Vibration Control
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Module - 3
Vibration Isolation
Lecture - 1
Vibration Isolation – 1

This is Dr. S.P Harsha from Mechanical and Industrial Department, IIT Roorkee, in the course of Vibration and Control, we till now we discussed about how we can control the vibration. Basically, when we strike on the root cause of that means the source. Even we discussed about you see that, what kind of you know like the control strategies are there specially in the passive control, that we can adopt easily.

And we can apply you see here for control systems like you see here even at what point of time, we need to apply say spring or the damper. Even in the damping you see we discussed about what exactly the complex nature of the damping is means, when the damping is coming out from the system through molecular structure, through column or through you see when we apply some kind of lube oil for viscous damping.

Then what exactly the complex nature of the damping is, now also we discussed about you see how we can apply the masses, and when you see we have a kind of dynamic and balancing. Then what you see you know like the masses can be done balancing of these things, or we can say for suppression of the vibration through flywheel. In previous lecture, we mainly discussed about the sun damping, even you see we know that you know like some kind of passive devices can be applied directly.

But, some damping is something, which is coming out from the system itself through resistance inductance and capacitance. And how you see these circuits like in parallel or in series can be applied to the system, to control the power or in other terms you see to control the vibration amplitude. So, sun damping is mainly used when we know that the circuit parts are there, or when you see in the entire electronic components some kind of oscillations are there, we can suppress those things straightway, instead of applying some kind of a spring damper or the masses there itself which is not feasible.

In this now lecture, we are going to discuss about how to design the vibration isolator, what exactly the components are there in those systems, through which we can say that. These are the basic you see, you know like we can say the parts of the machine, and through you know like adopting these we can say the principles of the isolated design we can suppress the vibration isolations.

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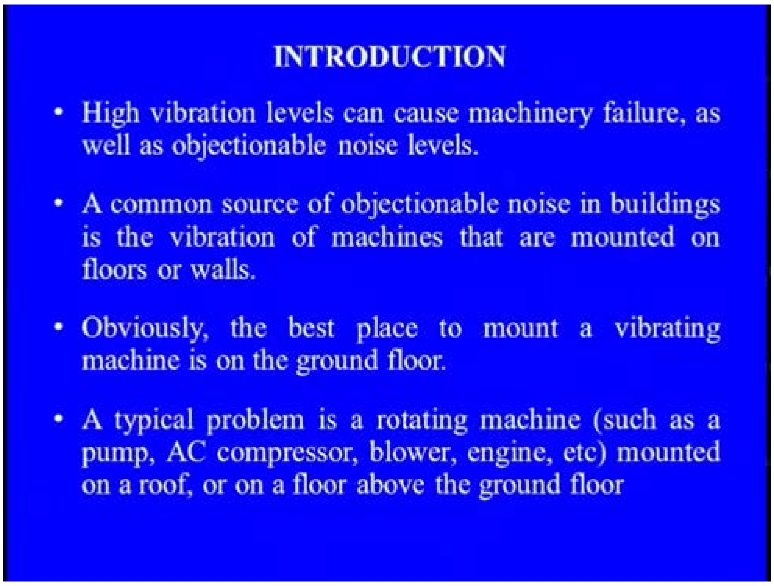

So, you see here in that we know, the basic theory of the vibration that high vibration levels can cause the machine failure, because you see here if it is because the nature of the vibration or the dynamic forces are of fatigue nature. So, when these cyclic loadings are being applied to any structure, and when the system is exciting in there higher harmonics mood.

We know that it can straightway damage the machine itself, or sometimes you see here there is a basic cause for machine failure is high vibration level. And also you see here with these vibrations, we have a different kind of you see the noises which are coming out, the different kind means here that sometimes even the mixing of noises are there or when or sometimes, you see the audible range of this is, so high that it clearly cause damage in the machine.

A common cause for this objectionable noise in buildings is the vibration of machine, which are being mounted either in the floor or on the walls. Because, we know that the basic theory says that always we need to go to install the heavy machines on the foundation, but sometimes you see here. There are many machines, which will come according to their operations, which will come on first or higher floors, and this structure is a good support for transmission of these vibrations, irrespective of higher level or low level vibrations in the amplitude.

So; obviously, the best place to mount the vibrating machine is generally the ground floor, and a typical problem when we are adopting the machine like the pump the compressor AC compressor or blower or any kind of engine. We need to mount on roof or on any of the floor, which should be above than the ground floor, and because of the rotating element in these components, they are causing the high level of vibrations. And these vibrations because they are rigidly mounted on the floor, or on the wall these vibrations are transmitting rapidly through these solid surfaces, because of the molecular nature of the vibrations are.

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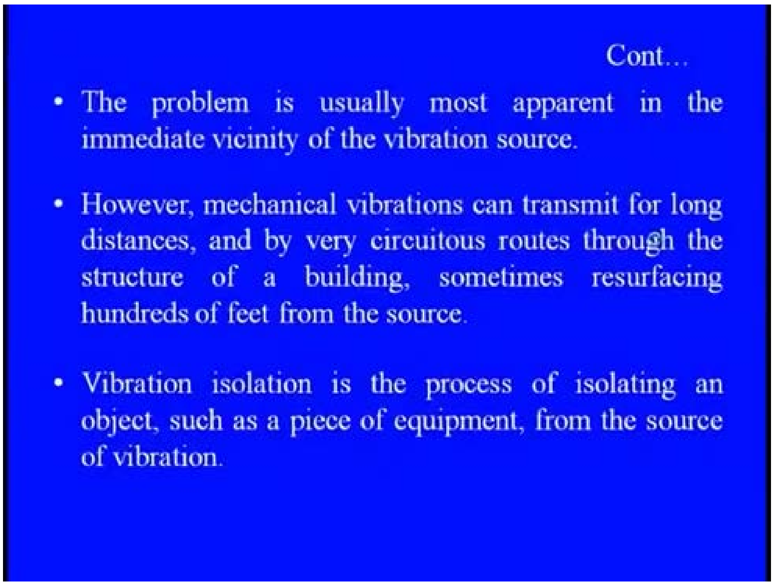

So, the problem is usually most apparent in immediately vicinity of the vibration source, and we need to apply straightway, the concept of vibration isolation on these sources. However, mechanical vibration can transmit for long distances as well, and by very continuous rotors or the routes with this, where you see you know like the rotating elements are there.

These routes are always providing some kind of support, and through these routes they are straightway approaching to the structure of building, and sometimes these vibrations are causing a huge. You know like we can say the damages on the entire roof, when they are transmitting through this, entire roof or the structure, when they are transmitting through these medias.

So, we need to apply the vibration isolation in that and vibration isolation is nothing but it is a process of isolating an object such as the piece of equipment or entire equipment itself you see here from the source of vibration. Means, we need to apply something, say in passive nature or something like you see through that, we can at least disturb the path of transmission from source to the structure. Else, we can you see by adopting something we can reduce the amplitude of that oscillation, so that whatever you see the transmission is their it should be of the low amplitude of this nature.

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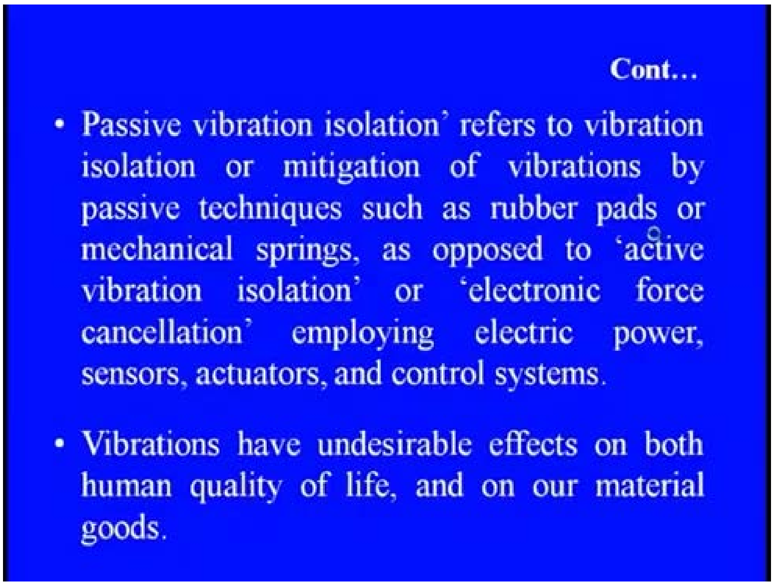

So, here we are saying this isolation is coming under the passive vibration isolation, and it refers to the vibration isolation or the mitigation of vibration by passive techniques, such as the rubber pads mechanical springs or as opposed you see here. We can also go with other part, because these are the passive means we need to apply something, we can go towards the active vibration isolation. In which the electronic force cancellations are there, by adopting the electric power the sensors the actuators, and some kind of control systems which needs to be designed.

So, that this force the electronic force the electro mechanical the electro dynamic or any kind of the force can be cancelled out by adopting perfect circuit theory, or the control system itself. So, both the techniques are adopting according to the type of source, vibrations have always some undesirable effect, as we discussed already on both human as well as on our devices, in which the rotating elements are there.

The human you see here as far as the human part is concerned, we know that there is a clear damage on the human activity the comfort level. And even you see here when you know like when we are just traveling, and we want to do say any kind of activity by writing reading or even whatever the physiological parameters are there, they are straightway effecting at the low frequency of vibrations.

And if the amplitude of vibration is very high, at these low frequency say at 1 hertz or 4 hertz or 10 hertz, then certainly you see here the discomfort level is significant there. And even it is, it is straightway effecting the nerves, when through which the blood circulation is there, it is straightway effecting you see the common activities of a human. So, we need to check it out that, how we can control the amplitude as well as the exciting frequencies of the vibration, which can harm to both human as well as the material.

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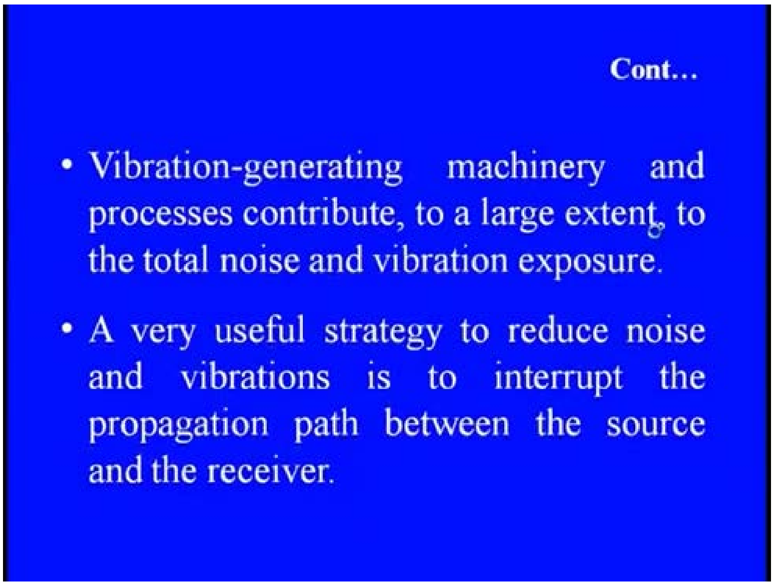

So, vibration generating machinery and the processes, they are both contributing to the maximum extent not only to the vibration exposure, but also the noise which is coming out from the devices. So, a very useful strategy to reduce the noise and the vibration is to interrupt, the propagation path between the source and receiver which we already discussed about that.

So, in this part also we would like to focus or rather we should strike on this feature that, how we can deviate the path of sound energy or the propagation of these vibration transmission by adopting some kind of you see the isolators. The first thing, which is coming as we discussed that when the machine is being mounted on the solid surface, if we can apply a elastic mounting in between the machine and the foundation. Certainly, you see here some kind of vibration either in terms of the oscillation or the energy, can be straightway absorbed by these elastic mountings.

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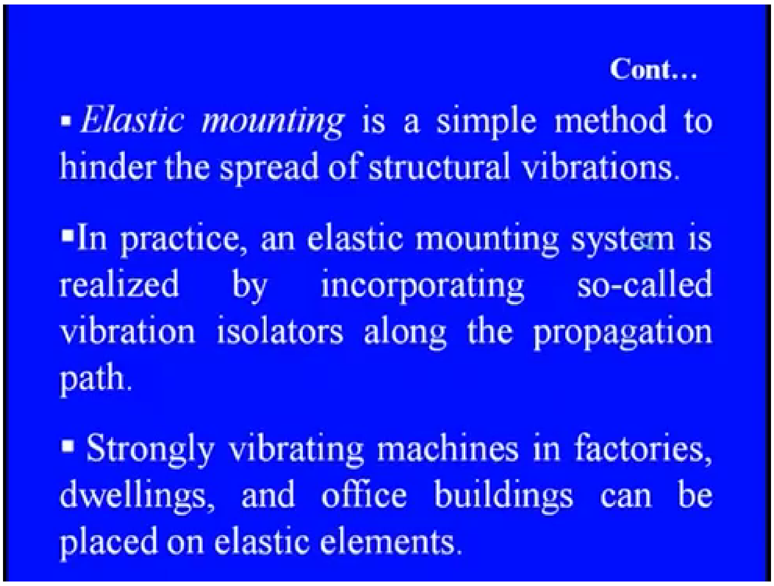

So, it is a simple method to hinder, the spread of structural vibrations and in common practices, an elastic mounting system is real is realized by incorporating, so called the vibration isolators. Just along the path of the propagation of these vibration to this structural system, and strongly vibrating machines like in factories, we can we know that the heavy turbo generating machines are there. In which the rotor is rotating at such a high speed, and the mass of the rotor is significant, then certainly you see here you know like the kind of vibration generation as well as the noise is, so significant.

And the transmission of this vibration, because these heavy machines are always being mounted on the solid surface, so transmission of these vibration and the noise is, so rapid that the entire office buildings are absolutely you see under damage. So, we need to apply some elastic elements, along the walls or on the foundation or in between the machine and the rigid foundation, so that the transmission can be avoided or eliminated from the source itself.

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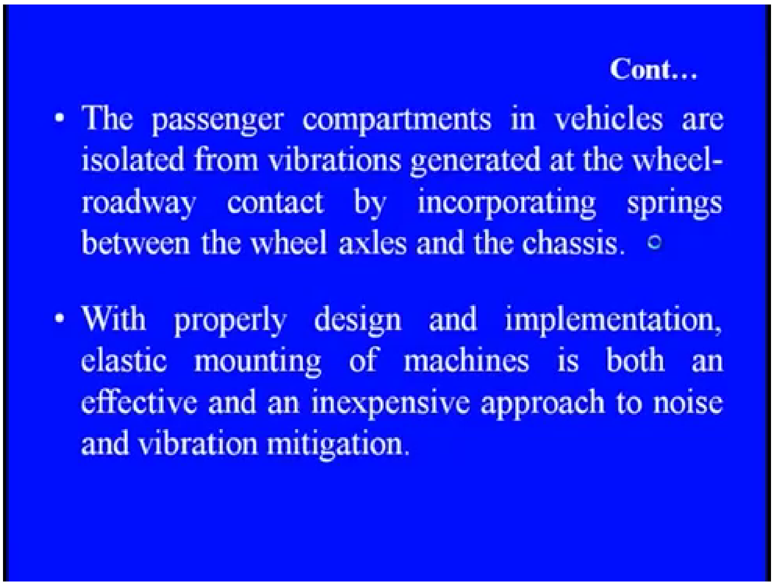

So, the passenger compartments and the vehicles also or isolated from the vibrating vibration generated, at the wheel and road we contact by incorporating the springs. And you know that even if you are talking about the railway vehicles, we have two suspensions system. Mainly, one by damping when the bogies are being provided in between the wheel setup, and the entire wagon or any cartridge, passenger or even we can apply the coiled spring.

And these coiled springs can be straightway, just known as the secondary suspension system can be act as the vibration isolators. So, even you see here we can adopt the spring in between the wheel axle, and the chassis the leaf spring coiled spring any kind of springs. And also the same time the damper either it is the viscous damper or it is the passive dampers, say you see here any kind of you see material damping and something can be straightway adopted in that.

And with properly design and implementation of these elastic mountings, on the machine can effectively absorb the vibration, and this is one of the inexpensive approach to noise and vibration mitigation. So, we need to see that how we can design this, what exactly the potential place, where we can adopt or we can put these devices, which is one of the main important feature here.

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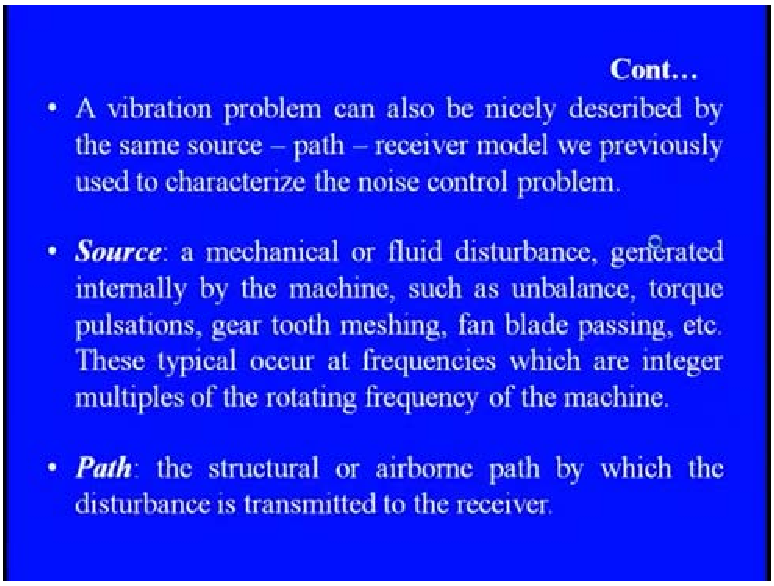

So, vibration problem can also be nicely described by same source path and receiver, which we already discussed you see here in that, and we can characterize the vibration as well as the noise problem there. So, if you are talking about the source, this is something the mechanical or few disturbance as we discuss in the previous lectures, any mechanical motion the rotating motion or the fluid disturbance can generate.

Internally by the machine such as unbalance torque, pulsation, the gear tooth meshing, the fan blade passing, the air is just passing through the tubes, the turbulence in the fluid, the whack formation or the vertex formation in that. So, all these you see here, the ways through which the vibrations are generated in that, and these typically occur at the frequencies, which are integrated in multiple ways towards the rotating frequency of the machine. So, these are the you know like we can say the potential devices or potential cause, in the devices through which the vibrations are generated. Second path second part is coming as the path, this is something the structural the solid surface or the airborne path by which the disturbance is transmitted to the receiver.

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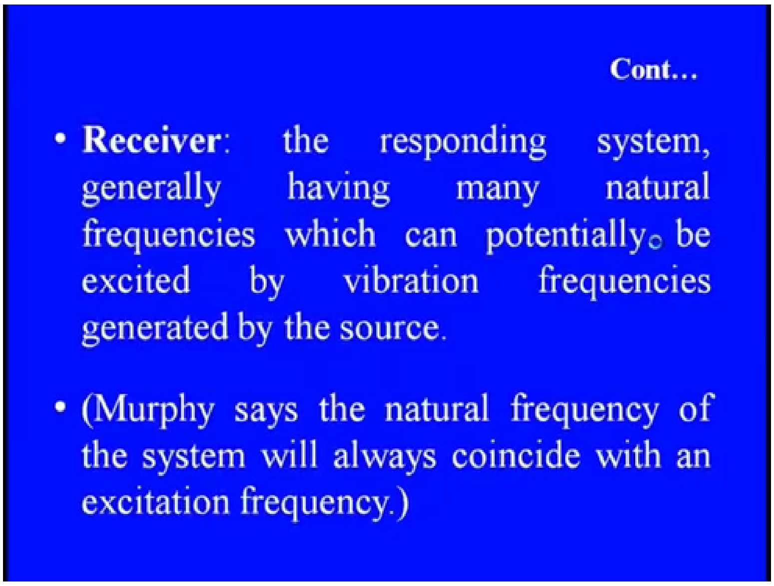

And the receiver is something, which is you know like the responding system generally having many natural frequency, which can potentially be excited by vibration frequencies which are generated by the source. So, the natural frequency you know like is being defined sometimes, you know like by the murphy, and it says that it will always be coincide with the exciting frequency, and you see here, you have always a huge amount of energy at the time of this exciting frequency.

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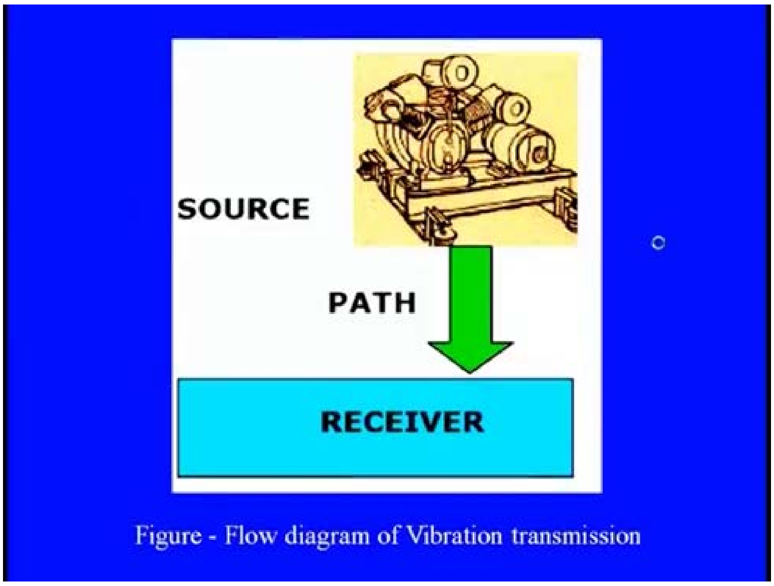

You can see on the screen, it is a clear picture that we have the source is something, which is nothing but you see the rotational components of the machine or the machine itself. When it is you see under operations, the path is something you see here where the machine is mounted on the solid surface and it is being transmitted, the receiver is of multiples. And the receiver is always being affected by this natural frequency, which are being coming out, these all frequencies are being coming out from the sources and transmitted through this.

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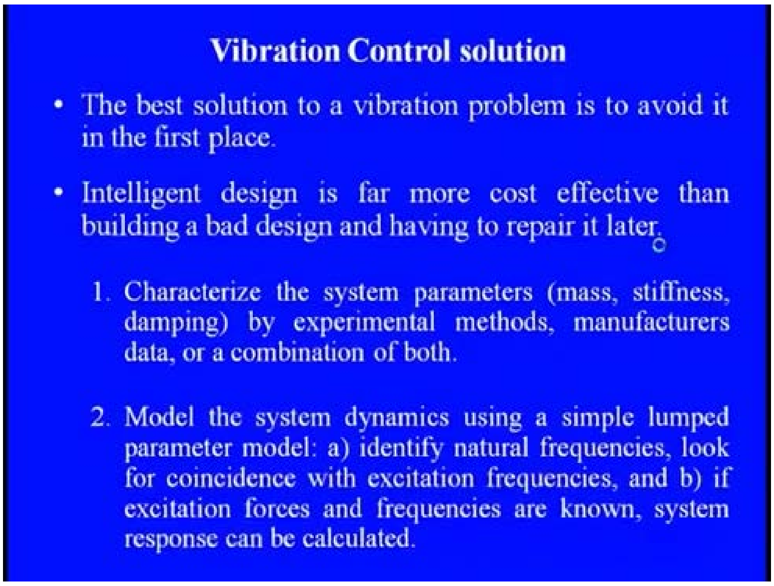

So, the best solution of this is to strike on the first place, and the intelligent design is far more cost effective than the building a bad design and having to repair it later. So, you see you know like we cannot continue the entire thing, so that you see you know like any way whatever the vibrations are being transmitted. We can keep as it is and whatever the damage will occur to the building, we can repair it later, it is a damaging feature as well as it is an a costly we can say affair for the system.

So, you can see there are processes, in which we can adopt a straightway the vibration control solution, first just to characterize the system parameter. As, we know that there are three basic things, which are being there under any dynamic action, and these forces are always being dominated and we need to characterize this. So, we need to characterize the system parameters based on the mass, the stiffness at the contact regions the according to the deformation, and the damping of any nature intermolecular the structural or any kind of fluid interactions.

So, we can do that part by experimental methods, by manufacturing data when you see manufacturing things are being there they are providing that or combination of. Generally, this combination of the experimental methods, and the manufacturer's data are the effective way to characterize the system parameter. Second model the system dynamics that, what kind of the dynamic forces or the energy transactions are being occurred when the such motions are being happening.

And this is sometimes, you see we are using a simple lambda mass or even sometimes you using a continued structure according to the system itself. And identify the natural frequencies, first, second, third or higher harmonics part, we can see that what kind of you see the coincidences are there in the with the exciting frequency. And if the exciting forces which are being generated, and the frequencies are known, the system responses can be easily calculated. And then once you calculate these system responses, you can characterize that how or what kind of first how to design and what kind of isolators are being placed there itself.

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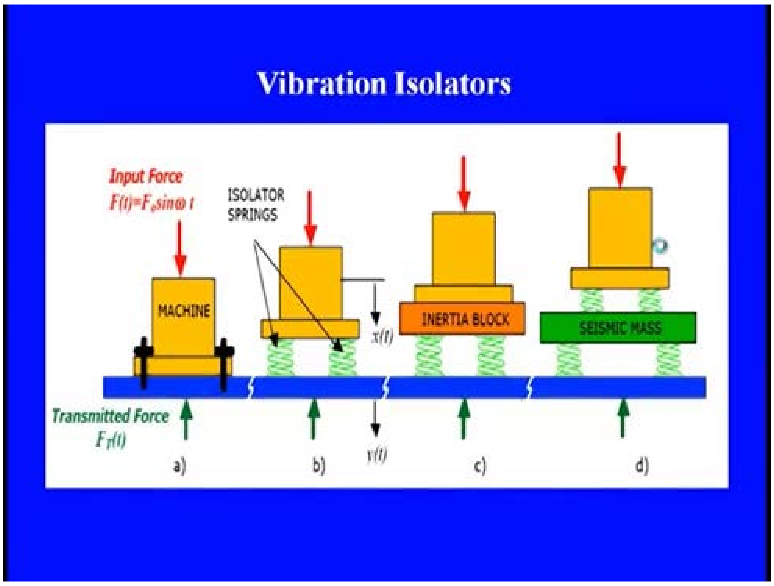

So, this is one thing you see the solution approach in that, as you can see on our screen see the screen, and then find that you see we have first part, in which the input forces the machine is being you know like lying on this surface. The input forces are coming, the nature of the input forces sometimes we are taking, which is pretty common is the simple harmonic motion or the you know like the harmonic excitation f 0 sign omega t. The transmission force which is being there, at the contact surface the reactive forces are also of the nature of the dynamic f of t.

So, when we have these things we know that the transmission of the vibration is, so rapid because there is a direct connection, the foundation bolts are there of these machines with that. Second, we can even put, these springs in between the mass or the machine we can say and the foundation, and the you can see the forces, in third part we can adopt the inertia block in between the machine and the spring and this one.

So, there are you see now the two devices, which are being acted just to absorb or just to you see control the vibrations in between the machine and the foundation. And finally, you see here even we can adopt the seismic masses, in between the machine and the foundation in this particular arrangement, in which you see here the seismic masses is are also in between the two springs.

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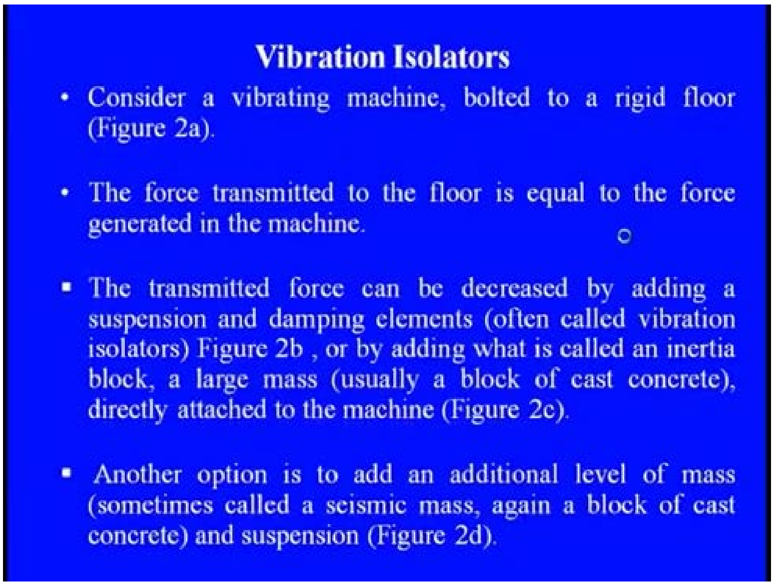

So, you see here these are the four you know like a, b, c, d you know like the types are there, and just you see here in that if we are saying that, the first thing is there in which you see here there is no isolator is being provided the rigid foundation. And the machine has coupled with the bolted, to the forced transmission to the force is equal to the force generated in the machine, so now, we would like to decrease this transmission.

So, the transmitted force can be straightway decreased by adding any suspension, and the damping element. Again, you see here it all depends on what is your natural frequencies are being coming out, and what is the exciting frequencies are accordingly, we can adopt the spring and the this damper as well. So, the figure two the figure p b which I was showing is was something you see here that the spring or the damper was added, and then we can say that you see here, when this is being happening, the frequency or we can say energy can be straightway controlled.

And we can say that you see here, whatever the energies are being the exciting energies are there it can be straightway absorbed by these devices. The another option in that was we can put the inertia block of large mass, maybe we can say the concrete or any kind of that you see here directly to the machine. Because, sometimes if you see the exciting frequencies are quite high as compared to the natural frequency, the spring and damper cannot be effectively adopted there itself.

We need to apply the mass to suppress these vibrations, or else you see here the another option in this case is to add the seismic masses, or we can say that an additional level of mass. Again, you see here of the same nature and then the suspension towards that, so you see here both the low frequency in a higher harmonics, the high frequencies can be immediately controlled by this kind of arrangement.

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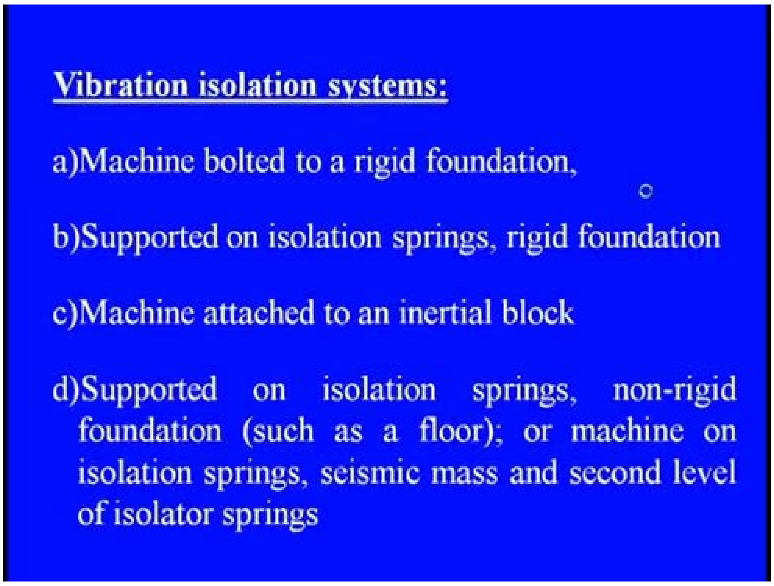

So, you see here these are the 4 ways, the 3 ways, through which we can control the vibration and it all depends on again, it all depends on what is the exciting frequency the forcing frequency and what is the natural frequency of the system. And accordingly we can adopt that part, but these are the ways through which we can do that, so the system which we are saying the vibration isolation system.

It consist the machine bolted to a rigid foundation as we see supported on you see here the isolated spring to the rigid foundation b, c was machine attached to inertia block. And you see there were you know like isolated by the spring, and we can say sometimes whatever the seismic masses are there in between. So, in that in the forth diagram which we were discussing, it has you see the secondary suspension the second level suspension part was there. So, you see here these are some of the effective ways of doing this in the vibration isolation solution.

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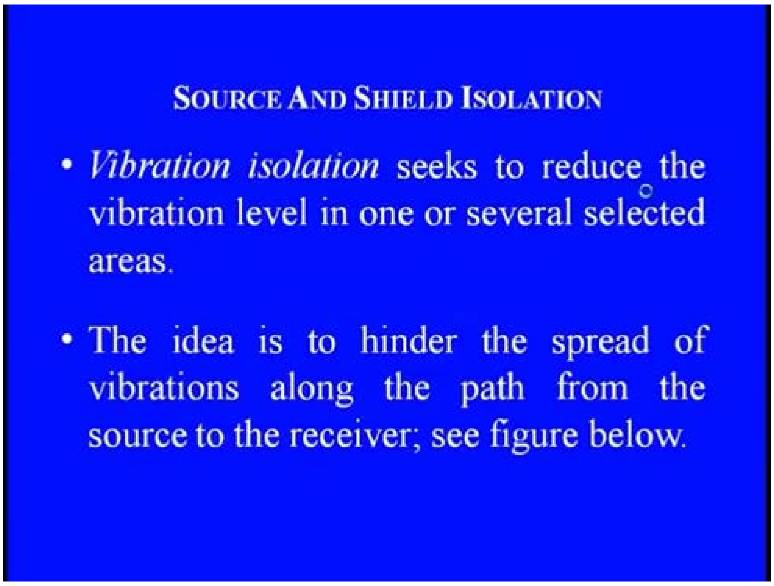

Now, you see this is one of the more we can say significant criteria, which we can adopt by adopting the source and the shield isolation, as we know the vibration isolation seeks to reduce the vibration level in one or the several selected areas. So, the main idea here is in doing this one is to hinder the spread of the vibration, along the path from the source to the receiver.

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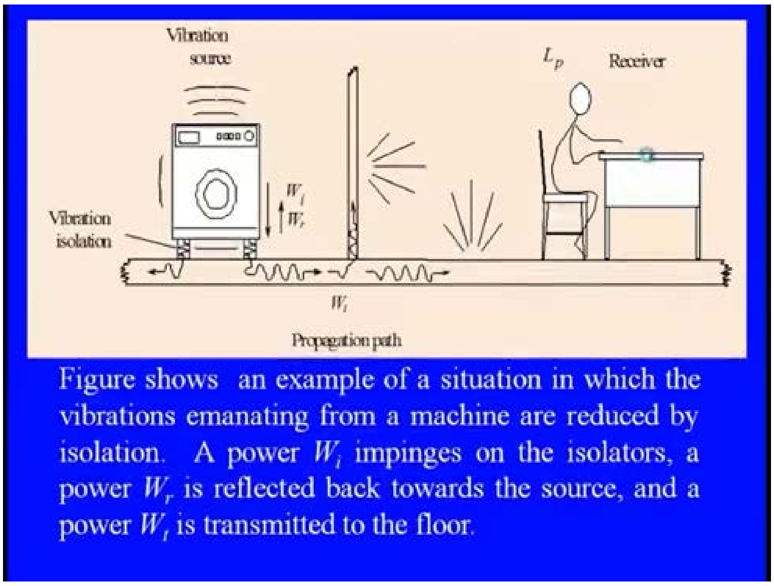

Figure shows an example of a situation in which the vibrations emanating from a machine are reduced by isolation. A power W_i impinges on the isolators, a power W_r is reflected back towards the source, and a power W_t is transmitted to the floor.

As, we can see you see here in this diagram, the source is something which is you know like the rotating machine, and it is creating huge vibration along with the noise. We can see that the vibration isolators are being straightway provided in between the vibration source, that is machine to foundation. And say that you see here you know like the controller or anyone who are any person is working near to these places, they have a clear exposure of these things and we want to reduce that.

So, either we will provide the vibration isolator and also you see here we are providing some kind of you see, the obstruction maybe of any structural feature or anything just to absorb the vibration. And the same time whatever the sound which is transmitting through these machines, and you see here when it is when these sound energies or the vibration. When, they are approaching to that it is already being absorbed by the spring or the damper or these you see the structural devices which are being abstracting, the path of these sound wave propagation.

So, if we are saying that say the power w i, which is being you see the impinges on the isolator of power w i is reflected, you can see on the diagram, the w r is reflected back towards the source and the w i is nothing but the transmitted to floor. And you see here there is a clear reflection of these it is going back, towards you see the machine and it is also going towards other direction of that, and it is being even obstructed when the obstruction is there they are also transmitting to that. So, you know like these are some of the ways, when we are designing these components we can adopt that part, so you see here we are also taking another example, in which you can see that you know like the in this particular part

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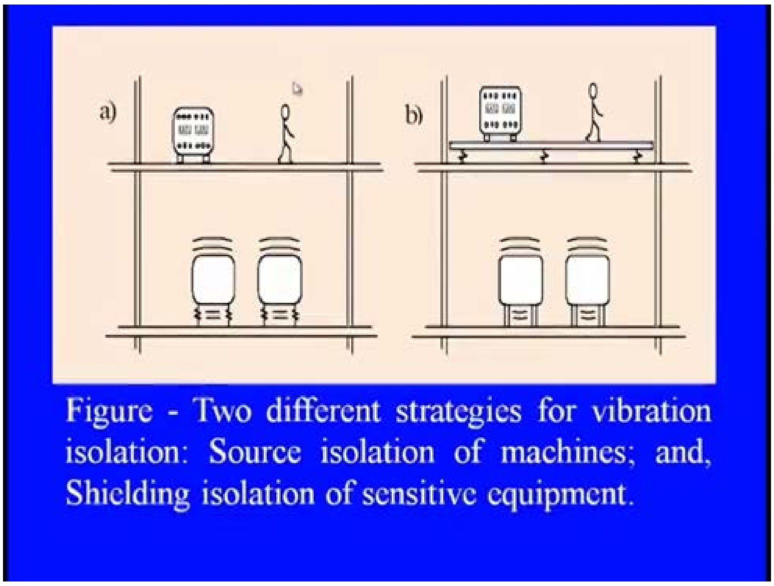

The a part, and b part; these two different strategies are showing for vibration isolation, first the source isolation of the machine, and second the shielding about the sensitive equipment.

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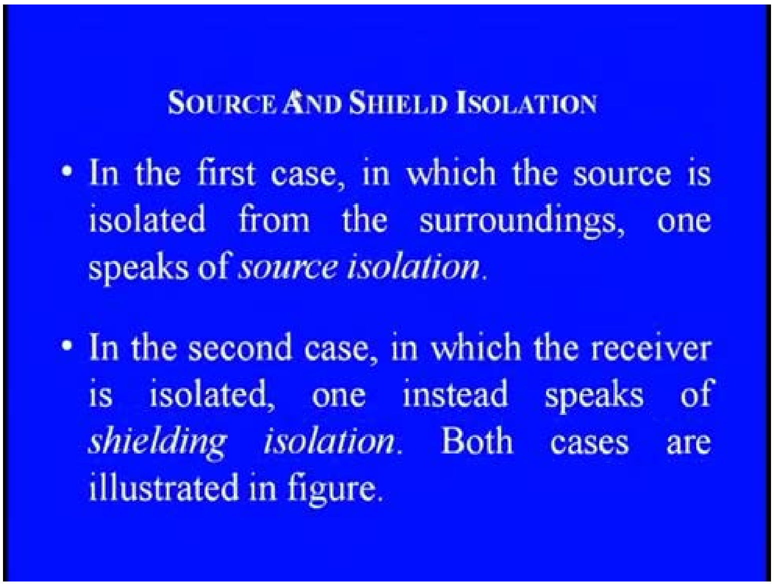

So, in the first case, in which the source is isolated from the surrounding, we can say that this is source isolation, because we are providing elastic mountings in between the source to the structure. Second we can say that since the receiver is there, at some end we need to isolate the receiver as well, so when we are doing these thing instead of you know like this part, we are saying that this is the shielding isolation. And both cases are equally important according to the type of application, and according to the type of arrangement of the system.

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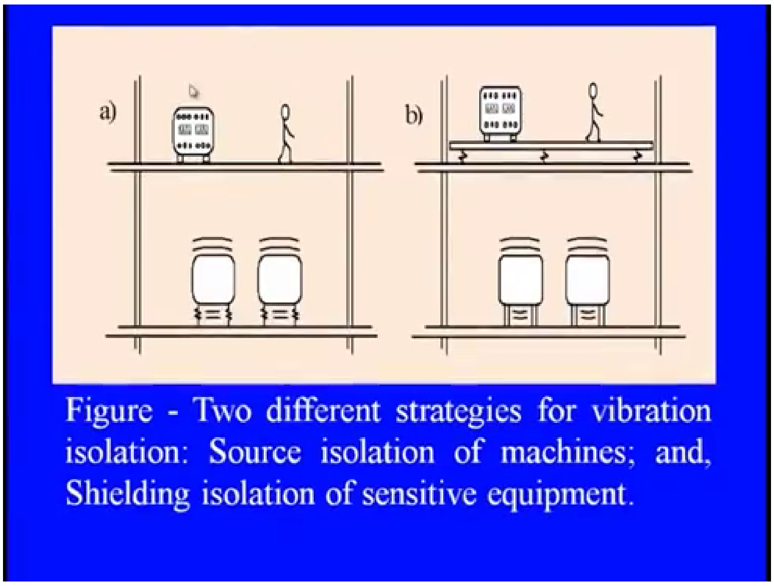

Figure - Two different strategies for vibration isolation: Source isolation of machines; and, Shielding isolation of sensitive equipment.

So, in this case we can see that in the first part since, the receiver is pretty close to the source we need to isolate these things, so you see the source isolation was there, because you see it is straightway transmitting. And then you can see that on bottom of that the entire source which is generated, the vibration you see you know like through these part it is being straightway isolators are there. In other part you see the receiver is being straightway affected by this, so the source can do something even we can put some kind of light isolator, but the receiver part you can see that springs are there in b case.

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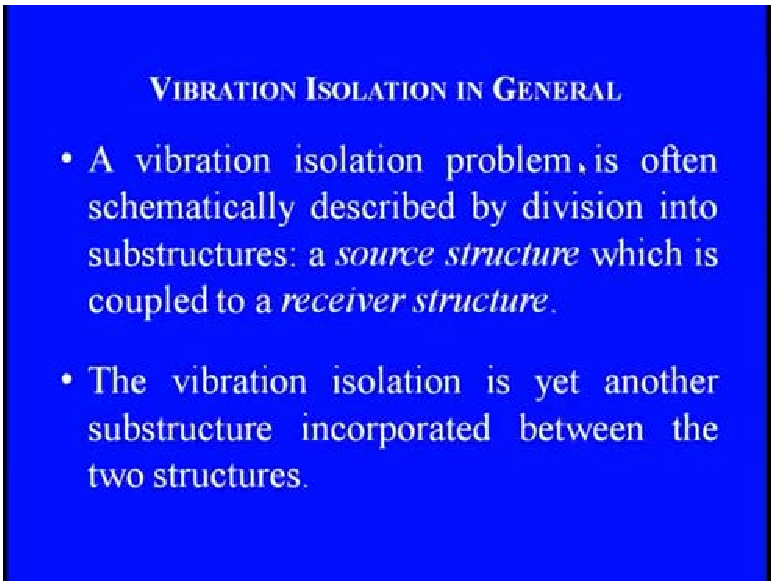

So, either the source isolation or the shielding isolation can be done in that way, a vibration isolation problem in general is often you know like we can say describe by putting 2 things. The source structure, which is coupled to the receiver structure, so we can say that you see you know like, we can incorporate the isolators in any of these the source and the receiver feature.

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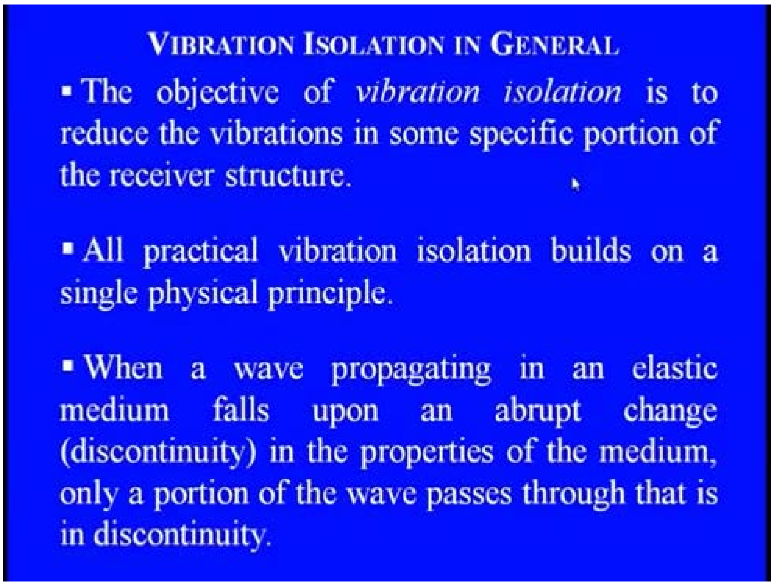

And the objective of this vibration isolation is to reduce this at specific portion of either of the source or the receiver structure, and all the vibration isolation practical problems are just you know like buildup with the combination of these two physical principles. So, when in a wave is generated, the elastic media is always being coming in between to abrupt change in the path of that. And through that you see here we can straightway deviate the path of this propagation, and also the same time we can absorb the energy which is being there in that propagation feature, so that the exciting features can be decreased directly.

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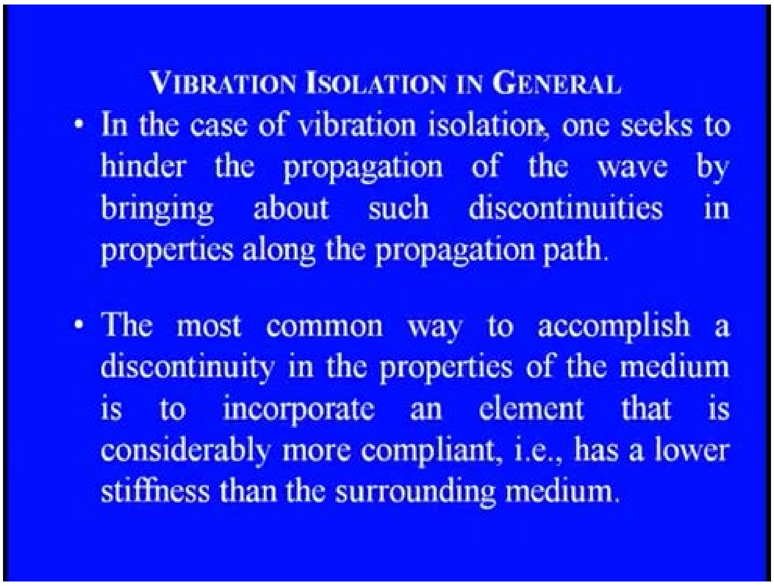

And in case of vibration isolation, one can straightway seeks to hinder the propagation of that, as we discussed just by you see providing some discontinuities in the propagation. Just like we discussed that if we are simply putting some kind of you see the wall or some kind of you see the devices through which the discontinuities can be happen in that. And the most common way to accomplish these discontinuities in the properties of the medium is to incorporate an element, as we discussed. That should be more you know like compatible to the system itself, either by providing the stiffness or by providing the damping towards the surrounding feature or even sometimes the masses as well.

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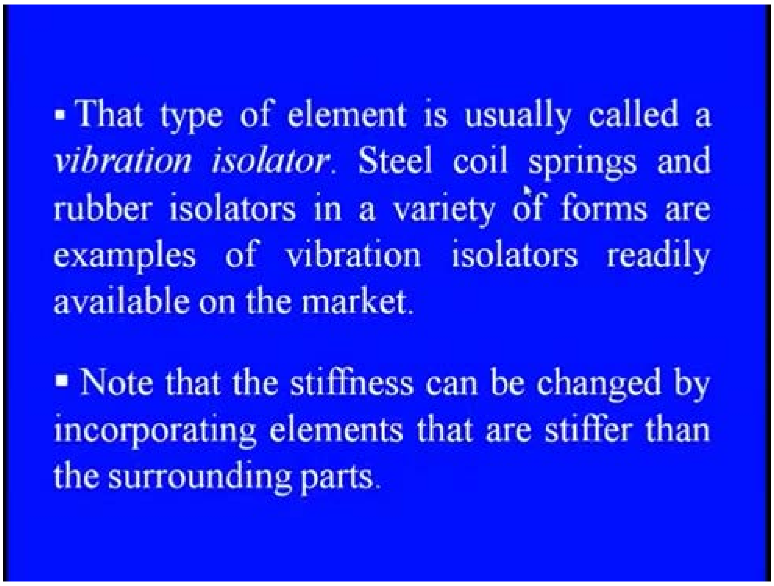

So, the type of element which usually you know like putting there is called the vibration isolator, so as we discussed already it can be of coil this steel coil in terms of the spring sometimes, they are the rubber isolators. So, spring coil is you know like providing by through the stiffness variation, the rubber isolators providing you know like services through there damping feature, or else sometimes you see here the masses.

They are straightway providing that you see here you know like through their weight, in the suppression of the isolation amplitude. The stiffness can be changed even by putting you see here the different kind of you see the material properties of that, even in the in the rubber isolator and anything you see here.

And practical realization of the concept of blocking masses, just like the seismic blocks or added mass are also one of the significant for higher harmonics mode as we discussed. So, for long time machinery designers have mainly provided the vibration isolators using the trial and error method and then you see sometimes it is not, so significant to check it out those things, because in most of the common we can say construction material. They are even more stiff, and even with the steel and the concrete they are you know like providing a good surface for rapid transmission of these vibrations or the sound.

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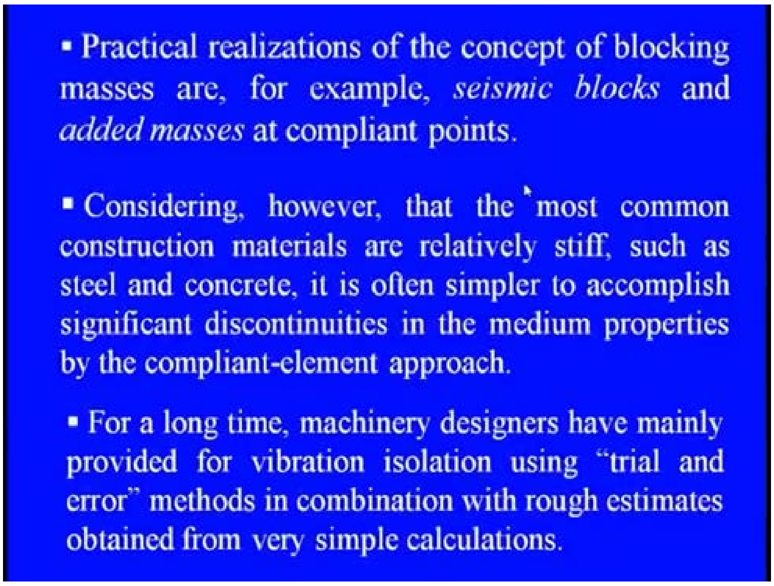

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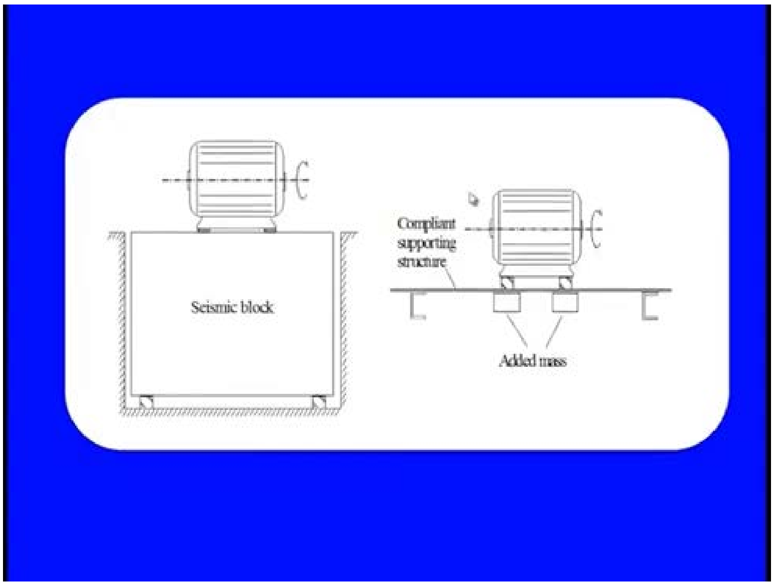

So, we need to check it out that exactly how we can design these things, so as you can see on your these you know like on the screen, that these are the two arrangements of the machine, that how we can absorb the vibration towards that. And when we see these things, we know that when these you know like the vibration, which are being generated by this machine, we have the seismic blocks there. And instead of having this seismic block, which is also providing some kind of solid surface to in transmission of that even in bottom of that you see here, we can even rather provide some kind of a spring. Else we can go to the compatibility of this structure, because you see here the seismic block is a huge one as compare to the machine, so sometimes it is not feasible.

So, we can added the mass such a way that, wherever you see the contact points are there through which the transmission is happening, we can straightway apply the attached mass and we can suppress the vibration. So, again you see here this is hit and trail part, that you see when you know that we need to add the mass we can adopt that.

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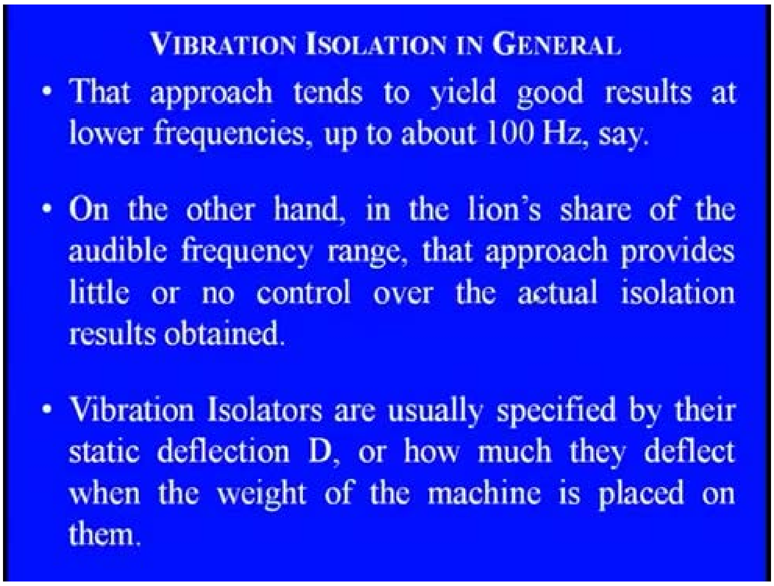

And this approach tends to yield good result in the frequency, you know like lowering up to 100 hertz or even more than that, but sometimes, you see here the audible frequencies of the lions or even anything you see here, which requires a active solutions there itself. So, we need to calculate it is not you see here, just you know like trial and error that we can adopt some kind of thing and we can get some effective solution. So, vibration isolators are usually specified by their static deflections, that how much static deflections are there, when the weight of machine or anything is being put on that.

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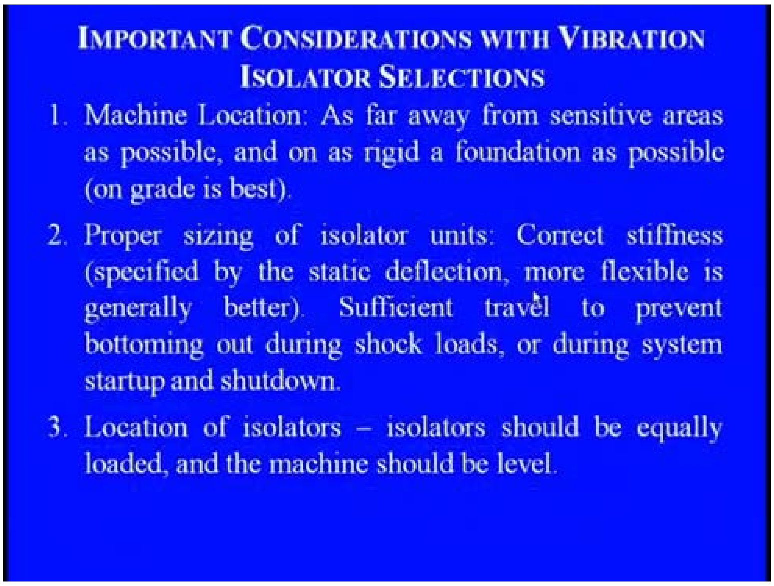

So, now, you see here there are few important considerations with the vibration isolators selections, the first which is very important the machine location. These are the real we can say proper steps, which one has to follow to control in effective way about the vibration and how to select the vibration isolators. So, first is machine location as far as from the sensitivity area as possible, and as on you see just the rigidity about the foundation we need to check, it out that it should be far away from that.

First, the sensitive area where the sophisticated operations are being occurred or else even you see the areas, where you see like the hospital, the schools or any the animal we can say features are being there, we need to remove those things. And that is why you see the locations, near to the railway tracks are always creating, so much damage to human health. Because, they are everyday they are transmitting or they are absorbing this transmission vibration, which are coming out due to the train passing feature.

So, this is you see the source location, second proper sizing of the isolator units, it is not that you see here we can apply any kind of you see the huge mass or any kind of the damping. We even you see it is under dammed or over dammed or even you see any kind of a spring, and this spring instead of absorbing it is creating more kind of fluctuations. So, proper sizing of isolator is one of the important criteria, so correct stiffness according to their flexibility, and the damper.

And then you see the corrective masses are to be adopted in such a way that, whatever the impact loadings are coming or the continuous loadings are coming to the structure. And through and due to that you see the vibration isolations are there they can be immediately turned off. Third important thing is the location of the isolator, so isolator should be equally loaded, and the machine with the machine and you see here the level should be absolutely same of the isolator, and the machine.

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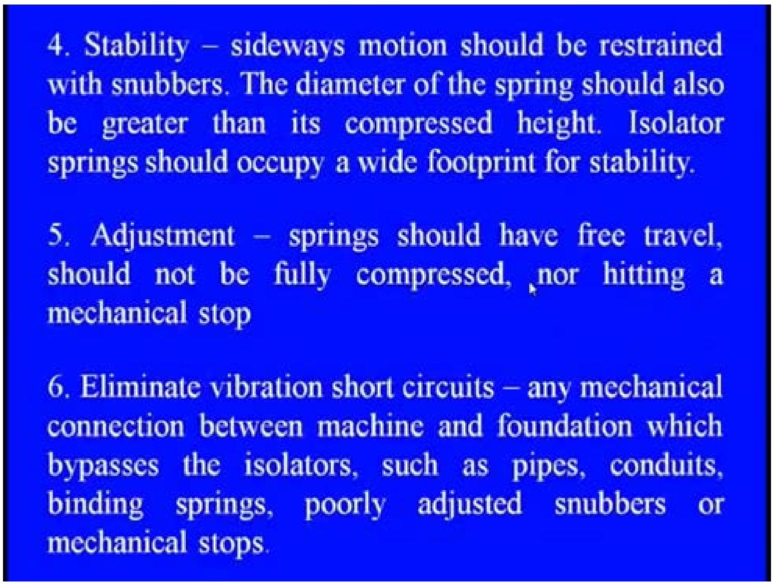

The forth is the stability, and we know that you see here the stability is real cause for that, because sometimes if you see we are providing inappropriate spring with the isolator. Certainly, the unstable features are there in the machine, because it is in between the solid foundation and the machine. And machines are absolutely lying on this spring when they are generating oscillation, and you see the springs are not leveled properly certainly the stability will come towards the machine base.

Second, the isolators with the damping feature, if we have all damping situation and there is a concept you see here, from the vibration, which I think the basic vibration says that. If the damping is adopting in such a way that, if it is applying as a negative damping, instead of absorbing the energy it will supply the energy to the system, and which makes the system unstable.

And even if we are adopting the masses, and the centre of mass is not particular focused with the central line of the machine, then certainly it will topple the entire machine, because of the movement and the couple acted by this mass under the exciting feature. System lid is also one of the important criteria, while designing or adopting the isolator adjustment, the spring should be you know like should have a free level, and should not be fully compressed or we can say hitting to the mechanical features or the stop.

It is not that all the time you see here it is hitting, and because of this hitting the impact forces are being generated there, the sixth one is eliminate vibration short circuits. Any mechanical connection between the machine and the foundation, which bypasses the isolator such as the pipes conduits buildings springs poorly adjusted snubbers or mechanical stops. And if any short circuits are there in between that any mechanical device, they are creating instead of absorbing the vibration, they are creating vibration and transmit transmitted towards these devices.

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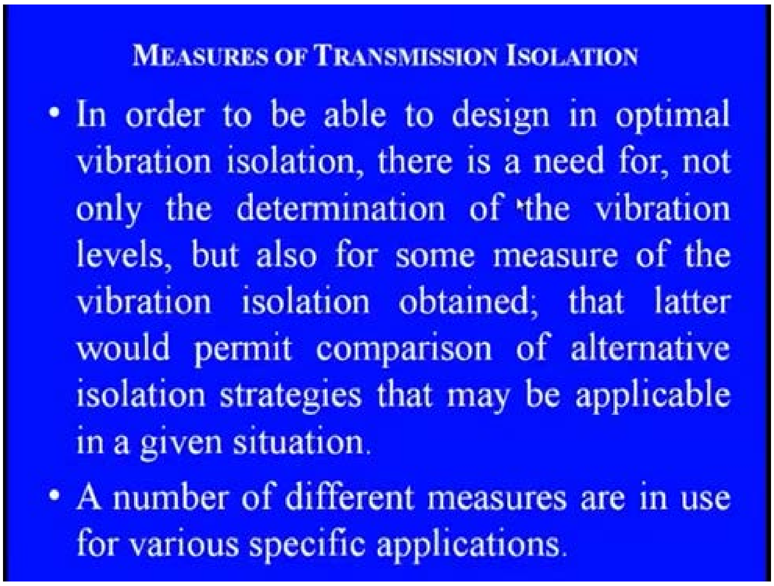

So, in order to be able to design in optimal optimum vibration isolator, there is a need for not only the determination of the vibration levels, that what exactly the exciting frequencies means the natural frequency. And what is the amplitude of the vibrations, but also for some measures you see here, of the vibration isolation obtained, it would be you know like easy to find out that what exactly. The frequencies are there and according to say low frequency, natural frequency, means the resonant condition or the higher level frequency, we can adopt the isolation strategies accordingly.

And in the corresponding way we can rather choose, that what type of you see the spring materials are there, so that we can provide the spring stiffness correspondingly. We can provide the critical damping by adopting a proper damping feature, or even we can apply by adopting you see any kind of masses. That they should not be any kind of you see unbalance features are there, by adding the masses, because when we add the mass there is a issue with the eccentricity.

And when the eccentricities are being created, because we are adding the mass we know that either the centre of gravity or centre of mass of the entire structure may be shifted. And when this is there is a eccentricity and because of this eccentricity, the unbalanced features are being there, so the number of different measures are there for a various kind of a specific applications and we can find.

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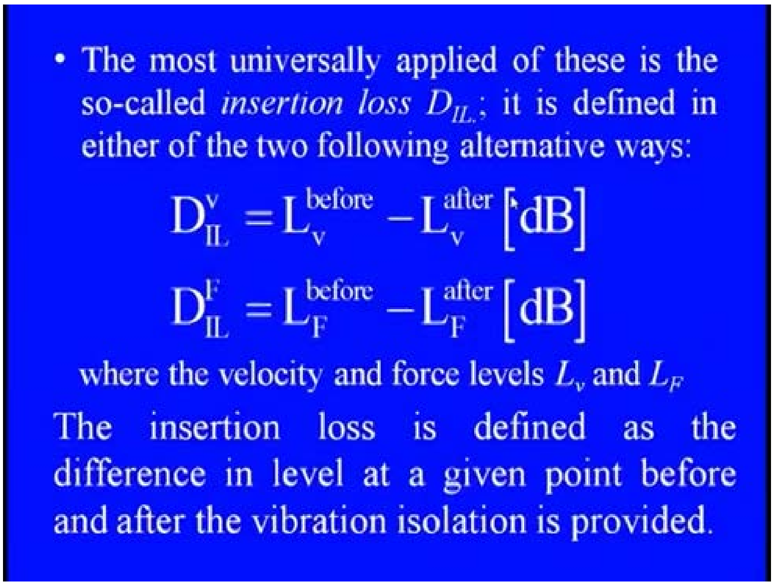

So, first a most universally applied to of these is, so called the insertion loss, they are two things in the insertion loss with the velocity, and with the force. When, you see the level of velocity is significant we can say the insertion loss with the velocity is l v before, l is nothing but the level of velocity, before and after. So, the difference is giving us the insertion loss, due to velocity and insertion loss due to the force.

So, we can define this loss, which is called the insertion loss as the difference in the level at the given point, before and after adopting the vibration isolation. Once we apply that we can see that how much means what the net change is there, in the velocity say before we have something and after we have something; that means, you see here some velocity is being absorbed by these vibration isolators. In other terms we can say the force that how much force is being absorbed by these isolators, if we have a significant insertion loss; that means, the isolator is poorly designed, in terms of velocity or in terms of the force.

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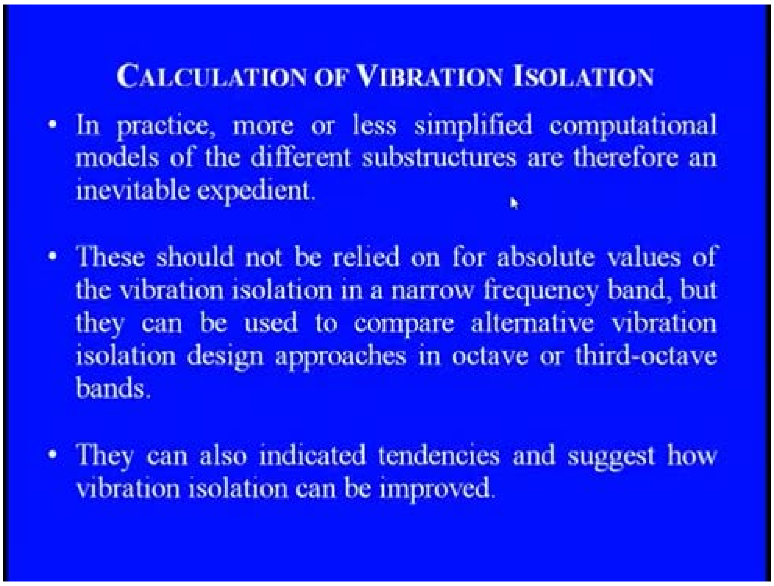

So, we need to have an effective calculation methods for this, so in practice more or less, the simplified computational models, which are being available and we can straightway see based on whatever the vibration calculations are there. But, we are not going with absolute value of these vibration isolation, in such we can say the narrow frequency band, but rather we can be used to compare the alternative vibration isolation design approaches in octave or third octave bands as well, because how much sound is also propagating or being absorbed, this is also one of the effective criteria in that. So, we can say that there are you see the tendencies, and the suggestion that how the vibration isolation can be improved in that way, so we can say that if we are using the basic vibration theory.

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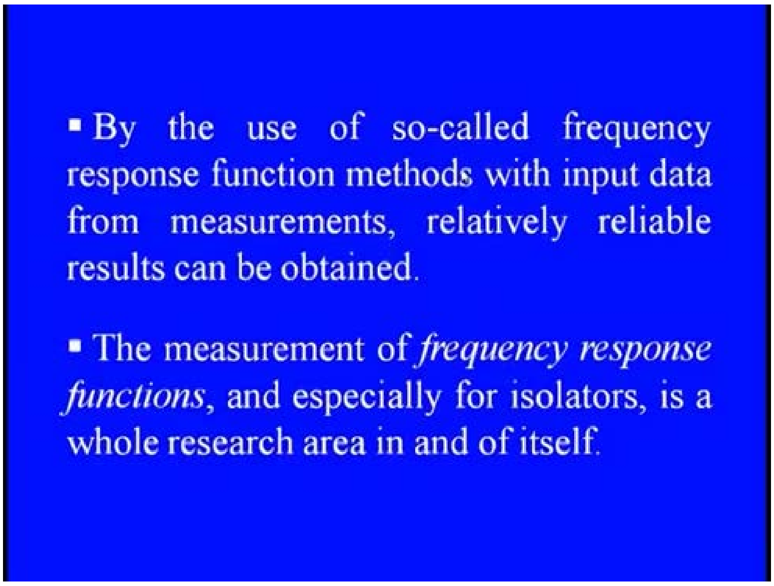

We need to use that what is the frequency response functions are means, what is the exciting level corresponding to the frequency itself. And from these measures, because this is we know that, whatever the vibrations are coming they have some kind of stationary feature. So, these stationary signals can be straightway characterized using this frequency response functions, and when we are adopting these things, we know that it is pretty easy to characterize those things and accordingly we can adopt the isolation properly. And the measurement of the frequency response function, and especially for the isolator is the main research feature, and that is why you see here many of the isolators or even the devices are characterized with this f r f frequency response function.

So, to simplify the problem, first we need to idealize the coupling as occurring via we can say the small you know like the contacts, we have the various contacts like you see the point contact the line contact the surface contact. And correspondingly the deformations are there and accordingly, you see here we have the exciting levels. So, first of all we need to idealize the contact surfaces or the coupling, and that is what we are doing you see here even, when we are talking about the ball bearing roller bearing, or you see we are saying the general bearing.

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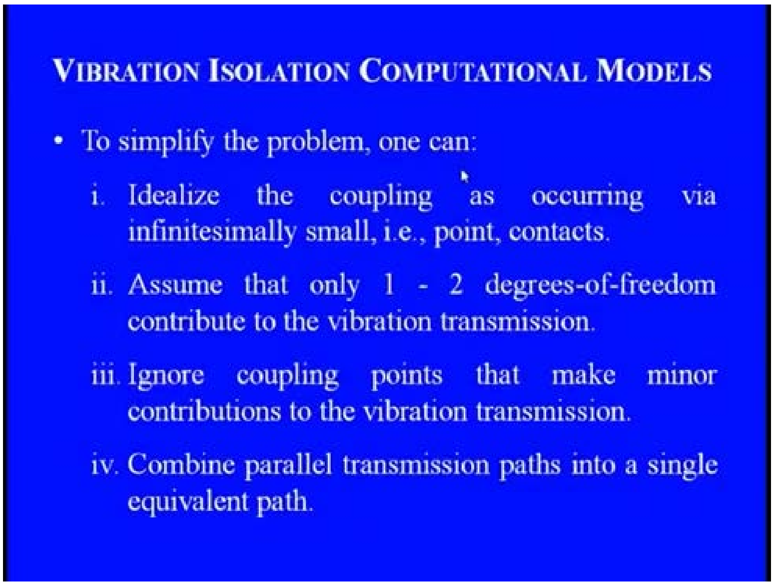

Else if we are talking about any kind of you see the tooth profile of the gears, the cycloidal the involute or any kind of we can simply put that what kind of the contact reasons are there. And accordingly we can apply the Hertzian theory itself, for the elastic deformation or the plastic deformation. And the another important thing is coming we need to assume, that what is the degrees of freedom in that, because that is how you see the vibration transmissions are being occurred, and effectively we can adopt the isolator.

Sometimes, we need to ignore the coupling points that make minor contributions in the vibration transmission, or else even sometimes we need to cut down or we need to put the constraints, rather cut down the degrees of freedom or putting constraint. So, that we can have some effectiveness in our solution, we can rather combine the parallel transmission path into some equivalent single path, based on the spring. We can the series spring connection, the parallel spring connection, the series damper or the parallel connection and these theories.

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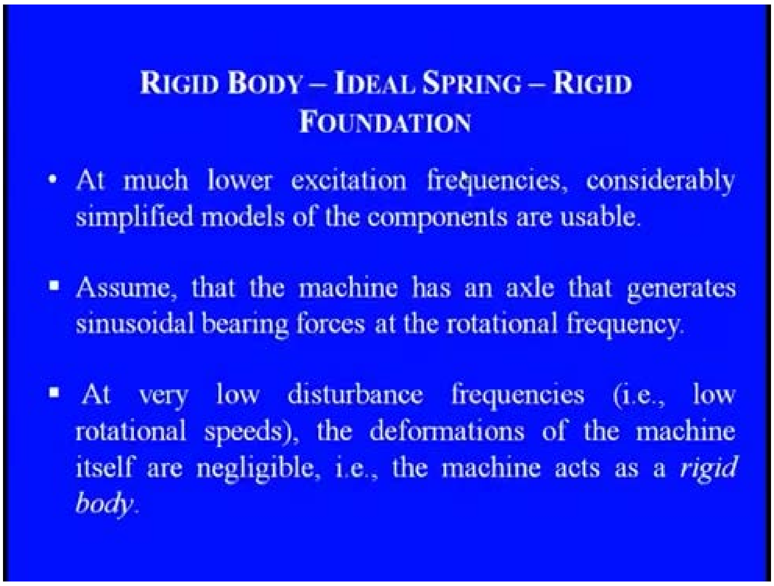

So, when we are talking about you see the last point in this is the rigid body, ideal spring rigid foundation, how we can do this means the body is sometimes, you know like the flexible body. Through, which you see the vibration transmissions are being there or the source is there the ideal spring, which we are assuming that its perfect with these two the rigid foundation the rigid body.

So, as much as you see, the lower exciting frequencies are there the models are pretty simple, and we can straightway find these things in terms of the frequency or the exciting level. And we can assume that the machine has sometimes, even we can say the axle that generate the sinusoidal bearing forces, through the rotational frequency, which is a very common feature for any rotating device. And it very low frequencies with the these disturbing frequencies, we can say or the low rotational speeds the deformation of the machine itself is almost negligible. We can say that these are somewhat the rigid body, because in that you see the deformation is quite less, and due to that the excitation frequencies are somewhat, very less as compare to the other features.

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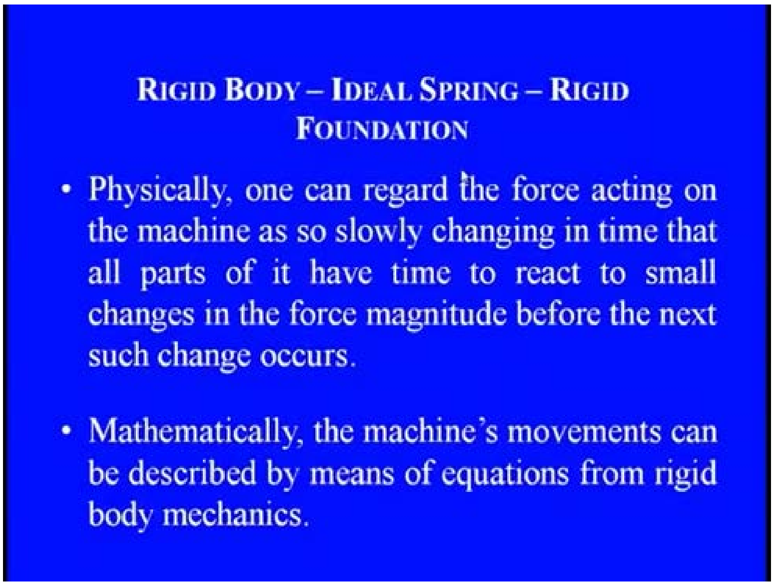

Physically, we can you know like say that the force acting on the machine as, so slowly changing in the time because the dynamic nature, all parts of it has just trying to react against these changes. And then you see whatever the changes are being occurred at the contact points, at the source or the transmission can be evaluated and can be you see you know like we can say isolated in proper time. But, if we are talking in terms of mathematics, we can say that the machine movement can be described by means of the equations of these rigid body movements.

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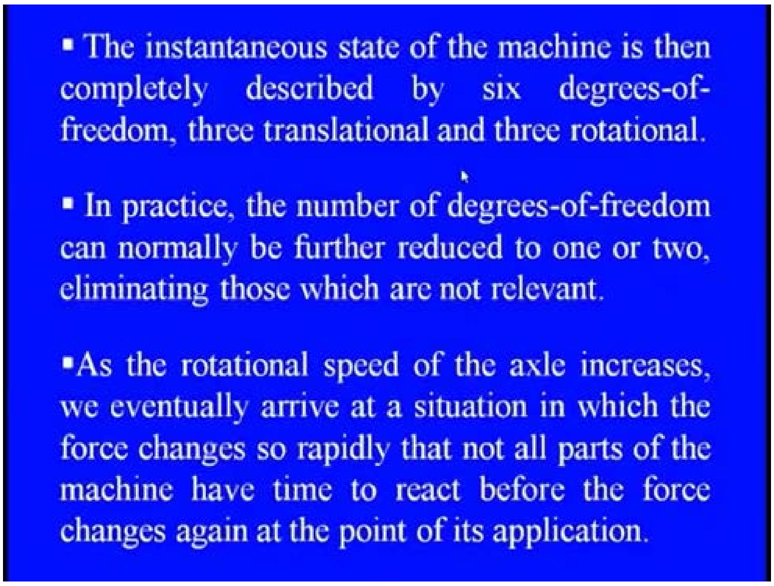

And the instantaneous state of the machine, can again you see be described using 6 degrees sometimes, because we are always assuming that we have Cartesian coordinates say three x y z. So, we have these Cartesian coordinates are just showing the translational motion, and when you see the machine is also rotating, because of the rotating elements are there we can describe using three rotational.

So, total 6 degrees are sufficient to describe the motion of the machine or the components within the machine. So, in practice you see the number of degrees of freedom can be normally you know like reduced 2 to 3 or 1 by eliminating, you see which are not relevant or which are not contributing significantly in that. So, as a rotational speed of the axle, we know that when the speed is increases, we are now approaching towards the changes of force rapidly. And when you see the time the machine, you see is does not have the time to react before the force changes, then we can see that there is a clear change in the exciting frequencies within with these components.

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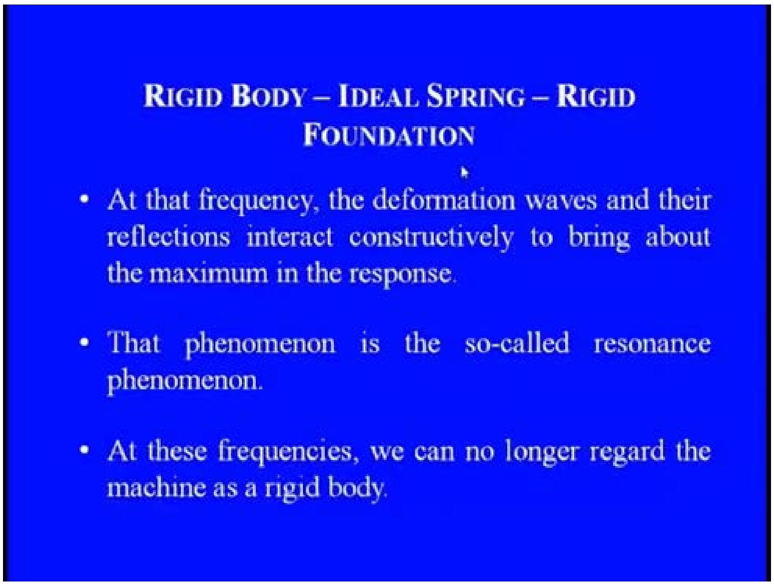

And at these frequencies the deformation waves and their reflections interact constructively means you know like in a continuous way, to bring about the maximum in the vibration responses. And when they are approaching up to the real, we can say nature of the systems itself means the inherent character of the machine, at which you see the natural frequencies are coming. There is a huge amount of we can say the amplitude of the vibrations are there or the huge amount of energies are there at that point, so the sound is quite significant. We can say this is the resonant frequency as we are saying, so we can say that at these points, where the system is exciting in such a high level, with the amplitude and the energy the machine is not treated as the rigid body it is a flexible body here.

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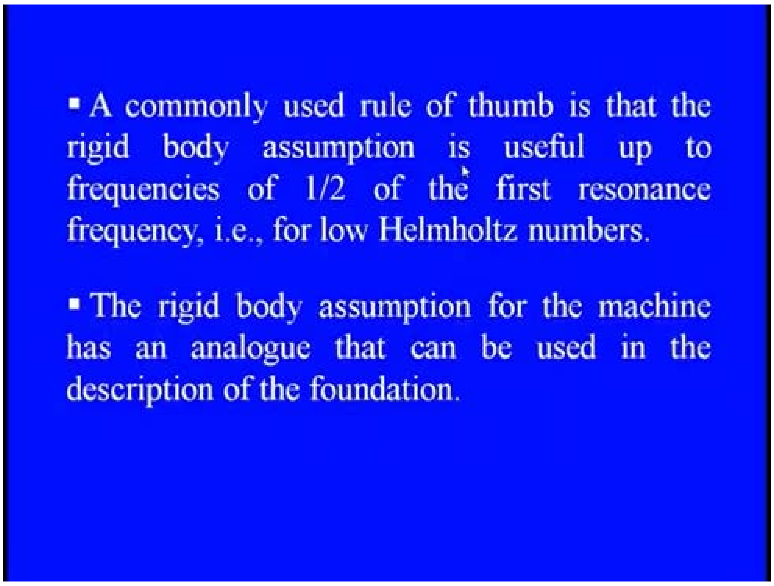

So, commonly use the thumb rule in that that rigid body assumption is always be useful only up to half of the first resonance frequencies, or that is we can say that the low Helmholtz's numbers. So, this is a very thumb rule that you see here, when the system is exciting just below half of the natural frequency, the body can be termed as the rigid body this is the great assumption, when we are designing the isolator. And the rigid body assumption for machine has a clear analogue that can be used in description of the any foundation, when we are just using that.

And when we are just going in another way that say you see, you know like we have rigid body rigid foundation and the spring in between that. So, if we have a machine which is you know like exciting at a very low frequencies, the joist the beam rather I should say, the joists respond with we can say a quasi static bending feature. Due to slowly varying force, because it is a low exciting frequency acting on the machine part.

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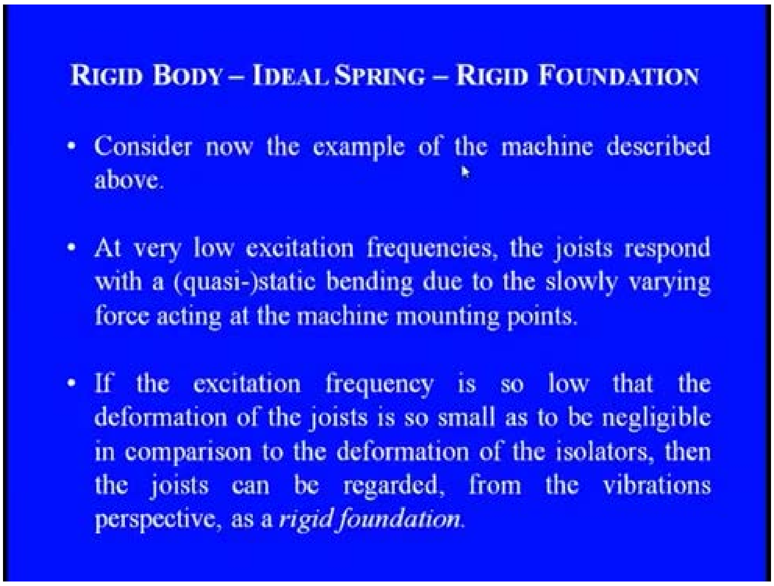

And if this exciting frequency this is a very good example by the way, in which we can clearly see the physics of the transmission, and the exciting frequencies all along with that. So, if this exciting frequency, which is a very low you see here is always creating low deformation to the joist the beam feature you see here. So, we can even since the deformation is quite low, it can be you know like considered as the negligible in comparison to the defect deformation in the isolator. And then the vibration which are being you see you know like, coming out from these is very low as we know that we can treat this as the rigid foundation.

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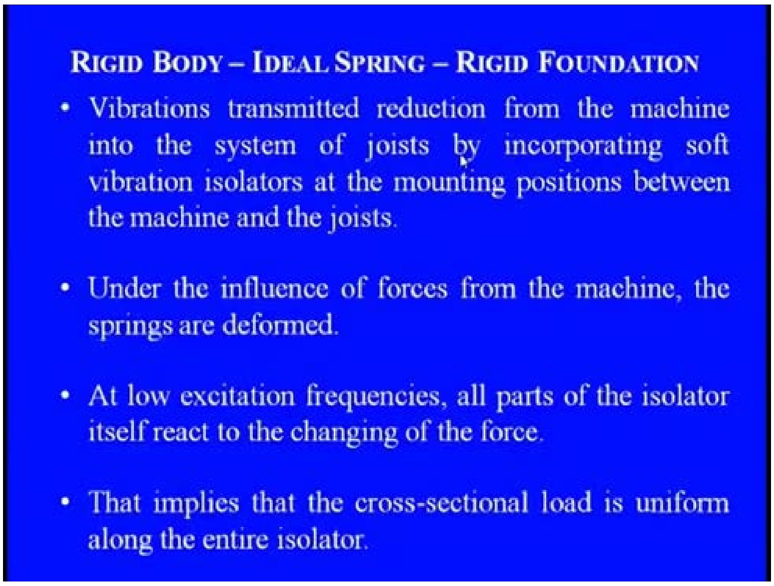

And the vibration transmitted reduction from the machine into the system of the joist by incorporating the soft vibration isolator is perfectly in that case. So, basically we would like to do this that if the low frequency vibrations are there, then even though soft vibration isolators are good enough. And we can mount these into you know like in between in machine between the machine and the joists to absorb these, and under the influence of these forces the machine, and the spring can easily being deformed and we can absorb that.

So, at low exciting frequency all the parts of the isolator itself, react to changing of the force, and this implies that you see here, the cross sectional load is absolutely uniform to the entire isolator, the isolator is absolute and we can even you know like fruitfully designed with the soft vibration isolator. So, this is one of the good you know example, and if we know that in other case that the exciting is quite high, then we need to see that how the transmission is there we cannot treat the entire arrangement of the joist and the machine, as the rigid body.

When, there is you see the different kind of adoptions are there in the isolators, the soft vibration isolators cannot be treated a perfect isolator in that way. So, this lecture you see here which is the basic we can say, lecture on the vibration isolator design is simply providing you that the kind of information, that how we can choose the vibration isolator. What are the basic strategy in designing of that, how we can characterize the vibration isolators.

So, now you see this was you see the basic, we can say lecture in which the physical significance of the vibration isolator was discussed, and in the next lecture now we would like to compute this in terms of the mathematical way. That if we are adopting these isolators at their proper location or something like that, then how we can effectively reduce this or else you see how much insertion losses are there with the poor design of this vibration isolator.

Thank you.