Machinery Fault Diagnosis and Signal Processing
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Lecture - 08
Vibration and Shock Isolation

We are continuing our discussion on Vibrations. As you would have seen in the last two classes on vibrations we had talked about the basics of vibration and then about some concepts of free enforced response, and then I had given an example of on automobile going on a wavy road and how we could find out the response with an example of the ECU.

The same is true for response at the human seed location and so on. Now, we will look into the concept where I am told you that there is a force which is coming in at the base of a body. And this force could be harmful, so this is what we are going to discuss on this vibration and shock isolation and we will see how this is done.

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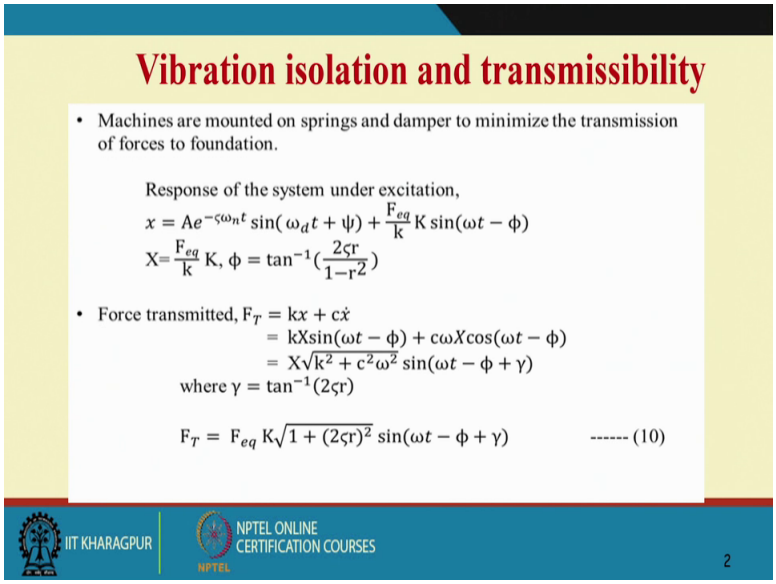

And this helps actually in the design of foundations of machines. So, machines are mounted on springs and dampers, as you know by now to minimize the transmission of forces to the foundation.

So, if I have expression like this; response of a system under excitation, so force transmitted to the ground is because of the force from the stiffness and the damping and this is the transmitted force.

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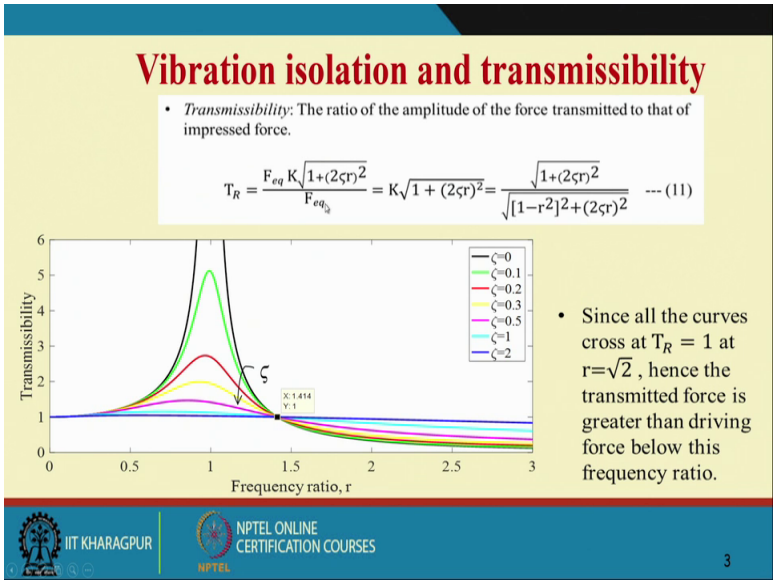

So, my force transmissibility will be given by this expression; the ratio before transmitted to that of the impressed force is this curve and I want this.

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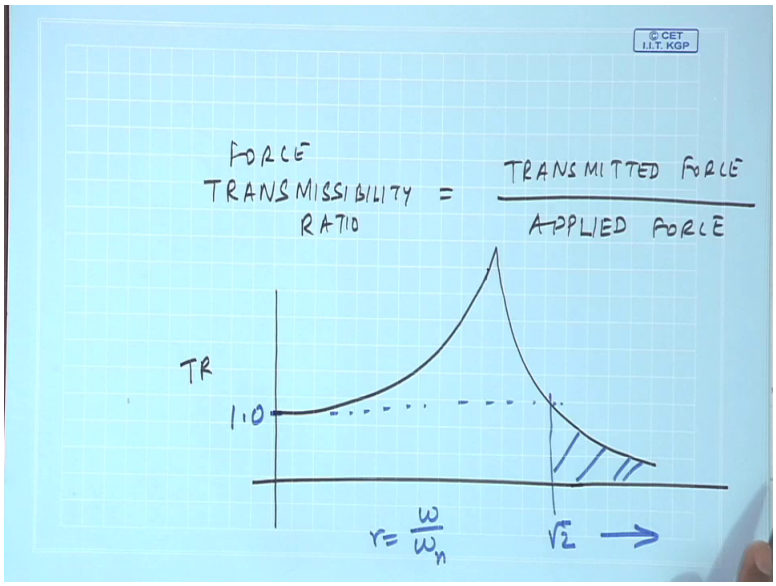

If you look at the transmissibility ratio, this is nothing but transmitted force to the applied force. And this force transmissibility ratio is given by this expression and this is very important that this is 1.

So, if I need to have always the transmitted force less than 1; so, and this value of r, r is nothing, but omega by omega n. So, this value is root 2, so the desirable range is that this value root 2 is 1.414 is always greater than the frequency response; I am sorry the frequency ratio is always greater than root 2; that means, F; T R is less than 1. So, whatever is the applied force; the transmitted force will be less than 1.

Now, so if the forcing frequency is not in my control; all I can do is change omega n and that is the basic principle behind designing isolators.

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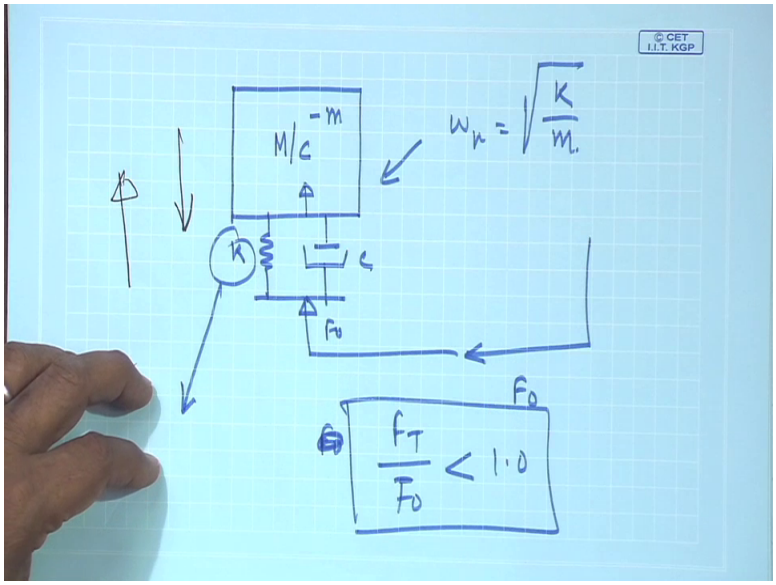

So, if I have a machine; it has certain mass M. So, if I have an applied force F naught coming into this ground. If I do not want anything to get transmitted into this body because it is a sensitive body, I can play around with this omega n of this body; omega n is nothing, but root over K by M. So, I can play around the stiffness of this bodies foundation, as to not allow this transmitted force F T should be less than 1.0.

So we have to now, one has to be very carefully, whether I am talking about force coming from here to here or force coming from here to here. And that is why the K of the

actual system was going to change. So, one has to be careful in vibration isolation what kind of K; I need to decide?

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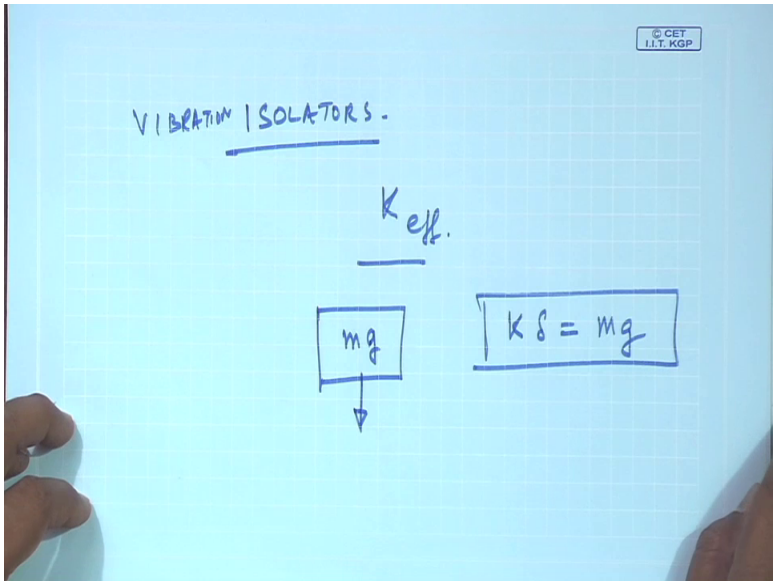

So, if you go to the market today you will find many such isolators; no this vibration isolators, which will come with an K effective, but this spring or the isolators must also withstand the static weight of the body say m g is a force. So, they should be able to withstand the static force K delta should be equal to m g. So, I can find out whether I require you know 5 numbers of spring or 6 numbers of spring and that is what is required when we design isolators.

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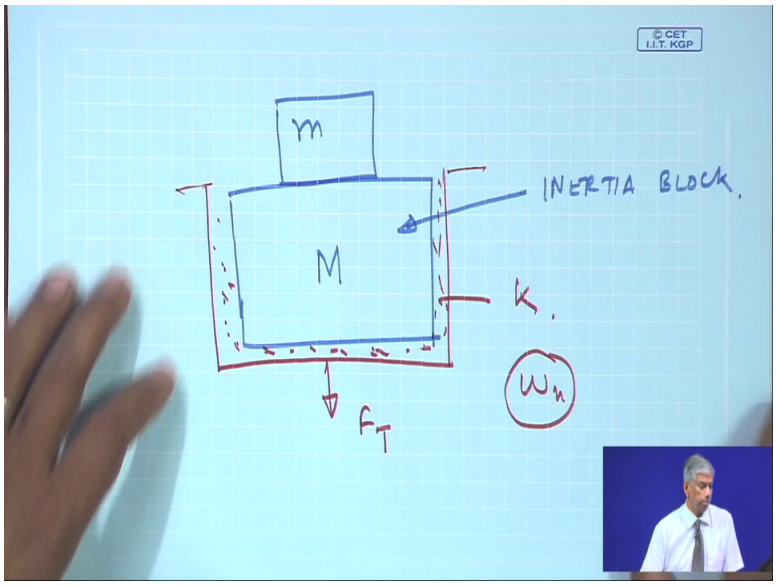

Many a times one cannot play with K; so sometimes we play with inertia. So, this body is put on a large mass of M and which is known as an inertia block. And this is put in a bit wherein we put some soft material wood etcetera to give the stiff. So, this kind of arrangement and then I do not want anything to get transmitted. So, I was just telling you one has to be very carefully whether I am seeing the force coming into the system or force going out of the system and accordingly your omega and definition is going to change.

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This is one example where in a tractor see the foot pedal; the driver puts his foot on this platform and this underbody is rigidly connected to the engine of do the frame of the track. So, all the unbalanced forces which occur in the engine during combustion is going to excite the structure and there will be a large amount of provisions. So, I do not want this platform to vibrate, so the transmitted force has to be less.

So, this can be done by proper selection of the isolators, so this kind of design has to be done. And this could be non numerically modelled by techniques often; relevant method or even by your single degree of freedom system analysis, you can do that.

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Same is to for gas turbines; gas turbines are put on a bay wherein they are rotating at very very high speeds. Imagine a small amount of unbalance because the speed is so high there will be lot of forces coming onto the frame. So, they have to be of course, you know in gas turbines we perfectly balance it. Nevertheless there has to be good oscillators kept everywhere.

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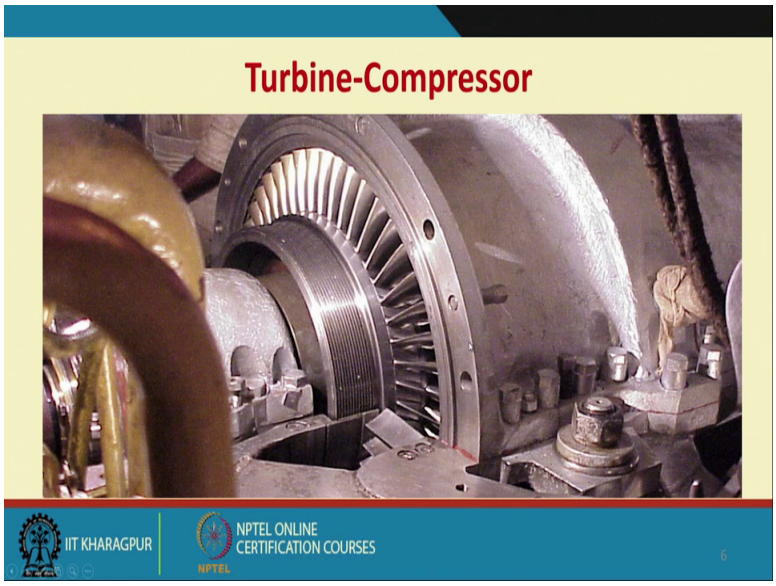

And this is the view of the turbine compressors; I am just show you this right now; so that you know what we are getting into when we talk about condition monitoring of a gas turbine. So, this will give an example to see the magnitude of the problem. You see this, such fine clearances between the outer shell and the rotor and these are all the blades which rotate at high speeds and are subjected to high temperatures.

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Now, this is you see these are all mounts; vibration mounts if you can see. This is the motor, it is a gearbox or the generator and so on. If there is any vibration in this frame, I

do not want that to be transmitted to the ground because this could be affecting some other machine nearby. So, you can have such isolators put in place and such isolators are known as the anti vibration mounts. And you can see there is another foundation where in another motors kept.

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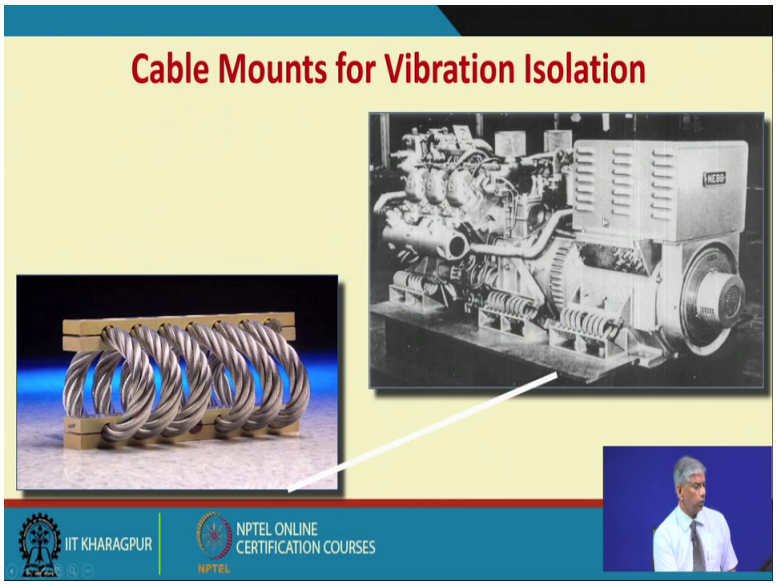

So, an foundation design looks into this; many a times you know these vibrations as restoring whose directional.

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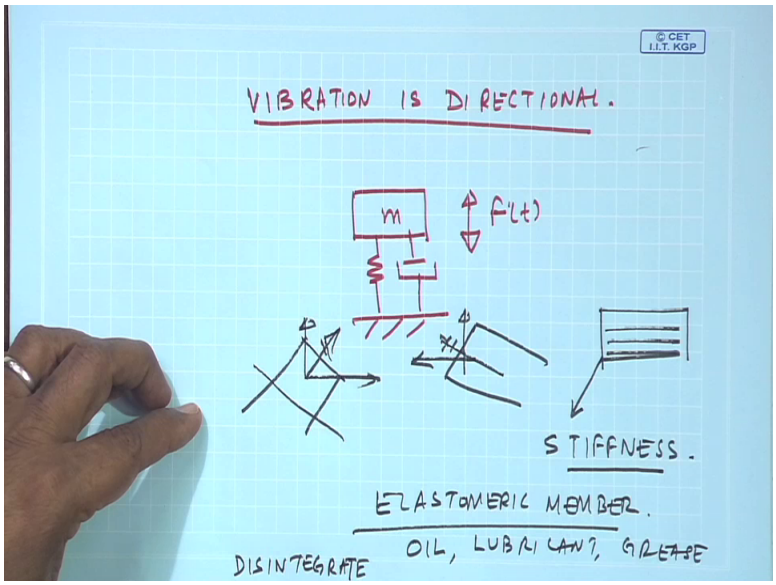

So, one has to keep in mind the predominant direction; imagine I have a body like a prush; forging prush, so all the forces are along this direction. So, I need to put isolator in this directions but many a times this is and if you will see here; isolators are put on a plane of 45 degrees; so, they will give some component in this direction also.

So, just putting it inclined; I provide some stiffness in the vertical direction and some stiffness in the horizontal direction. Such cable mounts are available where and you will see this reflex in any direction. So, depending on the predominant force direction there are going to flux, otherwise if we went for traditional vibration isolators, you have to stack them in a particular direction. So, vibration and another thing because we give stiffness in many of the industries; you will see that there is a lot of lubricant and oil being used for lubrication of the machines. So, this stiffness is provided by an elastomeric member.

So, when they come in contact with oil or lubricant or grease; they will disintegrate. So, such isolators do not have a long life and you will see, there is the alternate to this is the stable mount made of steel ropes; which could have put under harsh environment and they will have a longer shelf life, they will not disintegrate with time and the most advantages because of these cables which are intertwined; they will also have given you a relative internal damping.

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And you see this one another missile launcher; wherein we have cable mounts being put so that the recoil is arrested and then large motion is not being propagated.

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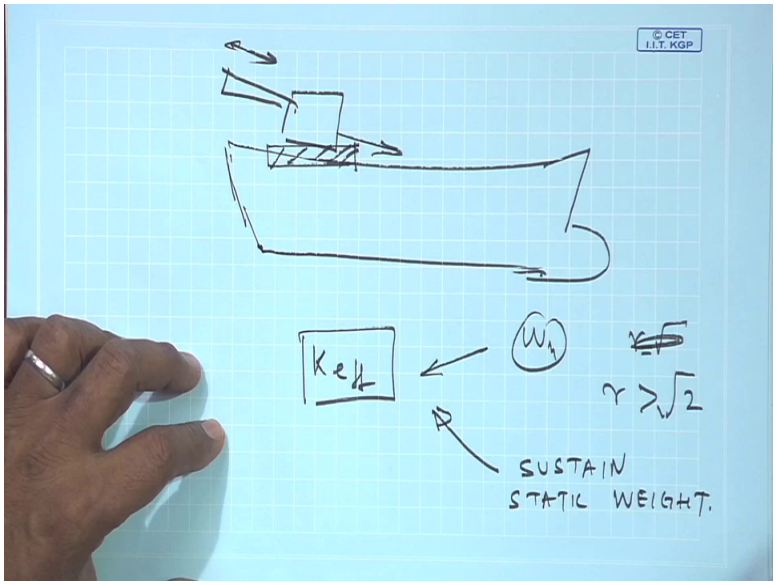

Imagine in a ship, you have a large field gun imagine you fire this gun and then there is big amount of recoil. If this recoil was not arrested, but such observers; vibration observers what would happen to the motion of the ship? A lot of fatigue in these stresses would occur. So, this is arrested by this heavy duty cable mount isolators.

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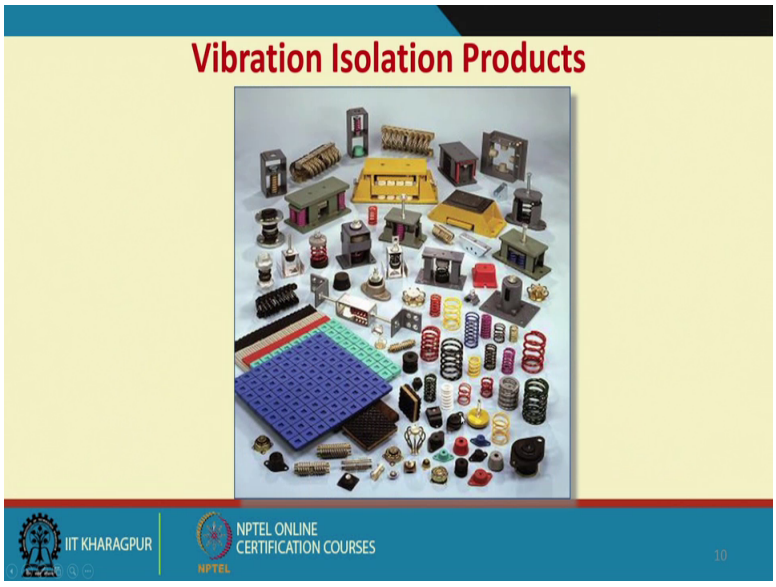

But today, if you go to the market you will find vibration isolators of many sizes, shapes and forms. These are the helical coils spring mounts; these are the cable mounts, these are summing pads; neoprene pads with little holes in them and which also act as isolator. So, you can stack them and so on. So as a designer all you have to do is find out effective; K effective which will relate to the natural frequency. So, that r is greater than root 2 and they will sustain this static weight of the object they are supported, this is something one has to keep in mind.

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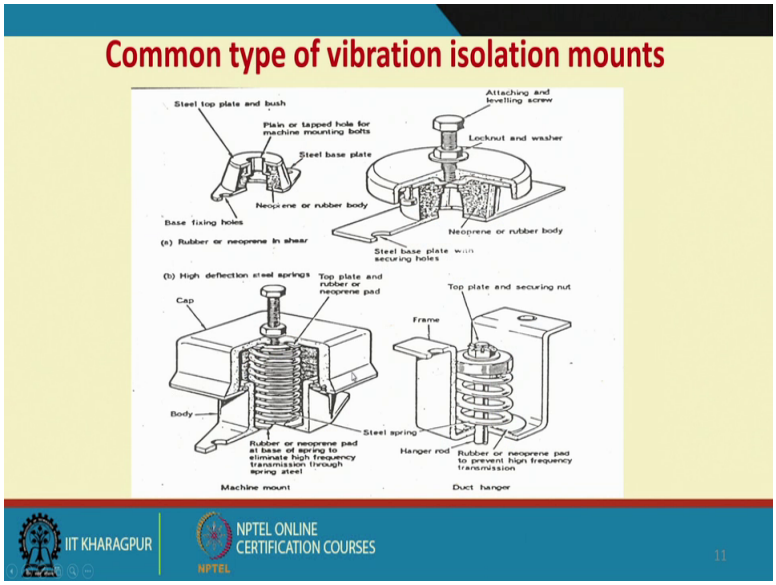

So, common type of vibration isolation mounts because let me tell you when you are doing condition monitoring of machines.

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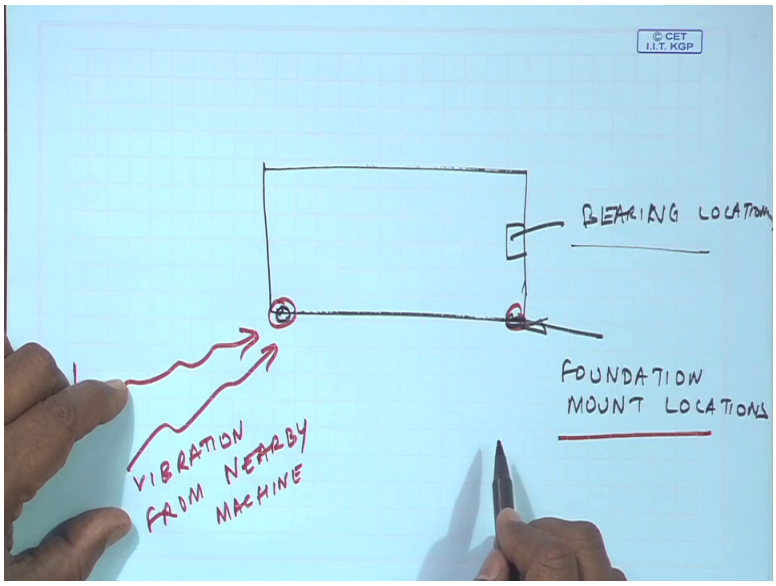

Many a times the transducers where when we measure will be at the foundation mount locations or the bearing locations but as a sterling you; the vibration from a nearby machine will always influence your measurements for a particular location. So, one has to very careful as to understand that this machine has been having proper foundations and what are the limits of the oscillators.

So, we look at the common types of vibration isolation formats; we will have neo plains or springs. So, there is inherent damping already built in apart from these stiffnesss.

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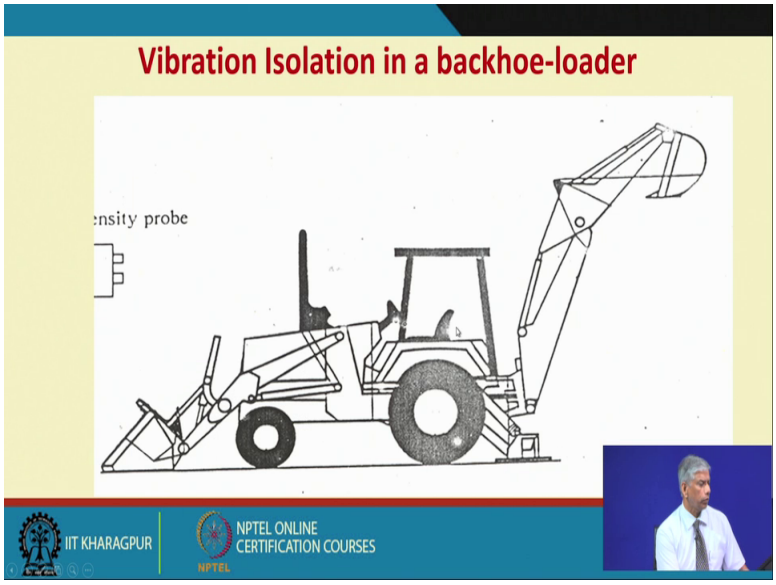

So, you will see an example where in a backhoe loader because this cabin beam is put rigidly on the frame of the backhoe loader. And this backhoe loader is subjected to large amount of forces because it is doing off highway operations, so this driver seat has to be isolated.

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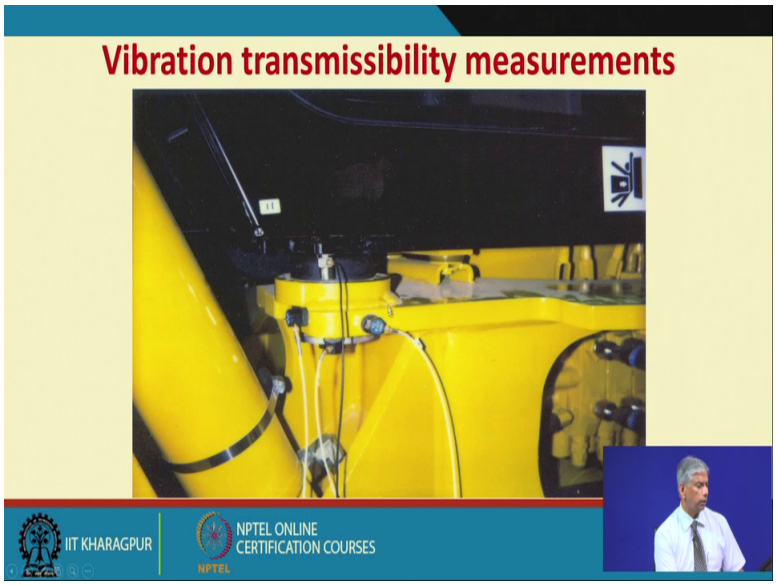

And this is how the vibration transmissibility is been measured, we will see transducers measuring on the frame and transducers measuring on the cabin of the cab and this is supported by isolators.

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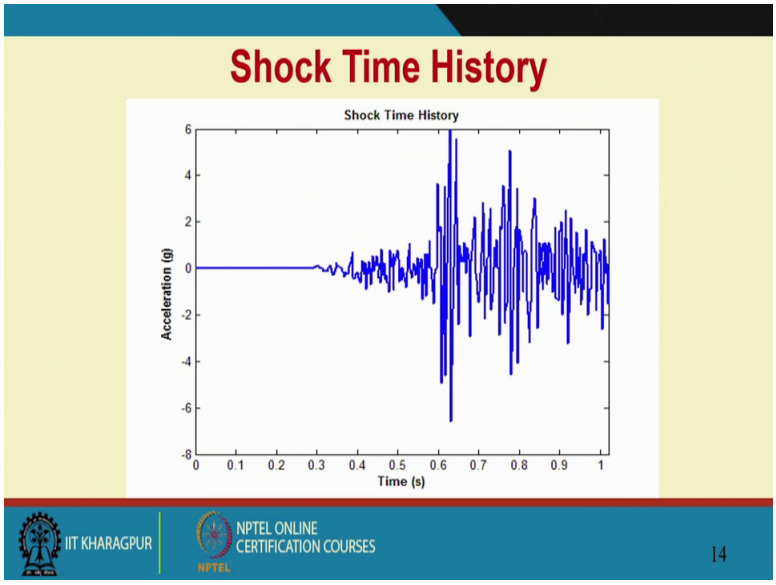

But once I have talked about vibration isolation, I must tell you about shock; many a times shocks are very very high frequency impulses for a very very short duration.

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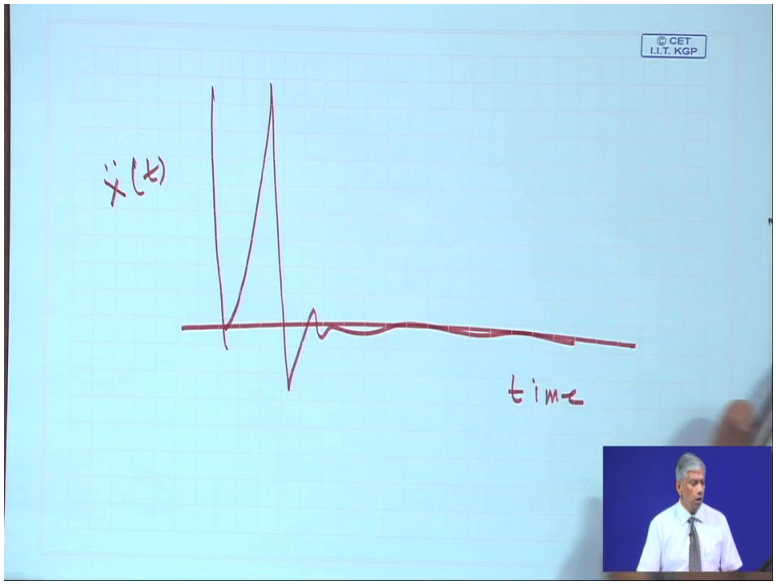

Imagine an impulse occurs like this; is very shock it happens maybe once some. And you see even in 1 second; you see the amount of acceleration it has been produced high acceleration. So, shock isolators are another form of vibration isolators; wherein they absorb this energy and then they release it by dissipating them slowly over time, if you look at the energy graph with time.

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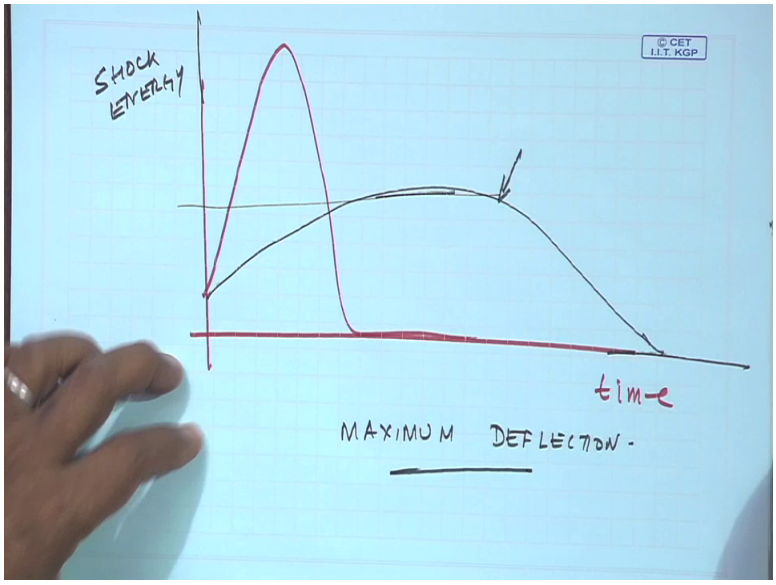

So, this is my shock energy; very high peak they will arrest this, but they will do it like this; same energy they will dissipate within less vibration amplitude. So, this is the function of shock isolators, so limit of such short isolators is the maximum deflection.

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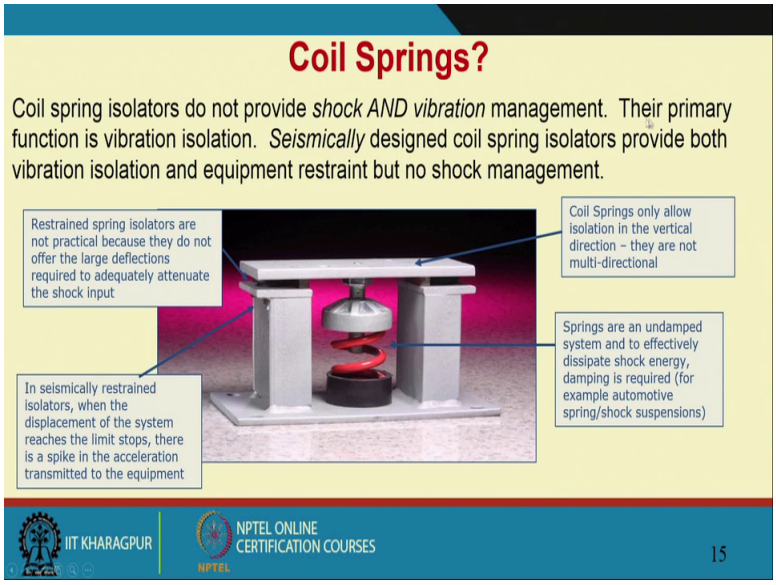

So, in many applications you will see shocks needs to be isolated. So, vibration isolators are actually done by coil springs, so coil springs isolators does not provide; they provide primarily vibration isolations; all if you can read this.

So, nowadays there are buildings which are supported particularly the hemianopia chambers, very sensitive equipment etcetera are provided with such coil springs automobiles is another example.

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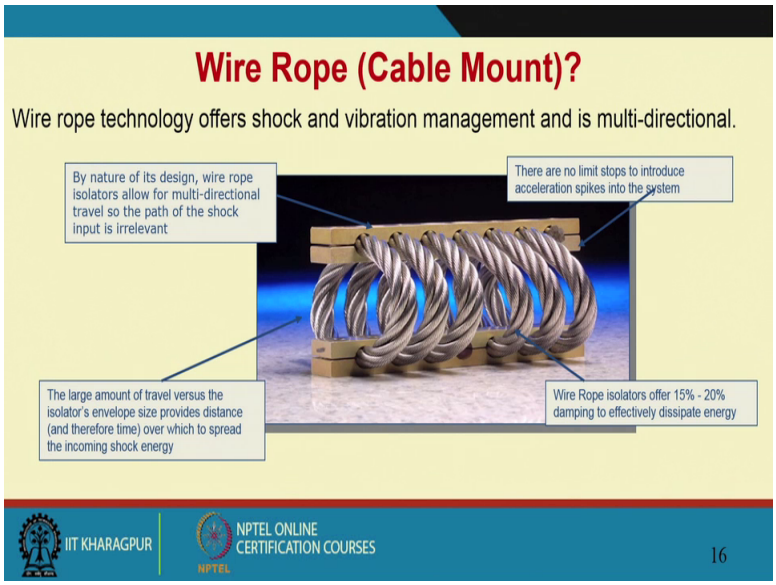

As opposed to wire rope or cable mounting; cable mount it is multi directional that is the advantage of such cable mounts. The reason I am showing you this is when you go to the industry, you will see many such applications of isolators; be it cable mount or be it helical spring. Now this kind of isolators are there and then we have to measure at these locations when they are mounted to these machines.

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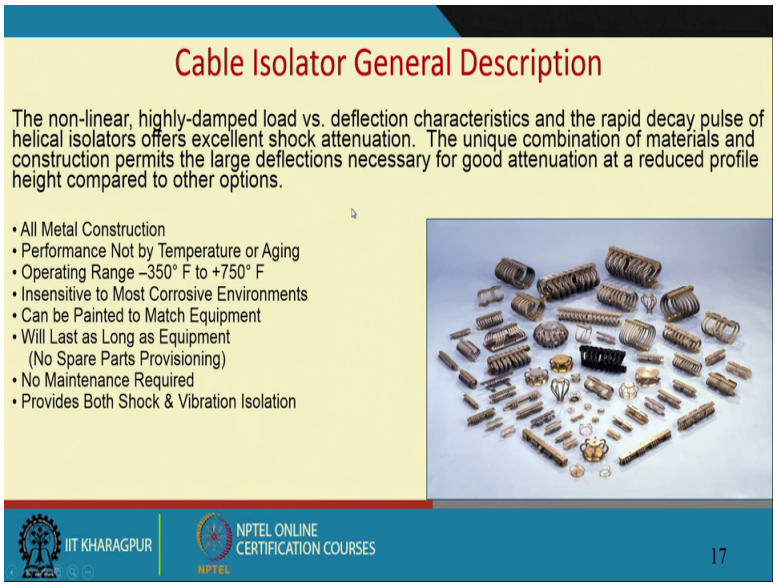

So, there are many different forms of cable isolators; they are all in metal, construction, they will not affect because of temperature, insensitive to corrosive environment and that

is very very important in our machines and if provide both shock and vibration isolations.

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So, to understand the vibrations being produced in a vehicle; this was work which I was doing during my postdoctoral fellowship. And these understand the role vibrations coming into the vehicle, so one can work on the transfer path analysis.

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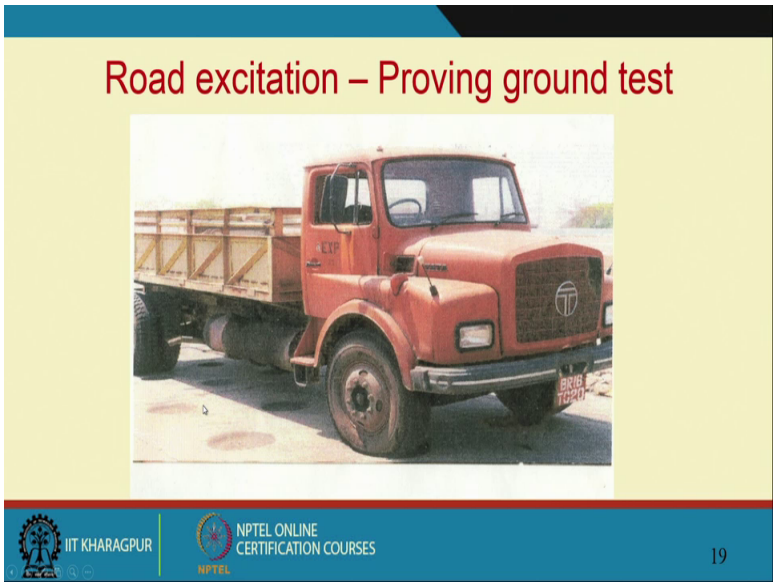

In the last class, I was talking about we had an example wherein we had an wavy road, but if you go to the actual proving ground of auto manufacturer, we will see such roads with potholes, with washboard type.

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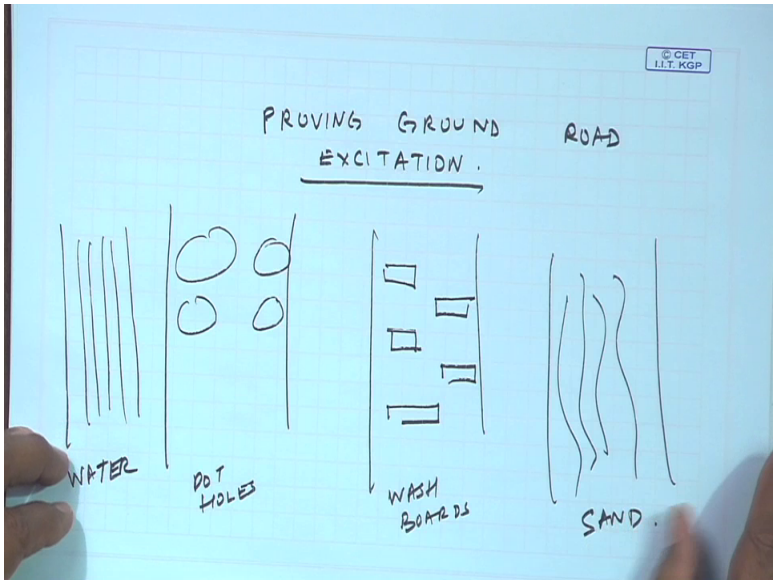

So, basically; so there will be bottles, there will be four by fours wash board type, there will be you know lot of sand, water. So, such proving ground excitations are there physically to do what is known as the transfer path analysis.

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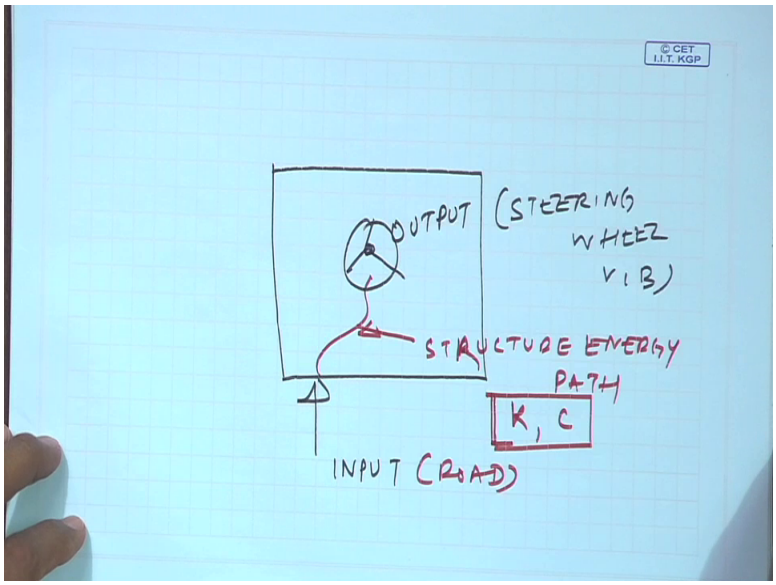

So, transfer path analysis; I have some input, I have some output. Output may be could be a steering wheel vibration because there is always a path; structure one path for the vibration energy to come from the road input to the steering wheel variation. So, in this structure one path; I can play with the stiffness and damping K and C.

So, as a designer such studies helps and proving ground simulations actually validate your designs.

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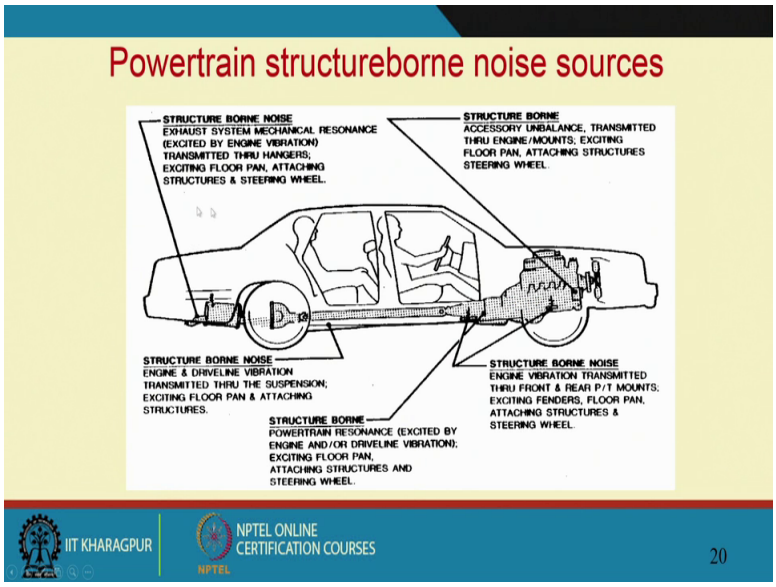

So, if you see in an automobile to reduce the structured warmth; they have a lot of isolations being put in all these locations to reduce the noise being reduced, if generated because of the vibrations of the power trim in the drive line.

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So, vibration isolation is there in a vehicle in almost everywhere; vehicle suspension, I showed you the example of that wavy road, engine mounting many auxillary motors like the power windows, wiper motors, windshield washer bottles, the electronics. So, all of these will get affected if they are not properly isolated.

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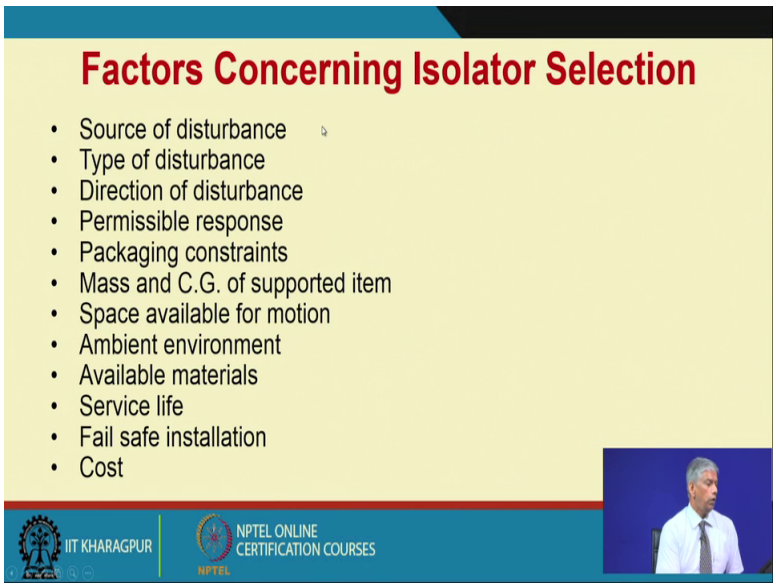

Well, one has to be very careful about how to put these isolators. So, we need to know these sources of disturbance and in particular the center of gravity of the supported item.

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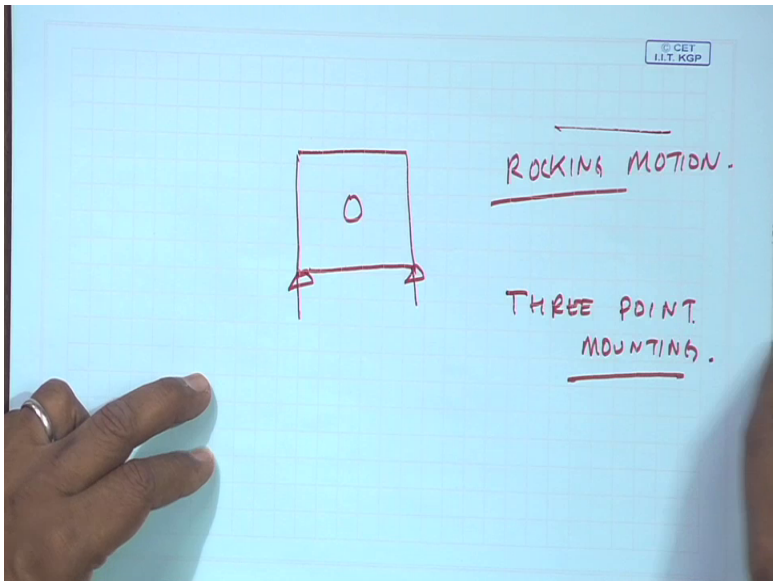

So, otherwise; this is not geometrically balanced; there will be always supports are not geometrically balanced we will have a rocking motion.

So, from a static analysis one can find out what is the optimum mounting. For example, in an engine they have autism in a three point mounting etcetera. And if you will see these engines are actually held on such isolators. So, this helps us to define the boundaries of vibration measurements when we are doing vibration isolation.

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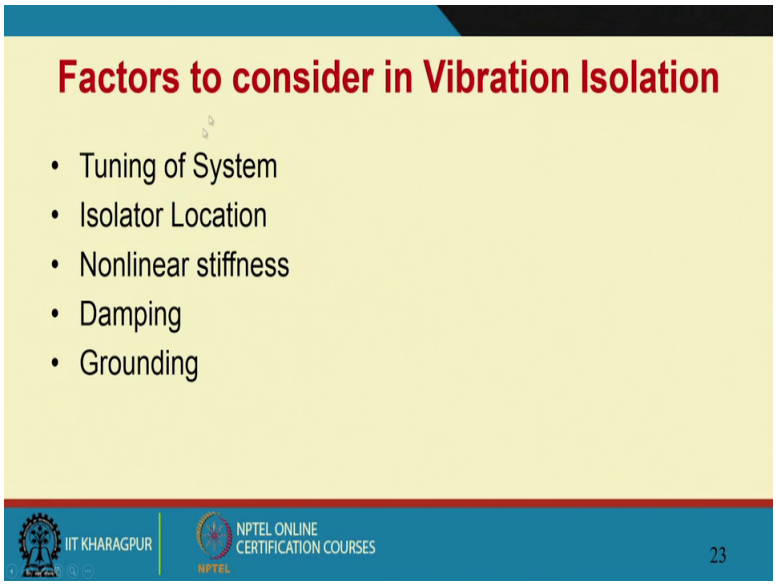

So, this will help us put where the transducers need to be put. So, factors to consider in vibration isolation; tuning of the system, isolator location, non-linear stiffness, damping, grounding has to be taken into account.

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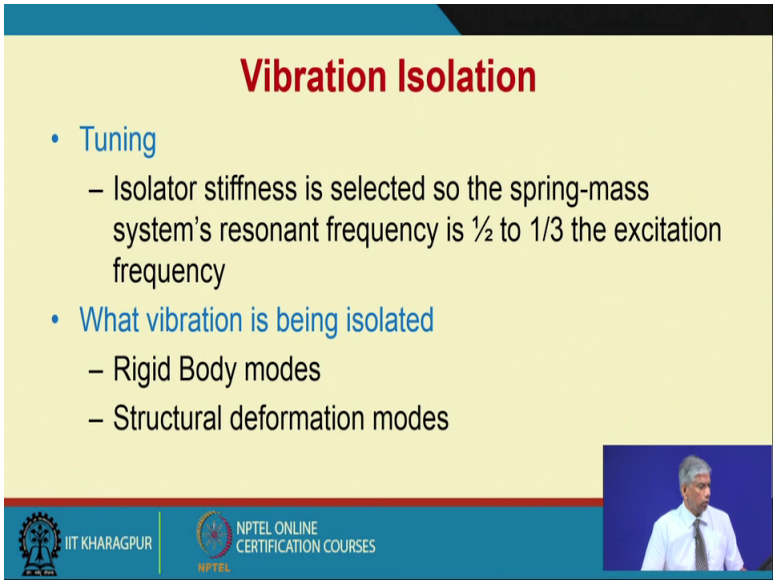

So, all if you must remember that vibration isolation; we need to find out the natural frequency and the frequency response should be less than or greater than root 2 so that the force transmitted force is less than the applied force.

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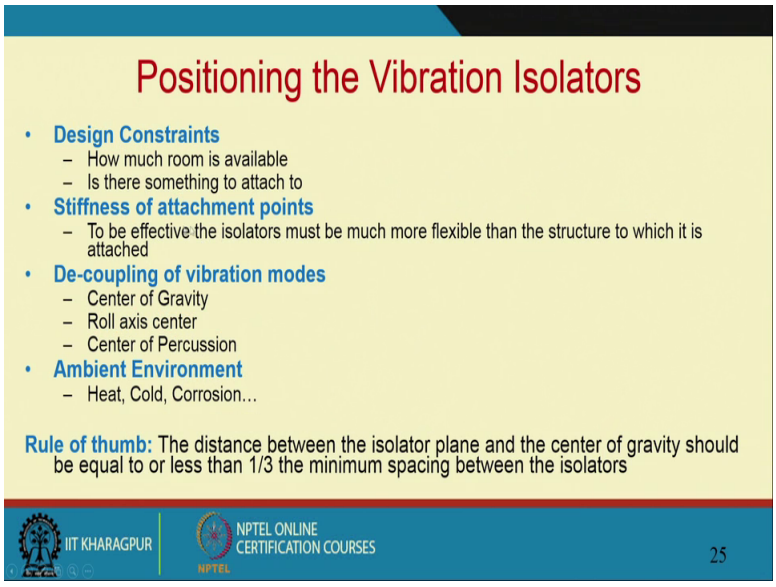

You know some ideas regarding positioning the vibration isolators.

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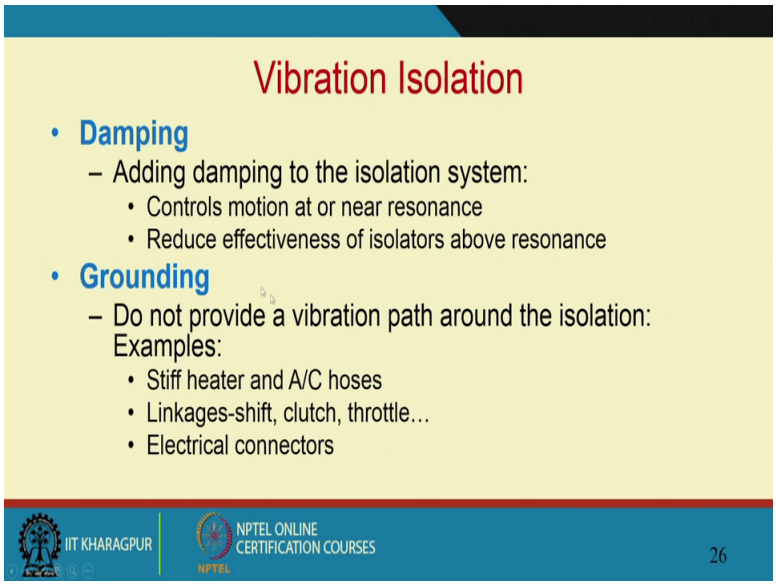

And there should not be any short circuit; we have done a good isolation, but then you see there is a metal to metal contact that must not happen.

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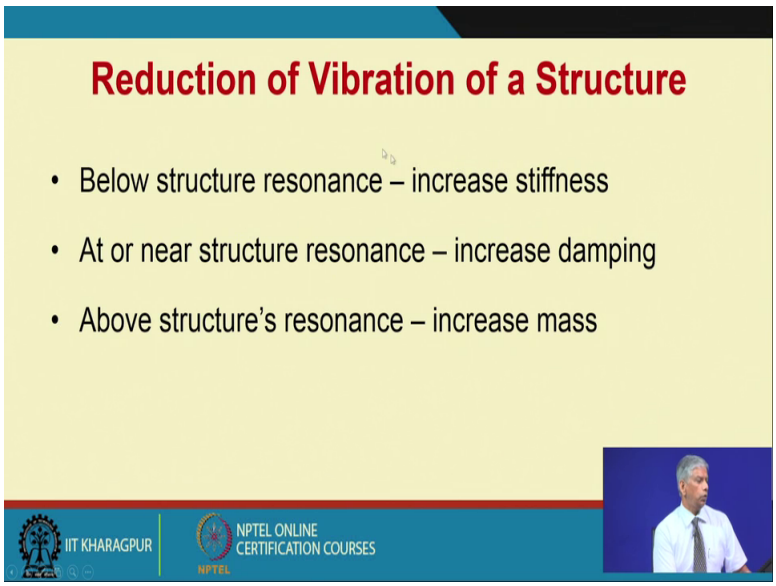

So, reduction of vibration of a structure; act resonance, increase damping, below structural resonance, increased stiffness and above structures resonance increase mass.

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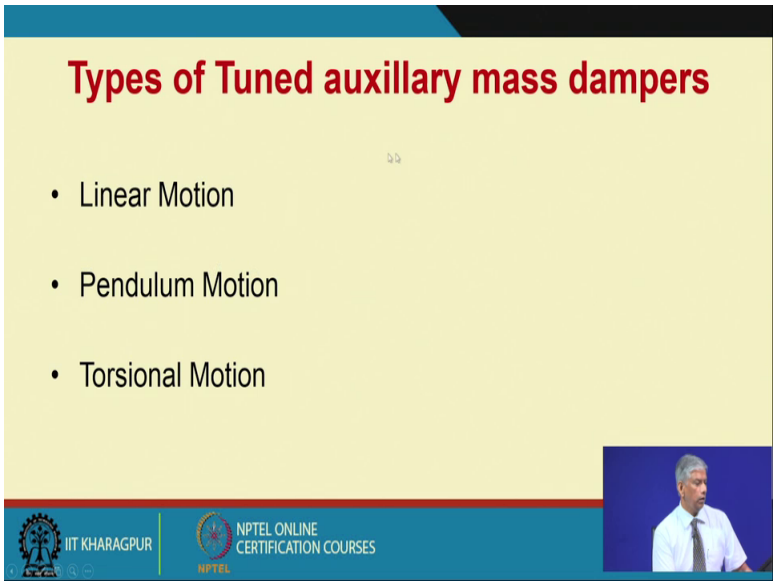

Just to recap, we talked about to tuned mass damper systems in the previous class. So, there are; for different types of motion we can have tuned mass dampers; one taking care of the linear motion, other for the pendulum motion and so on.

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And automotive applications there are many such tuned absorbers being used and this was an example of the transfer path analysis, so this could be a patch attached to the drum.

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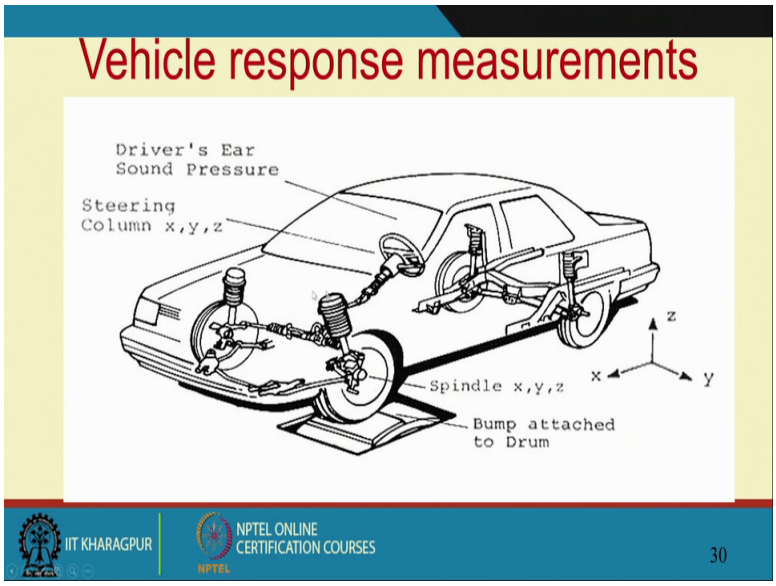

And then this is the steering wheel; suppose one does not understand; light the vibration, we can who as a vehicle designer; we have to play with K and C and either this could be done in the proving ground or this can be done in the laboratory, where there are roles on to which we can put different tire patches and this is what is actually done.

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And then we can put damping materials to reduce the vibrations.

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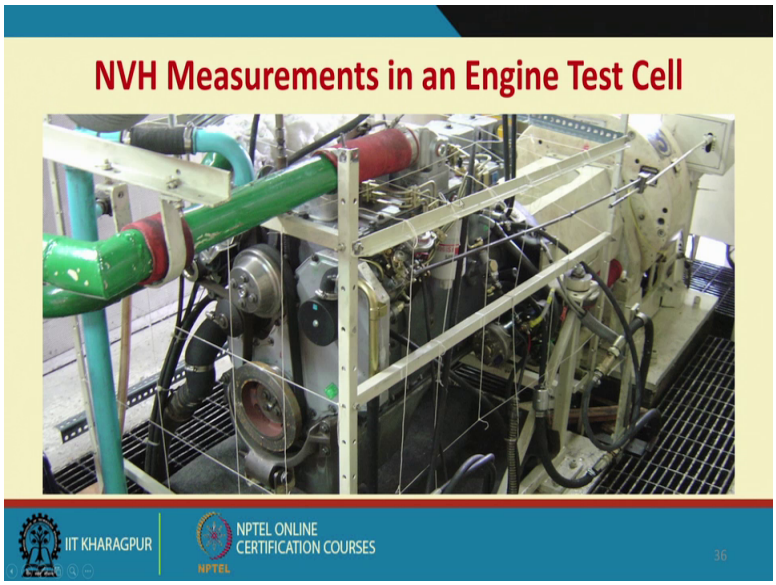

And this is a measurement being done in the engine test cell, which is again isolated because I do not want external vibrations to come and disturb my measurements.

Thank you.