Electronic Packaging and Manufacturing
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Lecture – 34
Shock and Vibration - 4

Dear student, welcome to the course on Electronic Packaging and Manufacturing. This is on Vibration control. In the last few lectures, you have learnt about the vibration, its usefulness for reliability testing and then vibration analysis. And in the vibration analysis we have learnt how to calculate the steady state response, the transient response, and also the response due to harmonic and random excitation. But, our main objective is to reduce the vibration and this is precisely what we are going to learn in today's lecture. So, here we start the vibration control.

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In this class you will have, you will develop the concepts of vibration and shock isolation vibration control by optimal design and vibration control by damping. These are very important topics in the sense that we have to reduce the level of vibration, but at the same time we will have to see that with reducing the vibration we should not disturb any other things which are also pertinent for design.

So, before going into the subject (Refer Time: 01:47) let us come to the general scenario used in vibration control.

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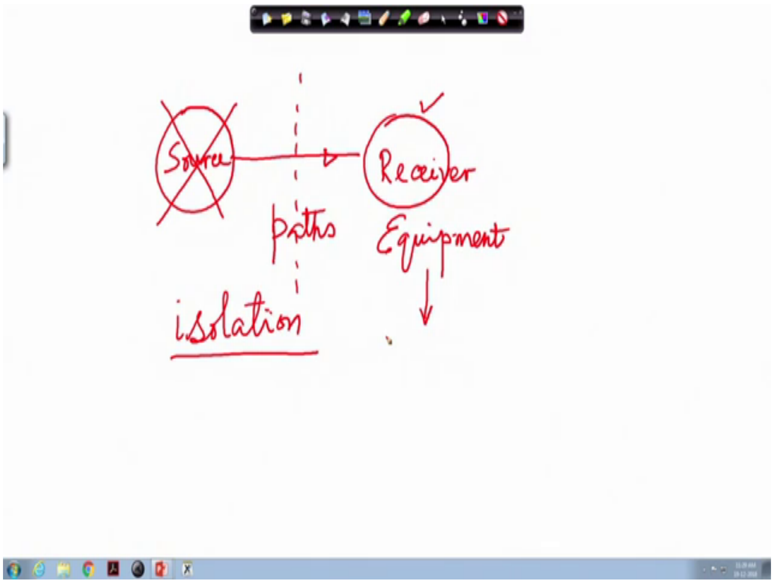

Here, vibration control actually so there will be a source of vibration and in our case the equipment is placed somewhere that may be in the harsh environment like the missile or certain aircraft instruments or maybe in submarine. So, there will be different sources from which the vibration may come into the equipment. And this is our receiver which is nothing, but the equipment and there are many paths need not be one, but many paths through which the vibration energy can reach from source to the receiver.

So, in the vibration control in generic, in general way we can reduce the level of vibration here. So, if we are not able to reduce the vibration for example, we may not have any control over the source of vibration during happening due to the turbulence when the aircraft is flying. So, we do not have any control over the source, but our objective is to reduce the vibration at this point. So, we can take two strategies one is that we can build a barrier which will not allow the vibrational energy to move from the source to the receiver. So, this strategy is known as the isolation.

So, this vibration isolation refers to control of the vibration during the pathway. And when this is in fact is exhausted we go to the receiver and develop certain strategies for which the at the receiver end vibration is reduced. So, we will first talk about the vibration isolation this generally happens for the entire equipment.

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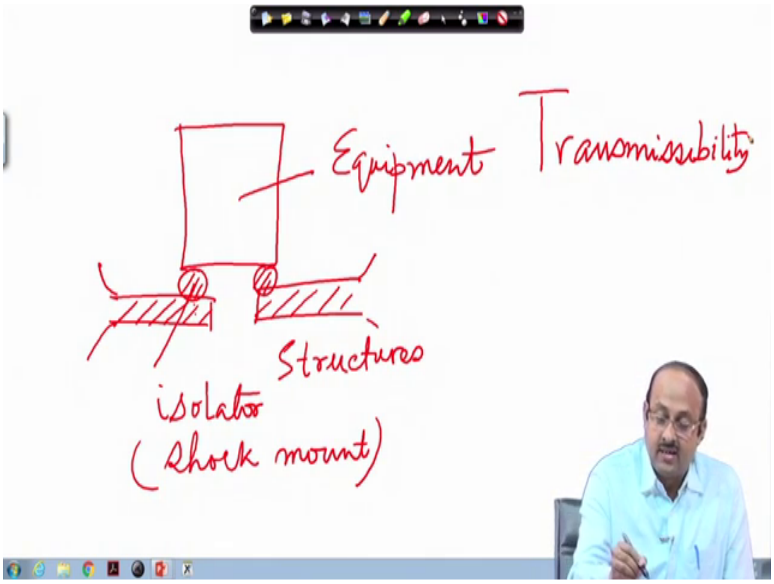

Supposing that, we have an equipment, electronic equipment which is of course to be supported on certain structures so let us call this as the supporting structures. Now, this is the source of vibration because this is connected to the aircraft so therefore, suppose that it is an airborne aircraft borne equipment. So the aircraft vibration is failed here in the structure and this is the equipment. So, in the pathway that is from here to here we develop certain strategy whereby the vibration is reduced and this is done with the help of what is known as the isolator or shock mount vibration and shock mount.

The basic principle of this vibration isolation is that the motion or the force which is which is acting on the structure should not be transmitted. So, the main criteria for the vibration control is actually through the transmissibility which we have learnt in last class. So, let us quickly recapitulate what is meant by the transmissibility.

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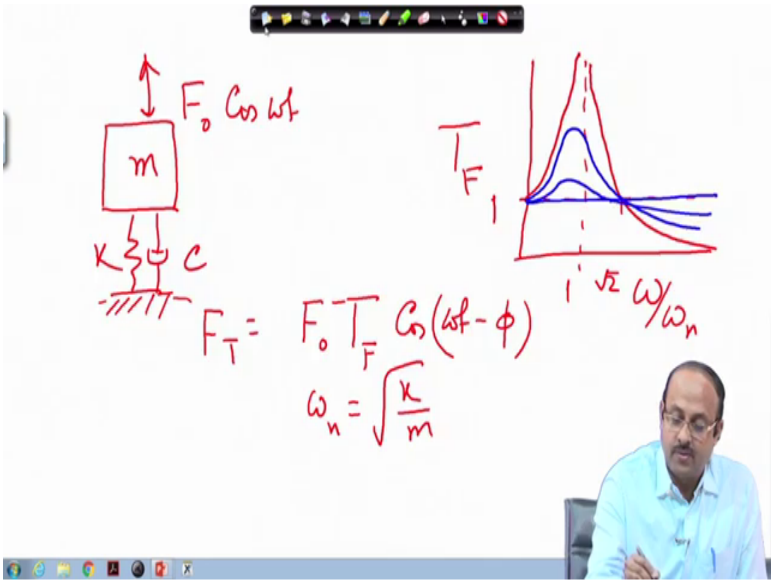

So, if you have a vibrating system which may have certain damper. So, m K C if this is actually excited by certain force F naught cosine omega t then there is force transmitted to the so this is our system and this is our structure and this is the system which should not be excited by that much of force.

So, the force which is transmitted F T this will be equal to certain force F naught times the factor which is I will call T F the Transmissibility Factor and this cosine omega T minus phi there may be a certain phase difference. Now how does this T F look like? This T F we have seen that the T F will be the force Transmissibility will be for an undamped system it starts from one and this is root 2 this is omega equal to omega by omega n where omega n is the natural frequency.

So, here it goes from here, if we have a damping for example, suppose we take small amount of damping then with this damping goes this way higher damping like this and infinite damping will actually take it to 1. So, this is the force Transmissibility.

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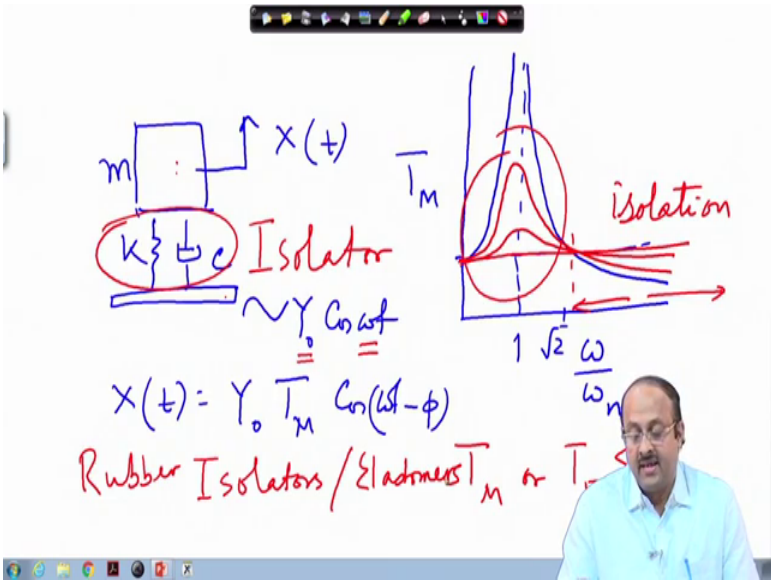

A difference in scenario occurs when we have a motion being transmitted. So, let us consider another system where this is y naught cosine omega t and here again m K C we can have this X t, X t will be again y naught time here I will call T M and cosine omega t minus phi. Now again, T M will be a looking the same as T F because the system is linear for undamped system like this going like that and if we have some damping this way increase the damping this and with the very high amount of damping this is how it goes.

Now, in both the cases we have seen that T M or T F actually less than 1 the which occurs in this region that is here we have the excitation force gets reduced while transmission and also the exciting displacement gets reduced because X is related to Y naught through this T M. So, this is the region for isolation, this is the region for isolation. And naturally, we see that depending upon the excitation frequency the isolation takes place if omega n is actually low. Because, as we go this ratio becomes higher and higher then the isolation becomes good.

Of course, we do not need much damping when isolation is very good, but remember that there is a possibility in this region where the transmissibility is quite high; that means, the vibration gets amplified and here the damping play certain role and this role is very much desirable that is if you increase the damping then the transmissibility goes down. So, damping is one of the very important part in what is known as the isolator remember that this part that is what is inserted between the structure and the structure and the equipment or structure and the equipment here this is known as the isolator.

So, isolator design is quite important because here the for a given value of M the K has to be designed so that the isolation is proper and C has to be designed. Now, the designing with the taking the proper value of C is quite interesting and quite difficult as well because C plays double role. Here, when the in the high frequency region we do not require high amount C whereas, in the low frequency, excitation we want to have a high value of damping.

So, therefore there are many researchers whereby different type of new materials are being developed which will have certain type of damping mostly the isolators are made of rubber or certain isolators are rubber isolators or elastomers. Elastomers are useful because they have the inherent damping the material its has certain amount of damping for which this rubber isolators or elastomers are quite useful. But again, I will come to this point later on thus damping is to be selected judiciously because this is remember then electronic equipment so this these has certain other implications in other part of the design which we will see soon. Now, this part is the isolator now isolators of different type.

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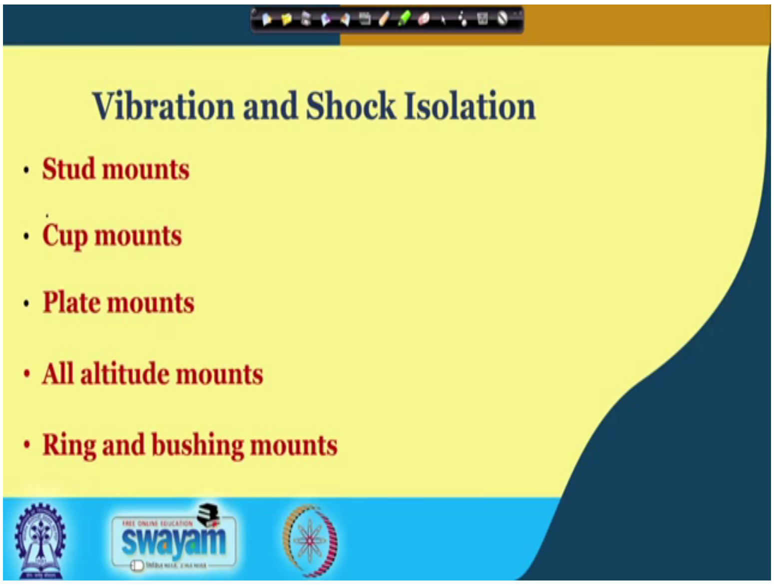

We have seen the isolators and there are different types of isolators. One is that the start mounts are nothing but the isolators, it has different different structures. Sometimes this is the cup mount, sometimes this is plate mount, and then all altitude mounts and ring and bushing type of mounts. So, there are many manufacturers which will supply this kind of isolators one has to choose properly based upon the considerations which we have already discussed just now.

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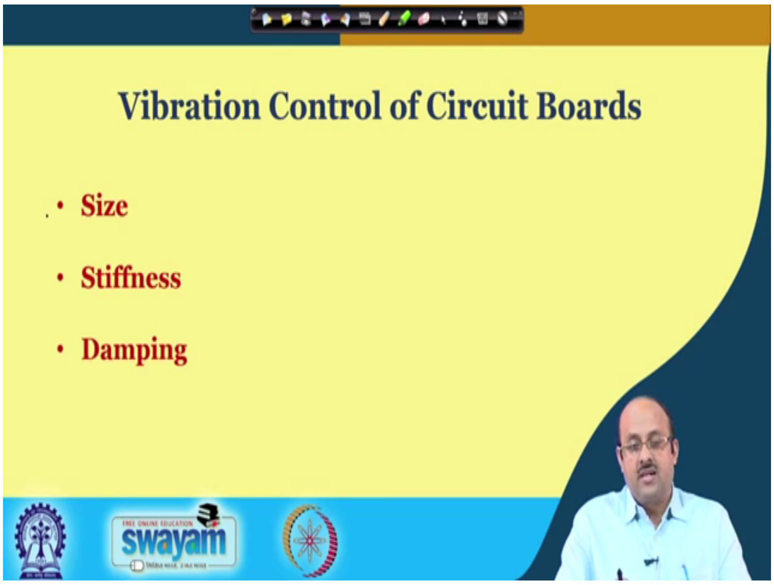

Now, then we come to very important point. So, here what we have done is that, we have placed an isolator between the equipment and the supporting structure. But then, this reduces the level of vibration coming from the structure, but still there will be some vibration which will come to the come to the structure come to the equipment and our task will be then to reduce the level of vibration. On one particular structure which is prone to vibration to a large extent is the circuit boards or the PCBs. And circuit boards, we have learnt in the last class that is the circuit boards are continuous structures.

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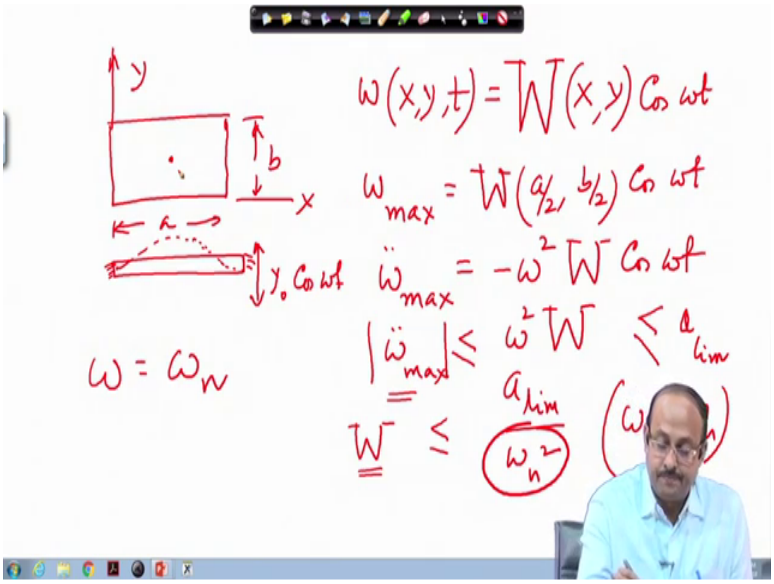

So just to see what we can do to reduce the level of vibration for this circuit board let us consider, let us consider the PCB. Suppose this is our PCB and this is subjected to the vibration. So, let us consider that is the PCB part and this is connected by h connector or by some other connections. Now, the vibration is actually getting transmitted to this structure let us consider this as the Y not cosine omega t the entire structure is vibrating. Now the PCB is a flexible structure so therefore it will vibrate and we have known that the PCB that is the circuit board will have the response that is W X t and X t and Y we consider this X this is Y so it will be better to take X Y and t.

And this is actually a shape y and we will consider cosine omega t assuming that there is no damping over there. Then of course the acceleration, so we will consider this part because this has the number of different modes. So, it is only the first few modes which are quite prominent because the other modes the higher order modes which will have higher natural frequencies will not contribute too much to the vibration. So, it is only the first few modes which will contribute.

Now, let us consider that one particular mode is being excited which is which is predominantly the first one of the first 3 modes. So, the maximum level of vibration is almost occurring here which will have certain value that is maybe here if I consider a and length and the breadth as b then X equal to a by 2 and y equal to b by 2. So here, omega maximum so W maximum may be here will be equal to W at a by 2 and b by 2 and cosine omega t.

So, the maximum acceleration maximum accelerations will be minus omega square W at this value and cosine omega t. Then these maximum accelerations so, out of this so maximum of this one. So, this is actually less than equal to the maximum value W max dot is less than equal to omega square W. And the most critical situation occurs when W is equal to the natural frequency of that particular mode, then we have seen that the amplitude goes to a very high value unless damping is present.

So, if this is our maximum value of the acceleration and this is to be limited; that means, we do not allow the acceleration of this point to go beyond certain value. So, if this is the limiting value suppose this I want to be limited by certain acceleration limiting value limit of acceleration so this is the limiting value. And in that case, we see that the this function that is W must be less than a limited value divided by omega n square assuming that omega is equal to omega n.

Now, we see one thing that in order to reduce the level of vibration what we can do? we have to select the omega n to be quite high. Because in that case, for a given value of limiting accelerations we will get omega to be W, that is the response at this point to be yes response to be quite low. So, this will be our strategy to reduce the level of vibration here we will have to find out certain strategy certain structure structural modifications by which the x the omega n that is the natural frequency becomes quite high.

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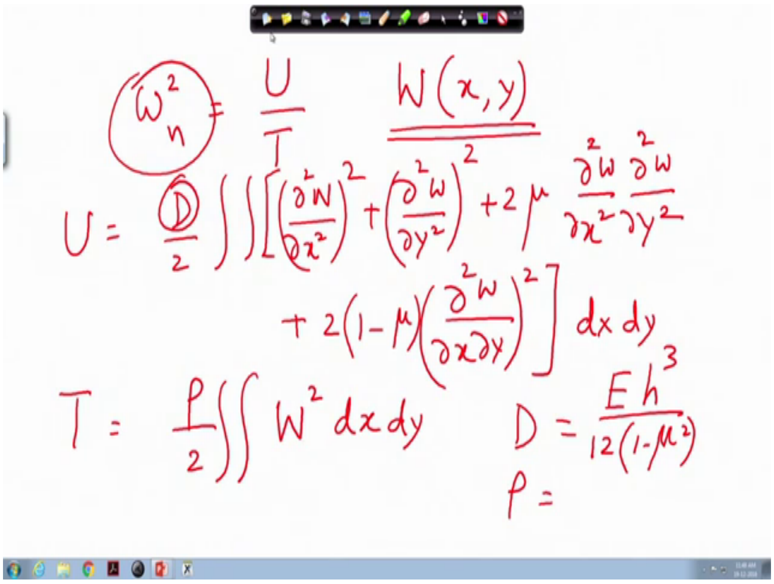

Now, let us come back to the natural frequency of the of the circuit board we have seen that the estimated value of natural frequency square this is the potential energy divided by the kinetic energy. Where, the potential energy this has certain complicated function complicated looking function which is a double integral that is over the entire plate and this will be del 2 W del x square del 2 W del y square plus twice Poisson's ratio del 2 W del x square del 2 W del y square plus 2 1 minus mu Poisson's ratio delta 2 W del x del y square and the double integral and t will be equal to rho by 2 then again W square d x d y.

Where W is actually a function W is a function of x and y which is conveniently taken depending upon the boundary conditions. And here D D is D is related to the material property as well as the geometry this is something like this it’s the Poisson's ratio square. So, this is the material property and also rho is actually the mass per unit area mass per its not the density its the mass per unit area. So, if we choose this W properly then we can find out the natural frequency square. Now, let us take few 1 or 2 cases where we should be able to get that one.

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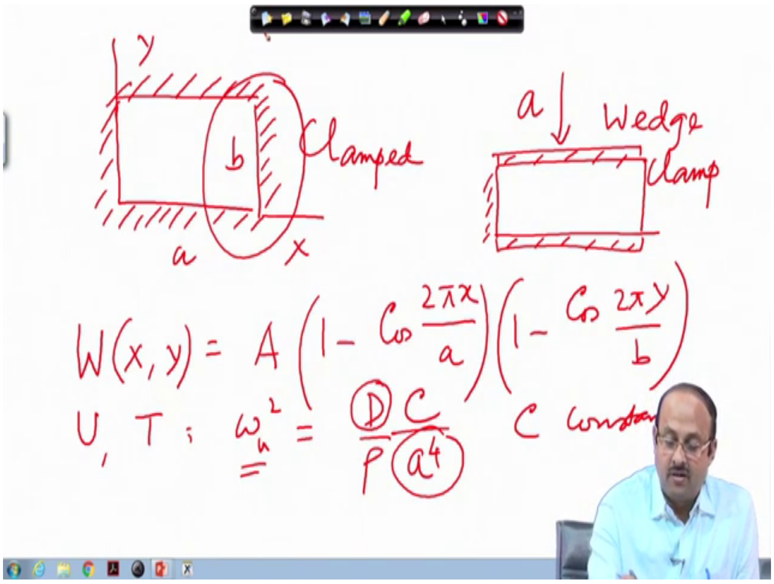

For example, if the PCB is actually is clamped at every side of course, it is very difficult to achieve this kind of boundary conditions for the PCBs because of certain restrictions and this will almost never be achieved, but let us consider this case for elucidation. We consider this one and so this is the clamped at all ends.

So, here one good choice will be this one as let us say A arbitrary constant and 1 minus cosine 2 pi x by a and 1 minus cosine 2 pi y by b. You will see that this will satisfy all the boundary conditions. Now if you select this one and then use the U and T and then from which omega n square you will get that this omega n square invariably this becomes a function of D by rho, big d comes because from the strain energy rho comes from the this energy and kinetic energy and here there will be a function which is a square a to the power 4 and there is some constants C. So, this is how it will C is a constant.

So, now if we want to increase the value of omega n, so what we can do we can reduce the value of a can be reduced; that means, the size of the of the PCB could be reduced, but sides if you have a large amount of A. Then this we have certain advantage that is we can accommodate a number of small components on the same PCB whereas, if you have this large A then its omega n decreases so it is not good for from the vibration point of view.

Similarly, if you have small a then omega n will increase, but it's again the size will reduce so therefore, it cannot accommodate so many of components. One another thing which comes here this is the boundary conditions it is seen it will be seen if you consider the other type of boundary conditions that if you increase or decrease the degree of freedom in the boundary for example, it is actually not allowing to either move or to bend. If you reduce the degree of freedom then its natural frequency increases.

So, this is actually one situation which we can explore for example, there are PCBs where only one edge could be clamped and the other edge could be made free. But, if you apply another kind of boundary condition here maybe the wedge clamp and so then its natural frequency could be increased. There is one way to increase the natural frequency that is by increasing the value of D and how this could be done? D is actually dependent on the on D increases if you increase the height or the thickness of the plate now if you consider the plate.

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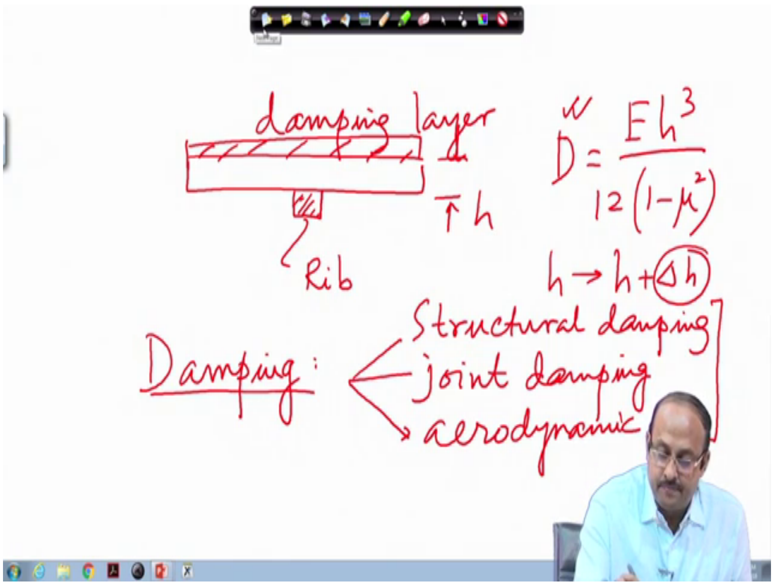

Now if you consider the plate which has certain thickness and then so this is the h D will be equal to E h cube divided by 12 1 minus mu square. Now, if you increase the value of the h definitely the value of D increases and so increases omega n. Now, PCBs cannot the thickness of the PCBs cannot be increased to a large extent, but what we can do we can attach rib over there.

So, if you have attached a rib then we can get so now, you see that it intuitively says that it will stiffen the plate. But, what we can see here that effectively by increase by applying attaching a rib there we are effectively increasing the h from the given value h to h plus delta h, certain amount of h is increased. So, D is actually increased. So, these are the techniques that is the structural modifications we can we can use to increase the level of increase omega n and decrease the level of vibration. The second technique which is very important this is known as this is the by increasing the damping.

Now, damping there are many sources of damping in the structure one is that there will be inherent structural damping, material damping, there may be the joint damping, and there may be other aerodynamic damping which occurs when there is certain kind of wind circulation around the structure. But, these are all not very not very effective choice for increasing the damping of the structure what we can do we can attach the damping layer over the PCB. So, this layer is made of damping damper, damping layer. So, this damping layer actually enhances the damping of the system.

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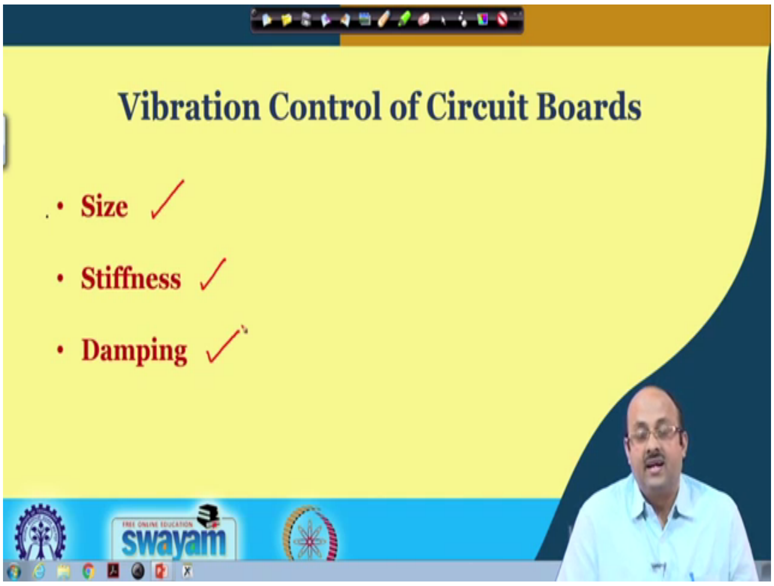

So, now you see so we now come to this point that is we have the size, the effect of the size, the stiffness, and the damping over there. So, this damping is important, but at the same time we have to remember that the damping in enhances also the heat generation. Because when the damping means that the energy is dissipated from the vibrating structure, but where does it go it goes to form the generate the heat and that is very important from the electronic packaging point because the damping now enhances the heat and there must be sufficient provision for this conduction of this heat to other part of the structure.

So, here we come to the end that is we see that how the vibration of the structure could be controlled by different structural modifications, but that has to be optimal. Here you have seen that the optimality is very important and crucial part and while designing the electronic component for its vibration point of view we have to always remember that there are other aspects associated with it. So, the damping has to be or the vibration control strategies have to be optimally chosen and here we come to the final point.

And, here I thank you for your kind attention.