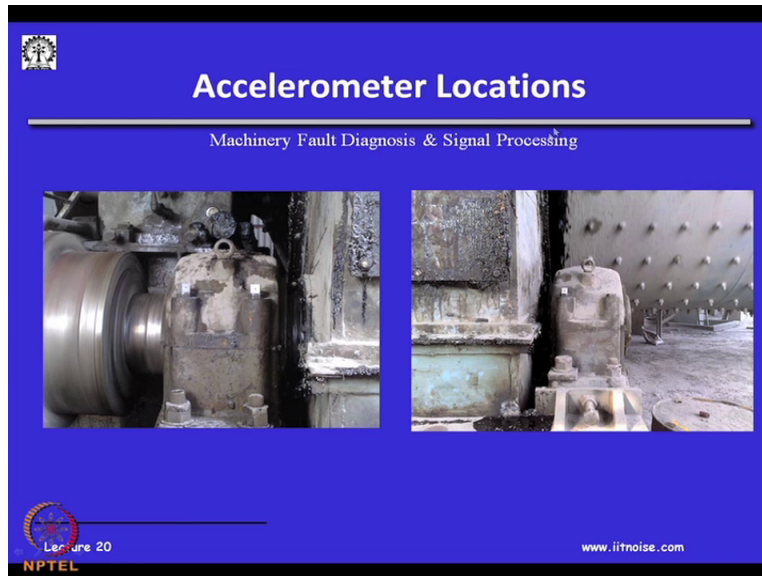
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Sometimes we can use also a Photo Tacho meter, wherein of course, this is a shiny surface. So, if you shoot a light beam, ok and if there is a shiny patch, it is going to reflect back, ok. Or if you can in fact, there are shiny patches. You can fix here and then you have a frequency counter and then measure the rotational speed or you can record it as well, ok.

This is out of a gear box, ok. And if you see here, you put a, here you can see a shiny white alum, aluminium block actually. It is an aluminium block wherein this is the casing of the gear box it is not possible to tap it, ok at the side. So, all we did was, put a mounting block and glued it with a cement. And if you see a couple of holes here, one hole here and if it is coming out on this accelerometer block we can either screw on the accelerometer to measure the acceleration.

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I will show you another view. And this is, and this is how dirty or on healthy or conditions are there in the actual industry; gears everywhere and grease everywhere etcetera and you obviously cannot put and there is no space to and that these are always rotating; plant would not shut down. So, what people can, have done is glued this blocks, mounting blocks.

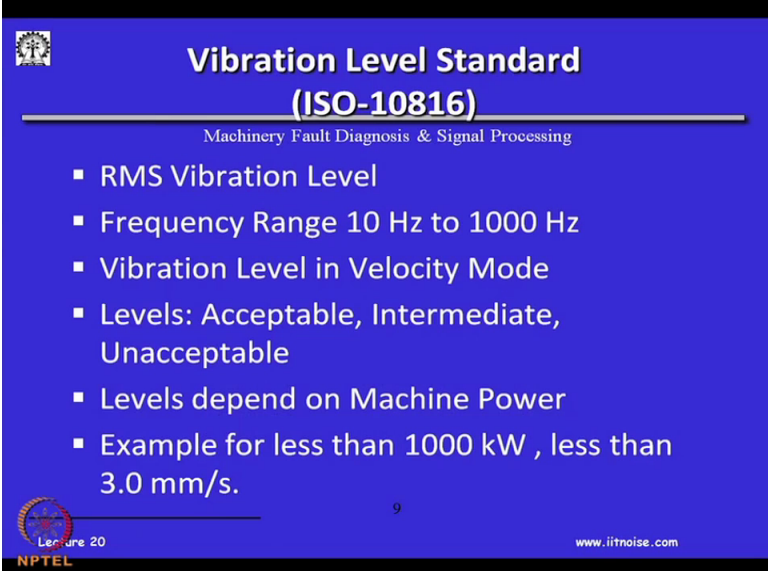
We just cleaned the surface, clean it, remove it of grease, put a cement and then its sticks almost instant glue is there and then you can put this block; and on to this block, you have the screw, the accelerometer and this is the Rotary kiln, I was talking about in a cement plant actually and this is the plumber block which is used to house the bull gear, ok.

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And all this is another view wherein we can see the accelerometer is, this is a tri-axial accelerometer. You see this 3 cables coming out, ok wherein we have put this block and then we can orient this direction to see the, measure the vibrations in the three directions, ok. So as I was telling you, vibrations in three dimensions is always very important from a diagnostic point of view whether we want to measure the radial vibration or the actual vibration at that particular location.

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Vibration Level Standard
(ISO-10816)

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- RMS Vibration Level
- Frequency Range 10 Hz to 1000 Hz
- Vibration Level in Velocity Mode
- Levels: Acceptable, Intermediate, Unacceptable
- Levels depend on Machine Power
- Example for less than 1000 kW , less than 3.0 mm/s.

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And typically in any plant you will see the configurations of the machineries of a, prime mover doing being driven by a, sorry, machine being driven by a prime mover, this Prime mover could be an electrical motor organising it. And this is the new ISO 10816 standards which says the allowable vibration level for a particular machine and the ISO 2631 was for the human being and ISO 10816 is for the machines;

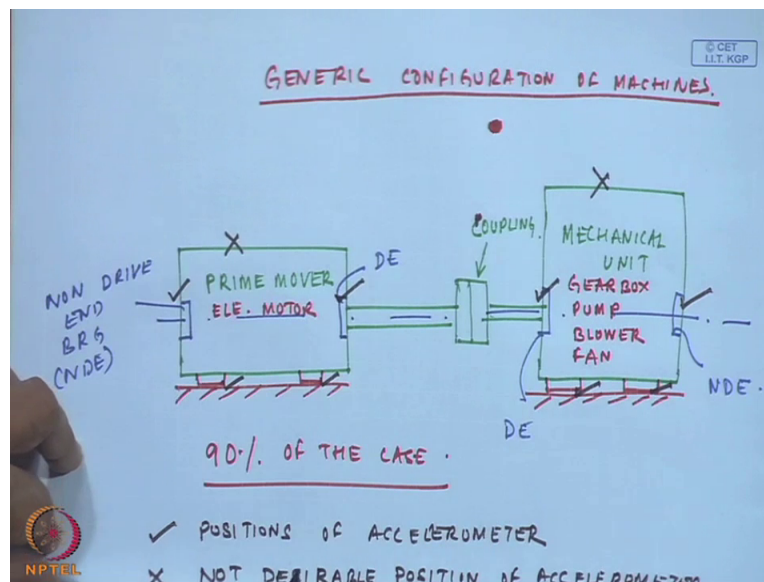
Which says, we have to measure the RMS vibration level in the frequency range from 10 hertz to 1000 hertz, vibration levels has to be in the velocity more, that is either in metres per second or milli metres per second; and then, there are three levels of vibrations: whether the machine is acceptable, machine is an intermediate stage, or the Machines vibration is, are unacceptable. The machine has to be diagnosed and corrected and of course these levels depend on the machine power.

And this for example, if it is 1000 kilowatt machine, this vibration in the highest vibration in any direction has to be 3 millimeters per second, okay. And this standard only tells you about the overall vibration level and then, we have to ensure whether it is acceptable, not acceptable. So, if you just have a vibration metre and an industrial accelerometer and you go around different places in your plant and just measure the vibration level itself.

And come up with the values that itself is a good survey to ensure that whether the machines are ok or not ok. If you just follow the standard. And many Industries definitely do that. But the problem which we have as machinery fault diagnostics engineer, what is the real cause of these levels of vibration if they have exceeded.

And for that, we need to record the vibration levels, do a spectral analysis find out this frequencies at which the levels are high and then try to relate why these frequencies are high, you know which is the physical parameter which has been responsible for making this level high and then how do we correct it, ok.

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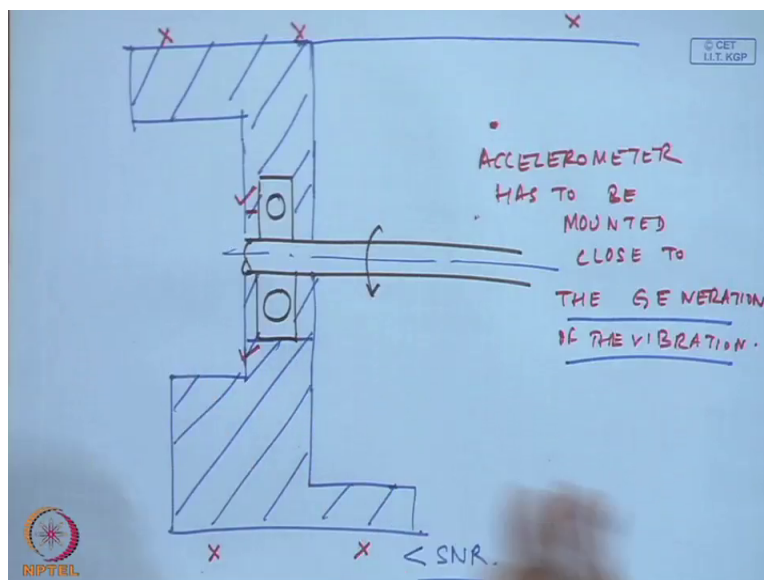
And typically if you go to any plant, this is how the configuration is. So, this is the prime mover, this is the mechanical unit and this is a coupling, ok. This prime mover could be a electric motor. This could be a gearbox, pump, blower, could be a fan peaceful ok and they have to be put on the

foundation. And this could be driving some other things, ok. And this is typically the configuration of the machines in 90% of the cases, ok.

And we have to capture the dynamics of the system. That is our objective. So, what are the good places to capture the vibrations? Of course we have a bearing here, this is the non drive and bearing NDE, similarly, we have the DE, this we have another DE, another non drive of the coupling. I will mark the ideal locations of the accelerometers.

Accelerometer should be kept close to this location, close to this location, close to this location, close to this location, sometimes close to the foundation. These are the typical positions of accelerometer. We should definitely avoid places like this, because casing is very important when you put it here. It is accessible it is easily accessible put one x, ok accelerometer here these are not the good places, ok. Not desirable, ok. I will one of these, use here and try to explain, ok.

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Suppose, I have a shaft and then I have a bearing, the shaft is rotating and shaft is put on a casing, just one here I am drawing, ok. So some machine component and this is a shaft. See, these are not good locations to keep your bearings. I have to put the accelerometer because they are far away from the dynamics of the system, ok.

The best location would be may be this is a good location, this is another good location, come here as close to the bearing as possible. Sometime, this may be too thin; we should try to go for a

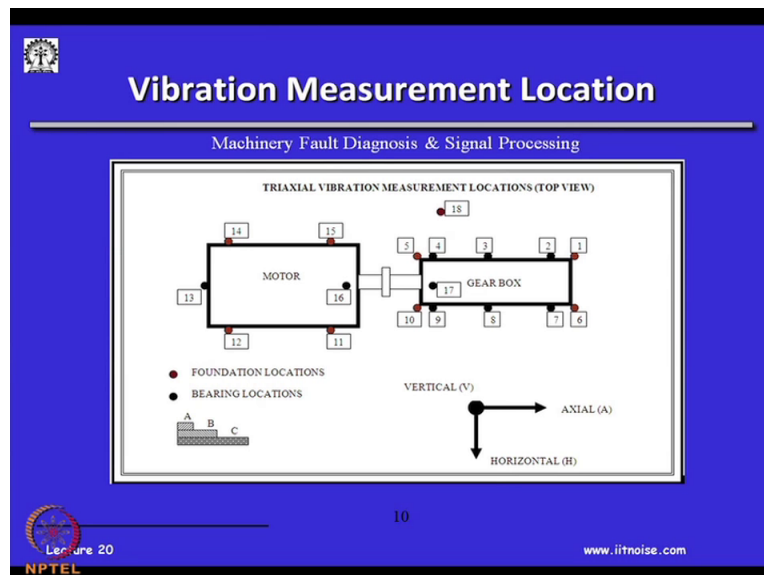
thicker system wherein the dynamics is captured, ok. In a system, there is no, this is no channel like this, this is no, not good locations to put an accelerometer.

We have to put the accelerometer, has to be mounted close to the generation of the vibration. Because the shaft, if it has a missile and etcetera, the forces would come at the support, at the bearings and this is where lot of motion will be there. If I measure here, they will have very poor signal to noise ratio.

I may get something but they will be burried with lot of noise. So, you have to be very close to the generation of vibration. And that is how, when you do an initial survey of a machine for doing vibration monitoring, you have to ensure try to find out where the bearings are located, where the rotors are located in a motor, OK, where are the loose of foundations, OK, where are the impact forces been generated etcetera.

So, these are places which we put vibrations or not on a flashy control panel not of meter there so you put an accelerometer there. No, definitely not. There are places where we should not put the accelerometers, ok. So, with this in mind I will show you another case, where we have actually a typical case.

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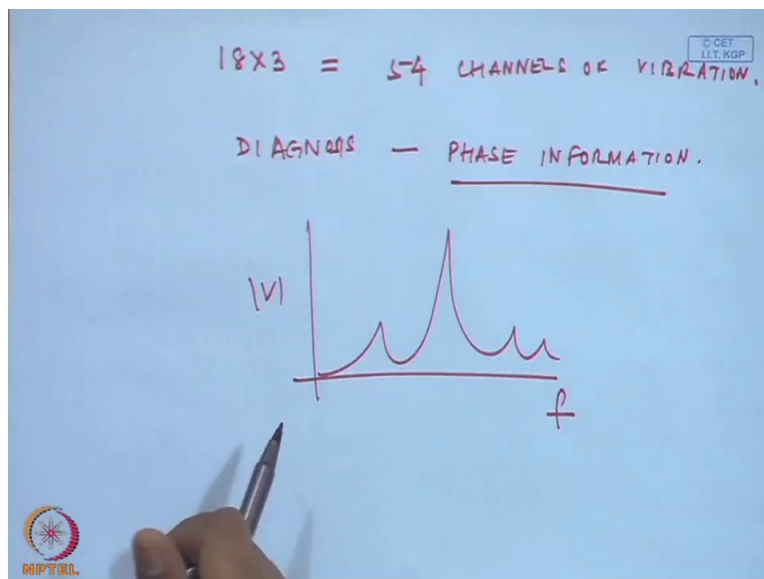


Motor, gearbox and this is the top view, ok and there are so many different locations wherein the vibrations were monitored. If you see the black ones, they are the bearing locations. This is the, 13 is the non driven bearing and 16 is a driven bearing. And this is a three stage gearbox, ok. So, there are shafts like this, Intermediate shafts, input shaft output shafts.

So, shafts are supported on bearings 2 and 7, 3 and 8, 4 and 9 and then this is the bewell gear, ok. So, there is a power shaft here so, there is another bearing here. And on top of it, every foundations of this motor, 4 foundations, gear box 4 foundations, they are measured. And just for comparison, another point outside the system is measured, just to ensure how high or how low the level outside are.

And in foundations, you know, in depending on the configuration foundations could be of different types, ok. Whether it is on the concrete, whether there is a steel frame, another structure etcetera and then, the direction is axial, horizontal and vertical is coming out of the plane of this projection here. So, you see in all this for vibration monitoring, there are 18 locations and every locations.

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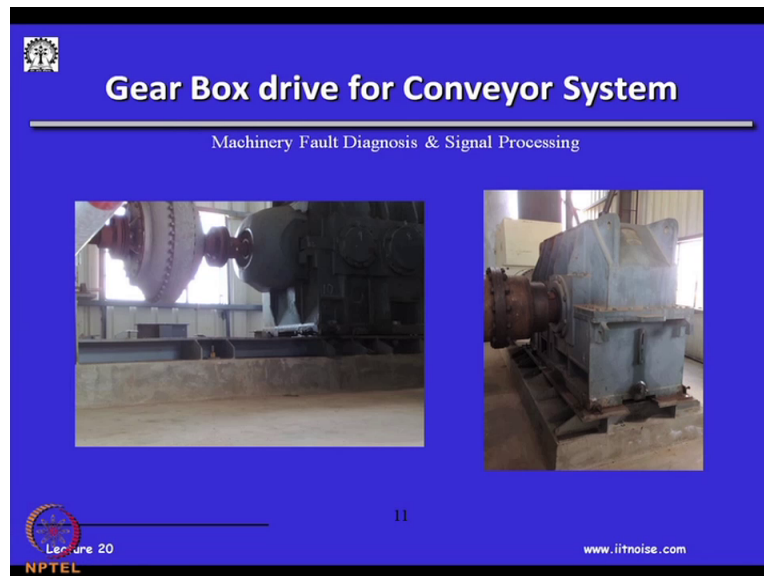


I am having three 18 into 3 channels of 54 channels of vibration are recorded. So, if I was to measure simultaneously, I need to have a system which will take in all those recordings together. But and because I know that will help you, do from a diagnosis point of you, if they are

measured simultaneously, I will return the phase information. Relative phase between the signals, ok and then, that will help me.

But sometimes, just even a single channel FFT also gives me some clue as to what the vibration levels are.

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And this is the typical arrangement wherein you see there is a coupling here. And this is the gearbox, ok. And actually this gearbox was used to convey raw materials in, on a conveyor system. If you see here, this is the motor here and this is the gearbox, okay in the Motor. So, you will see a bewell gear arrangement, wherein there is a 90 degree reduction in the torsion shaft arrangement.

And this is driving a conveyor system and you will see this bearings, you know, if you have marked here 1, 2 etcetera, they are different bearing for the intermediate shaft. And they are put on a concrete platform on to which, there is a steel frame on which these Steel frames are normally there, to ensure that the alignments are perfect between the gearbox and motor so that the shaft remains this shaft remains horizontal, perfectly horizontal.

Sometimes, once we have the steel structure, it is very easy to put in Shims so that the alignment can be done. And that is why and they can be all are manufactured in one piece and the

foundation is put; so that at site, in fact, at this location, this was about, you know, 100 meters from the ground on a platform made out of concrete.

And because, you know, the conveyor is coming out from large ships and they are high over the ground and obviously there; because this floor, if it is not on level, this system could be having a misalignment. So, now, it goes on to ensuring that the shaft between the motor and gearbox are on level in this same horizontal plane. Even a variation of few millimetres or microns is going to affect the dynamic forces.

So, perfect alignment has to be done, imagine, you know, 100 Feet above the ground, you are doing such, such an arrangement and then, how do you ensure that they are all aligned. And this is a provision stored in Shims can be done. And to ensure that the vibration levels are less than the levels allowed as per the ISO standard, we have to monitor at all these possible locations in 18 locations.

In this case, 18 into 3, 54 locations and see what is the highest levels and whether they qualify the standard of the vibration. In fact, in this case, we had situations where the manufacturing was so poor that the alignments were not done. They were few welders, you know, I do not have a better, but they were lying because this, this was used to unload raw materials from the ship.

So, obviously you can imagine this, this is near sea shore and seashore, the environment is very, very salty. Corrosive air is blowing and this system which was lying there for about 2, 3 months on the monsoon and on the corrosive wind, when we can see lot of corrosions occurring in the foundations near; the corrosions in the motor, this as well.

And this will weaken the structure; on top of it, if you want to, not do a perfect alignment, a lot of sources of higher vibrations can arise, no matter we may be having a very, very good new gear box, new motor new bearings; but your misalignment in the foundation is going to give you a lot of high levels of vibrations.

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 **Conveyor for Unloading Coal**

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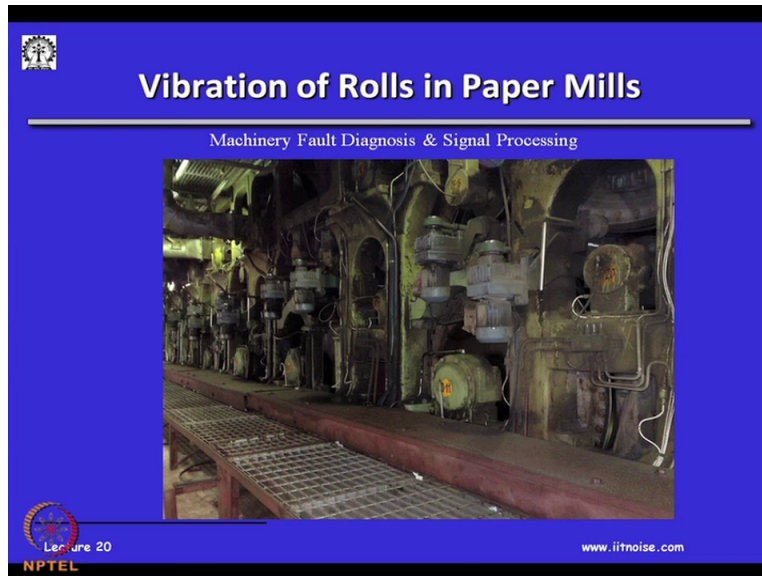
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And in fact, this is where the ships come in, I mean, unload coal as you know, in our country we do not have good quality of cooking coal, but we have good quality of iron. So, we export iron ores, okay the same converse systems. One system is used to export iron ore on to the ship; another conveyor, you know, takes in the coal from the ship and this conveyors go to large sailers wherein we dump the raw material.

And then, there are stackers and reclaimers where we will take this coal which we import and then put it on the wagon; sometimes will come to the Steel Plant or the power plants, ok. And in such a scenario we had a serious failures of the conveyor systems because, it was a new plant, new Conveyors, new bearings, new motors, new gear boxes. But they did a lousy job in installation.

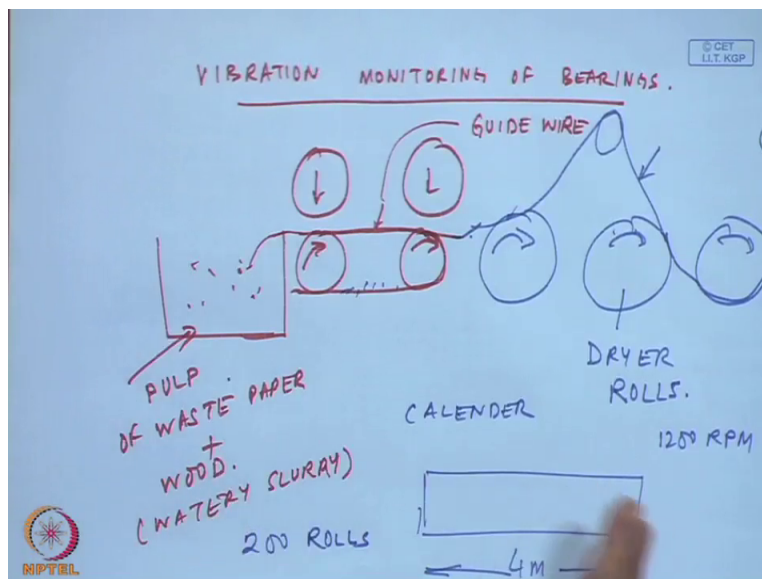
Misalignment was there and then this give rise to lot of high forces, unbalanced forces on the whole thing, some of the components did break, ok. So, we need to ensure that through vibration monitoring this can be avoided and this can be done.

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Another case of vibration monitoring, which is done:

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This is the case of a permanently installed vibration monitoring of bearings, ok particularly, this is the case of a paper mill. In a paper mill, even if you know how papers are manufactured, basically there are lot of rolls, ok. Lot of rolls rotating at different rpm's could be 200 rpm's and this paper actually briefly to tell you, this is a pulp, Pulp of waste paper. Class maybe some fresh wood, wood pulp which is made to a pulp after a chemical treatment.

This is like slurry of very, very almost full of water, ok watery slurry, and ok? And this is fed onto a roll, ok and which is spinning at high speed. This is roll, ok and because there is lot of

water, this has to be again pressed by heavy rolls, ok. And then, there has to be a guide wire, ok and these rolls are to be pressed.

Otherwise, you are squeezing the water out it and then, there will be lot of water getting collected, ok. And then there will be another and other series of rolls, ok wherein some will be like this, ok and then there is a series of rolls etcetera all rotating at very, very high speeds, ok. And these rolls, eventually will be taking off and then finally and these are actually known as the dryer rolls, ok.

So, basically they are steam dried. So, this is pulp is getting dried and these rolls could be as wide as about 4 meters, heavy rolls rotating at about 1200 RPM. Series of such rolls and there is another dry roll. So, basically we are drying the pulp, which, where the water has been squeezed off, ok. Then we are drying it and then we have to calendar it.

Do you know what is known as the calendaring? It is a kind of ironing it, ok. And towards the end there will be a pickup roll. So, any paper mill there are about, maybe close to about 200 high speed rolls about each about 1m, 2m in diameter. 1m is initially 1, and then, they will earlier, later on rotating at about 200 rolls, may be 100 rolls of the size of 1m in diameter.

And then 4 m in length rotating at high speeds and then, finally, eventually when the paper comes out and this is a view of the dry rolls. You can see the rolls here and of course, all these rolls have to be supported on bearings. And imagine if one roll breaks or phase, your paper is going to get jammed and there will be no production. This is a continuous process about 80 tonnes of paper comes out a day, ok.

This is continuously running, you know, you feed in pulp, all your day, series of rolls pressing it; drying it, ironing it or calendaring it, when you have a pickup roll. And in such a rolling mill because of the high temperatures, first of all, they have to run continuously. And because of this item, there is extreme heat on the bearings of the rolls, ok.

So the roll bearing shaft monitored and they have to be lubricated, have to be greased. And in such a plant, the bearings have to be monitored continuously. And do that at every bearing

location, if you see these Steel cables, Steel ropes kind of thing, this is actually every which are coming out from the permanently installed vibration sensors at each bearing location.

So, if there is a roll number do you know the bearing number, ok and in such a plant, in a paper mill continuously the data is being recorded.

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And that is another view of the other side. This is see again a transducer which is used to measure. This is one of the rolls of the paper mill and you can see lot of steam. These are all Steam jackets. Steams jackets are there to heat the dry rolls. These are all steam pipes. And very high temperatures rotating at high speeds every bearing has to be monitored continuously, ok.

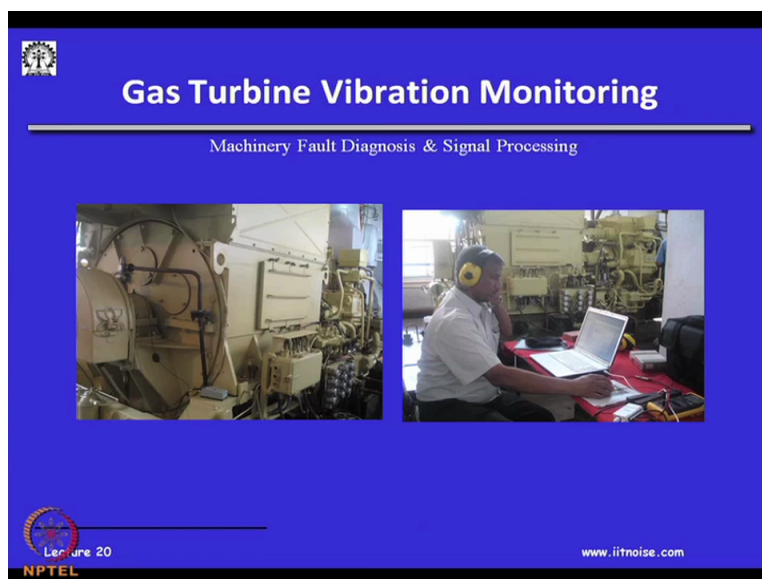
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And then, all the signals come to our monitoring Station where a person the analysis person could be recording it and could be analysing it. And there are automated alarm levels according to that standard whether if the levels are high or low, they will let you know, you need to take precautions, to reduce the levels of the signal and so on, ok.

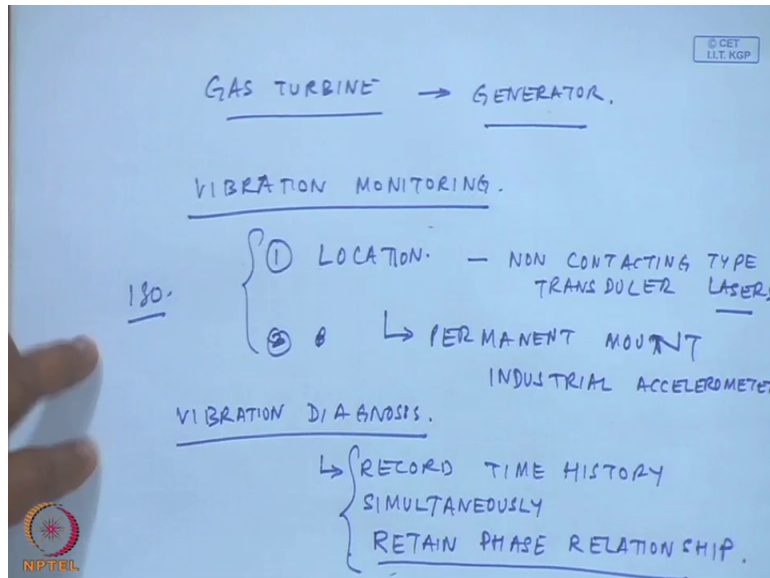
And that is what is done in the monitoring of the bearings from the paper mills, okay. And continuously we have to do that, ok.

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Another case is the case of a gas turbine.

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If you closely look here, this is actually gas turbine which is driving a generator. Many of the places, they have gas turbines used to drive electric generators, ok. Maybe in your Naval fidgets etcetera which are driven by gas turbines. Gas turbines drive generators, generators are used to drive Motors, which are used drive generators, ok.

Not directly couple to the gas turbines, these generators are the power source of the plant and of course, in the Northeast of our country, we have lot of gas turbine power plants, you know, 20 megawatt, 150 megawatt power plants driven by gas turbines. All you do is a gas turbine fuel, put in gas turbine and then, see here we are monitoring the gas turbine vibration levels, by putting an accelerometer.

If you can see here, this is an ICP type of accelerometer wherein this gives the power supply. And obviously the gas turbines are very, very noisy. So, we have to put ear muff here, very noisy environment. This was in a test bud in the health of the gas turbine to do the health monitoring. So, in summary, we have to while we are doing vibration monitoring, couple of things we have to keep in mind.

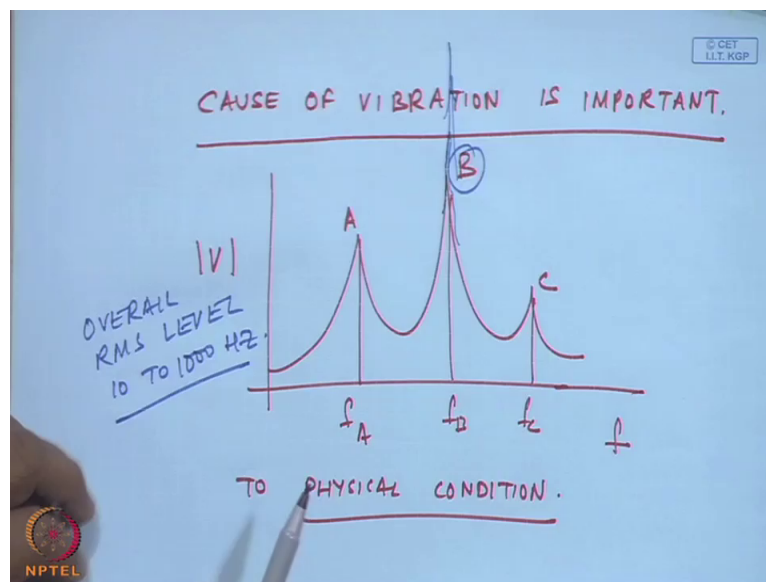
One is the location. Locations always may not be accessible; locations, in the, that case we have to use what is known as the non contacting type transducer like Laser. Or for permanent mount, we can put industrial accelerometer. By industrial, I mean, industrial accelerometer, same

accelerometer but very robust which can be subjected to high levels of acceleration, which can be subjected to high temperatures and they can be permanently mounted.

But for vibration diagnosis and for vibration monitoring, as long as I follow the ISO standards, I am doing good. But for vibration diagnosis, I need to record the time history, either through tape recorder or through digital data recorder, have them recorded simultaneously. Why do I record simultaneously? To retain the phase relationship; This is very important when we are doing the diagnosis.

So, as a condition, machinery fault diagnostics engineers, we would be more interested in recording the time history simultaneously and then, so that we return the phase relationship.

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So that we can know the cause of vibration, is important. Machines are going to give out vibration levels, A, B, C machine components at their characteristics sequences. So, this information is not available if I just looked at anonymous level of the vibration level from a permanently installed transducer, I will get a certain value. This only tells me about the value is more or less than the acceptable level.

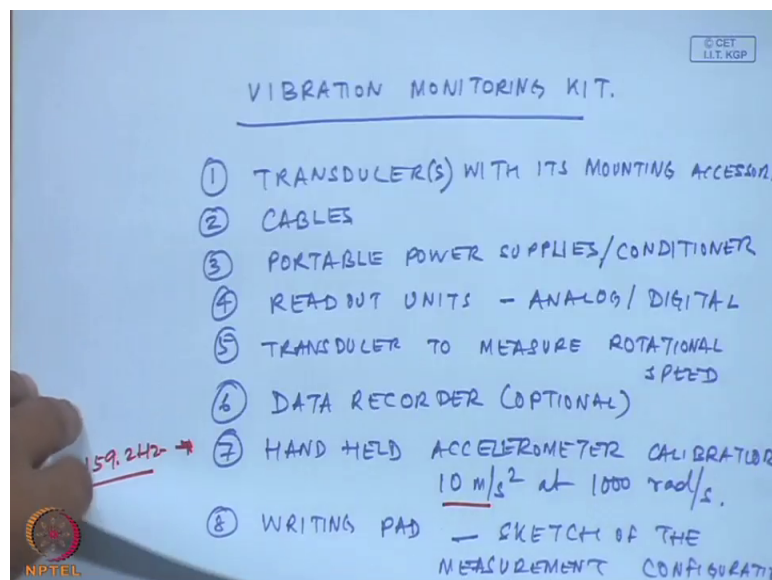
But if I do a recording in the time domain, do an FFT analysis, see the individual components which have come up in the spectrum, and then relate these parameters, f_A , f_B , f_C to physical

condition. Only then, can I say whether for the higher levels of vibration, whether the component B is responsible or A is responsible or C is responsible, I can do that.

For example if I was doing vibration monitoring in this way, I will be suddenly alarmed if this B was increasing I will never at all recordings my B levels are increasing, so, something is wrong with B. This should not be possible if I had just seen the overall level, overall RMS level from 10 to 1000 hertz, so I have seen the overall vibration level.

I would not know whether it was B which is responsible for such a high vibration level, A is responsible for high level or C is responsible for such a high level, ok. So what should be there in your vibration monitoring kit, ok?

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In a vibration monitoring kit, we must have a transducer with its mounting accessories like magnets, start, traps etcetera. The cables, the power supplies, portable power supplies, the read out units either Analog or Digital, transducer to measure rotation, sometimes the data recorder and of course the very important thing is the handheld accelerometer typically with 10 meter per second square and 1000 radian per second.

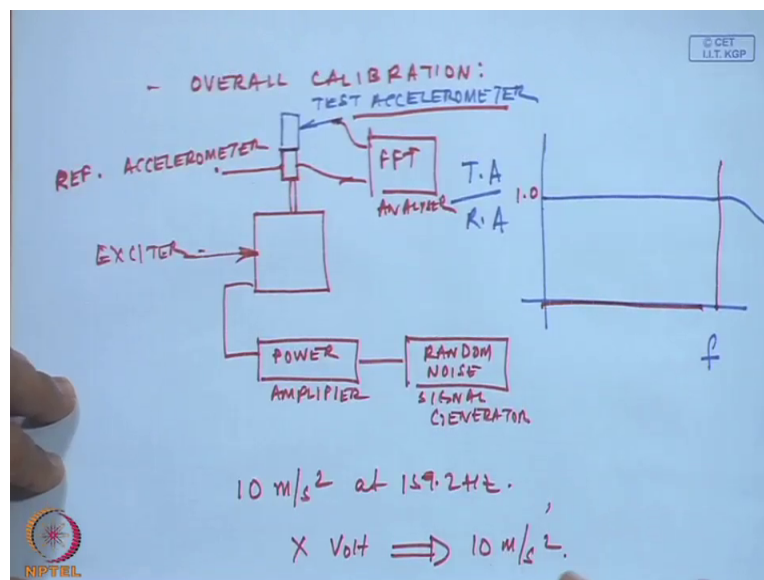
And of course, we have to have a writing pad to make a sketch of the measurement configuration as to axle, vertical and horizontal. We have to measure axle, vertical measurement.

This is what has to be in any vibration monitoring kit which is used to, and we can have multiple numbers of transducers, ok as the case may be.

If you have, if you are carrying this equipment with you, you need to understand how to do that and sometimes in another question on the calibrity is usually is: these 1000 radians per second, this means, 159.2 Hertz. So, if you look at the spectrum, coming out the calibrator, you will see a peak of 10 meter per Second Square, 159.2 Hertz.

Sometimes it is good to have this field calibrated just to check the sensitivity level because you can be having power supplies and may be a conditioner also a signal conditioner, like the charge to hold t he amplifier. And none of them you have to do in the accelerometer calibration, calibrator before you go to the field to do the vibration monitoring is given.

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Over all calibration and this is done by this method. We have to, in the lab, you can put an, power amplifier, random noise, signal generator, exciter and onto this, you attach an accelerometer, which is a reference accelerometer onto which we measure the test accelerometer. So, if you measure the transfer function between the test accelerator and the reference accelerometer, if I know the reference accelerometer is good from a certain bandwidth, you should see a plot like this.

So, this means, the test accelerometer is behaving the same as the reference accelerator, for the all frequencies of excitation. This kind of calibration, we cannot do in the field of course, you know, because this is, these two signals are effective in FFT analyser and other important. You can, just see the transfer function between the, this accelerometer and this accelerometer and divide one by the other.

They should be the same and that is why you will get this one value of one. Once you are done that, you can be, ah be sure that this accelerator test accelerator which you are going to take to the field is calibrated for all frequencies. And at the field, we have just given known value of 10 meter per Second Square at 159.2 hertz and see whether they corresponds, you are getting the same value.

Or if I get some X voltage in the system, I know this corresponds to 10 meter per second square, ok this can be done. So, this is very, very important.

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Handwritten notes on a blue background:

10 m/s^2 at 1000 rad/s .

$\Rightarrow$	10 mm/s at 1000 rad/s	$\omega^2 A$
$\Rightarrow$	10 mm	ωA
		A

$1000 \text{ rad/s} \Rightarrow 159.2 \text{ Hz}$

And as you know, there is a relationship between this 10 meter per second square at 1000 radians per second. Now, omega square A is the acceleration, so, this will boil down to 10 millimetres per second at 1000 radians per second or 10 micro of displacement because of the relationship; Omega A, omega square A. So, this is a handy rule and it is very easy to remember 1000. Actually 1000 corresponds to 159.2 Hertz and that you can see in FFT Analyser.

So, in summary, to do vibration monitoring, you have to be careful about the equipment which you take how you mount the accelerometer, what kind of precautions you have taken to ensure that the accelerometers are properly calibrated and what you get is what you should get, ok. Not that garbage in is garbage out. You have to ensure that you have measured correctly, nothing like, nothing like doing a correct measurement because all your diagnosis depends on how you measure the vibration levels .Thank you.