Vibration Control

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Module - 5
Design Considerations in Material Selection
Lecture - 3
Design for Enhanced Material Damping

Hi, this is Dr. S.P Harsha from Mechanical and Industrial department IIT Roorkee. In the course of vibration control we are discussing about the design considerations in the material selection. So, in last two lectures we discussed about that how we can do the sensitive sensitivity analysis because when we are just trying to go for the design consideration. Then we need to check it out that what exactly the sensitive parameters are there and how we can put the ranges of that according to the sensitivity towards the material selection. We discussed almost all about you see that how the viscoelastic features are there.

All other features are there for consideration in that and in the last lecture, again it was for the design considerations especially in the material selection, but it was on the design specifications. So, when we are trying to see the specifications then there were three main components which was discussed one the speed of response in which you see the transient feature was mainly discussed. How do we get the settling time and the prior to try to reach to the steady state that was discussed in that and then the second was the stability feature when we are going for the stability. When we are going for the specification part, then we need to check the stability part of this system when we are just going with the design consideration.

Third was there about the resonance because whenever you see any changes are there we need to check it out that whether we are trying to reach or exactly at the resonant condition or not by changing or by considering the design feature in that. Also, we discussed about when the system is of multi degree of freedom system which is the real nature of the system, then how do we do the effective analysis by reducing the order of model. So, in all discussions we simply observed that whenever you see the design considerations are there. The things are pretty sensitive especially when we are just choosing the material for our entire vibration separation. So, now we are again extending the same design considerations in the material selection for vibration separation and this design is basically for enhancement of material damping.

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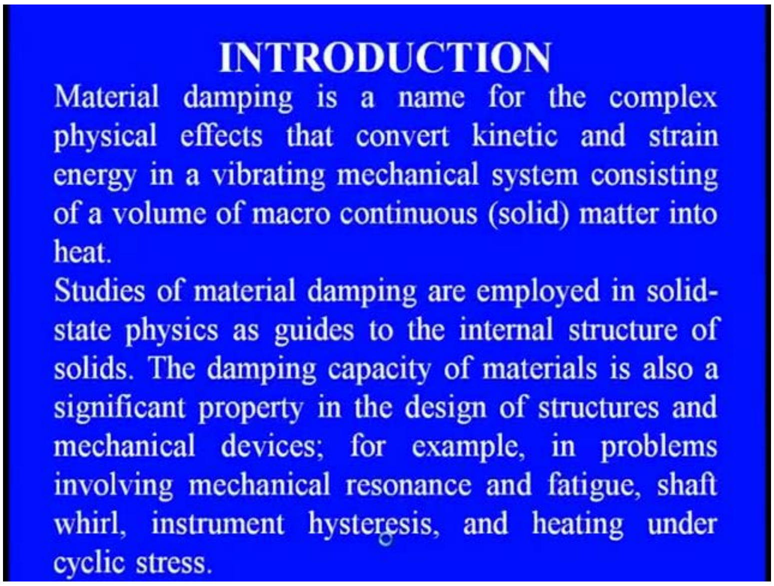

We know that the material damping the name is pretty simple, but the mechanism is somewhat more complex because the more complex physical effects are there which are simply converting the kinetic and the strain energy into the vibrating mechanical system. It consists of you see we can say a solid matter and then this kinetic this, the strain energy which is being dissipated is simply converting into the heat so that dissipation is absolutely the feature of the solid state part. We can say whatever the macro feature of these, the molecules which are being available with the various layers of the material part. In this section since we want to enhance that part, so we need to see the studies of the material damping which are being employed in the solid state physics.

It guides us in the form of the internal structure of the solids are the damping capacity of material is also you see one of the significant property for design of a structure or any mechanical devices for separation of the vibration. The transportation we know that there is a clear transfer feature this vibration signature. We can say the sound levels are being clearly transmitted at the faster rate according to the material chosen. If you are involving some kind of mechanical resonances or the fatigue the shaft whirl or hysteresis in the instrumentation feature or any heating under the cyclic stresses are very common problems when you are trying to design the structure.

The mechanical devices specifically when the material damping is one of the criteria for that so these are the critical issues which needs to be addressed while simply putting the material damping as a part. So, sometimes you see we can say that the material damping is one of the complex phenomena. It is not only coming by the intermolecular interactions, but also you see here whatever the structural features are there that also being one of the component in the material damping.

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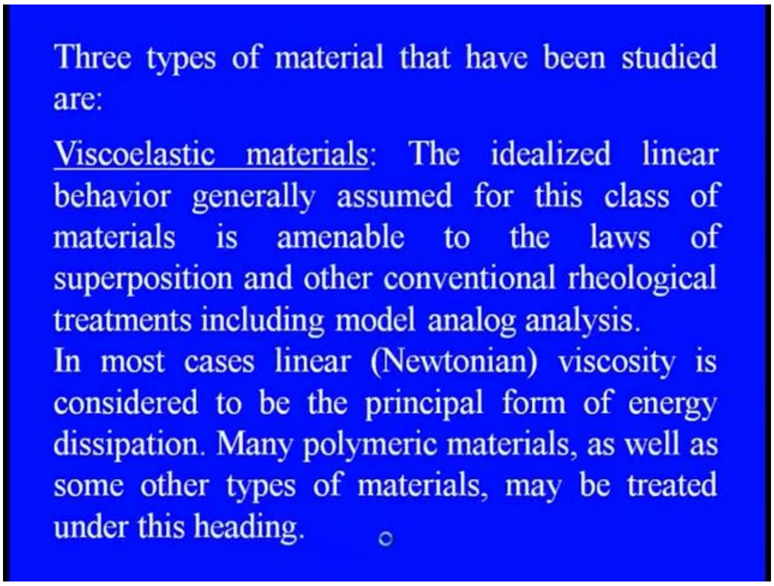

So, we can now divide the three types of material that can be studied here one is the viscoelastic material which we already discussed, but some part is to be incorporated here as well for enhancing the material properties for design consideration. So, we can say that the idealized linear behaviour generally assumed under this viscoelastic material is simply amenable to the laws of super position. Then the other convenient rheological treatment can be simply included in the model just to put an analogy in the analysis feature of the viscoelastic behaviour.

In that, we have the viscous feature we have the elastic feature and when we are talking about the overall part the overall behaviour of the viscoelastic material it needs a clear understanding about the Newtonian feature of the viscous part. The elastic feature according to that we can say the Hooke's law, so in most of the cases we can say the linear or the Newtonian viscosity is being considered to be a principle form of energy. This is being dissipated and converted in form of the heat, but many of the polymetric material whatever you see the polymers are there or other materials. They are being treated in such a way that the principle dissipation energy is always being forming in terms of the linear the Newtonian viscous effect. Also, they can exhibit the elastic feature so that you see here, it can be straightaway compatible in the overall formation of the kinetic and the strain energy and then they are being converting into the heat.

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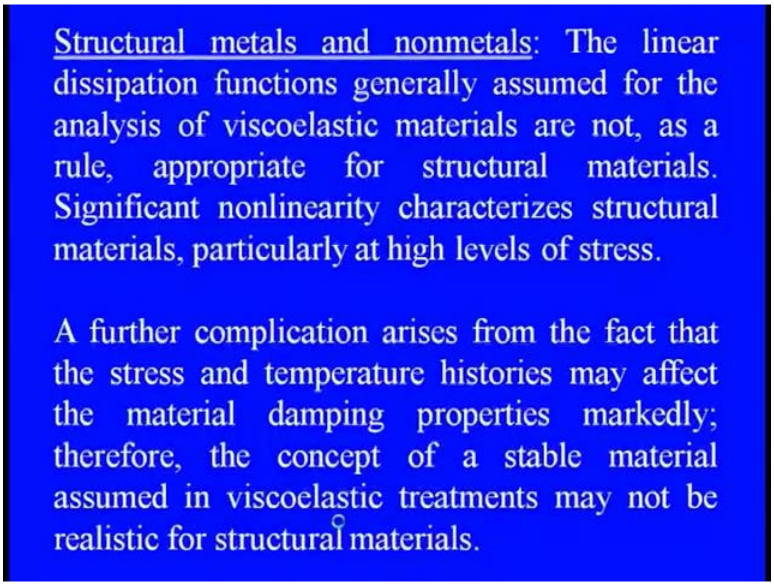

The component in this is the structural metals and non metals the linear dissipation function which is generally assumed for the analysis of any viscoelastic material are not appropriate. We can say as a rule towards the structural materials because significant nonlinearity is available when we are just choosing the structural part. We know that the strain energy and the kinetic energy which are being transmitted in we which are being dissipated it is not a linear propagation. So, we can say that the non linear, the nonlinearity characterizes, it is simply like with all characterization of this. The entire material with the nonlinearity consideration the structural material is always showing a high level of stresses.

When these high level of stresses are being distributed in all the materials, we know that the deformation or the strain energy this transmission is not in a linear part of that. So, we can say that whenever we are just going with the structural metal and this non metal the linear dissipation function cannot be adoptable in that a further complications can be there. With the stress and temperature histories with the material damping property and because of that you see here the concept of the stable the stable material in the viscoelasticity is one of the realistic feature of the structural element.

So, we need to check it out now only the stress and temperature histories of the entire material, but the same time we need to check it out that whether you see under such high stress in high level of stresses. Under this fatigue feature whether the system is stable with the consideration of the structural this structural damping with the consideration of this viscoelastic treatment or it is unstable under this feature. So, that is what you see sometimes the things are some somewhat more complicated with the consideration of the non linear parametric feature towards the structural damping.

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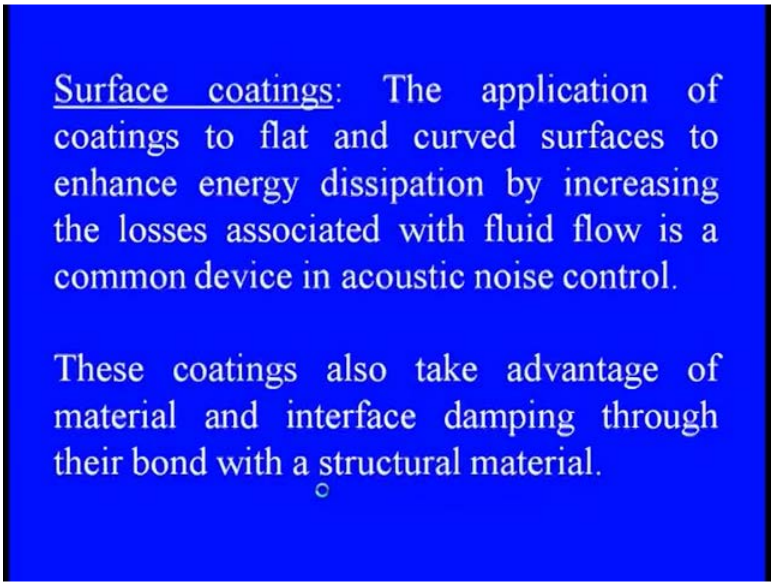

The third is the surface coatings the application of coating is to flatten towards the curved surfaces to enhance the energy dissipation, and that is what you see. This is one of the common feature where we know that we are just required to absorb required to absorb the energy of that. So, either we have a flat surface or the curved surface the application is to enhance the energy dissipation by increasing the losses associated with the fluid flow in any common devices especially in the acoustical noise control. These coatings are also giving some kind of advantage to the material and interfacing damping through their bond with the structural element.

We know that when we are just applying the coating there itself there is a clear bonding feature in between the surface of the coating and the main surface of the object. This bond is simply giving a typical kind of we can say interfacing damping through that you see here, few of the energy can be dissipated with these kinds of thing towards the structural element.

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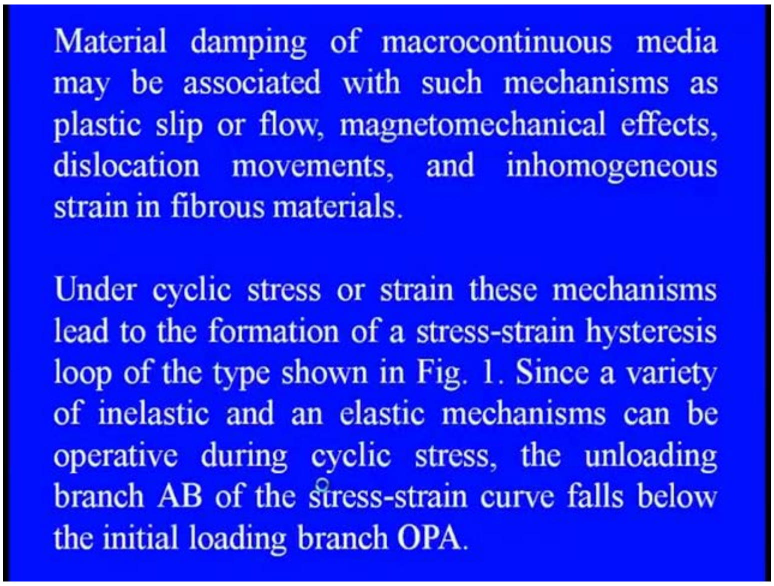

So, when we are talking about the material damping, the material damping of any macro continuous structure or the media can be directly associated with those mechanism in which the plastic slip of any flow. We can say the magnetomechanical part or magneto mechanical part is being there or also you see, we can say that they are directly associated with the dislocation movement of the macro. We can say the molecules which are simply showing if we have the fibrous material which are clearly showing the inhomogeneous strain.

We know that whenever we are just considering the fibrous material the distribution of this strains are not uniform and certainly we can say that this is some kind of inhomogeneous behaviour of such materials under the loading. So, when we are just talking about the macro feature of this material damping always we need to consider the various mechanism in that just like the slip factor.

The mechanical features are there through which you see some kind of deviations are there even under the loading condition or the stress conditions, there is a dislocation movement is there which can be even put the plastic flow in that. So, under these cyclic stresses or the strain these mechanism will simply lead to the formation of stress strain hysteresis loop which is nothing but showing a loss of energy under the entire loop is and since the variety of inelastic. The elastic mechanisms are just operating under the same cyclic stresses the loading and the unloading feature is always being drawn a hysteresis loop which is the clear indication of the loss of energy.

So, here now even with the elastic and inelastic nature or elastic or plastic nature we have a clear mechanism where the heat is being dissipated in the kinetic and strain energy form. At the same time, it is being loses because of this hysteresis loop or in inelastic behaviour during loading and unloading of this cyclic hysteresis.

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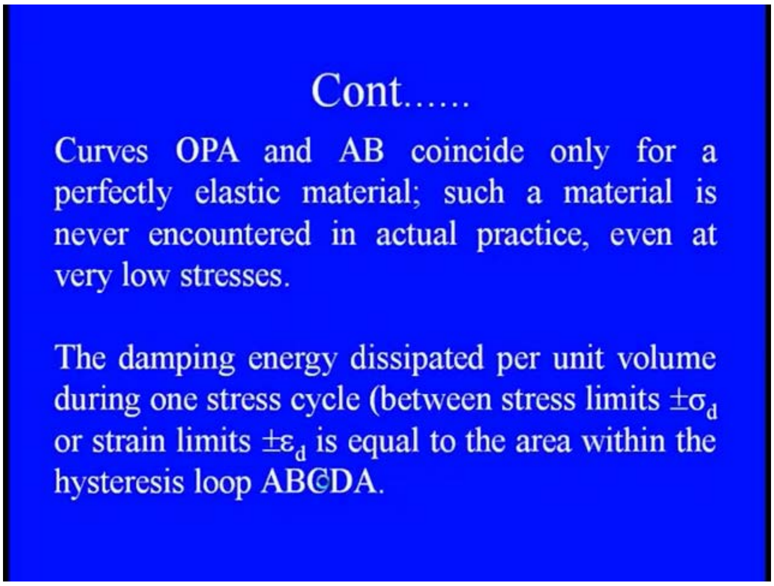

Now, you see the curve which I am going to show you has like the two main features say OPA and AB coincide then certainly means when there is no hysteresis loops are being formed. It is the perfectly elastic material and this perfectly elastic material is allowing the energy to be absorbed and equal amount of energy is to be released during loading and unloading condition. This behaviour you cannot anticipate during the real world problem even when we have a lowest stress cycles.

We know that whenever the things are being happening there is a clear deviation in the path of the absorption and the released feature of energy, and they will certainly be even a small hysteresis loop where there is a clear loss of energy. So, the energy the damping energy which is being dissipated per unit volume during each cycle is simply calculated. If we are saying that it is the sigma d like the stress limit is there plus minus sigma d and the strain limit is there plus minus epsilon d, it is absolutely equal to the area. Whatever the damping energy which is being dissipated per unit volume during this cycle is nothing but it is just showing the area of the stress strain diagram within the hysteresis loop of this ABCDA.

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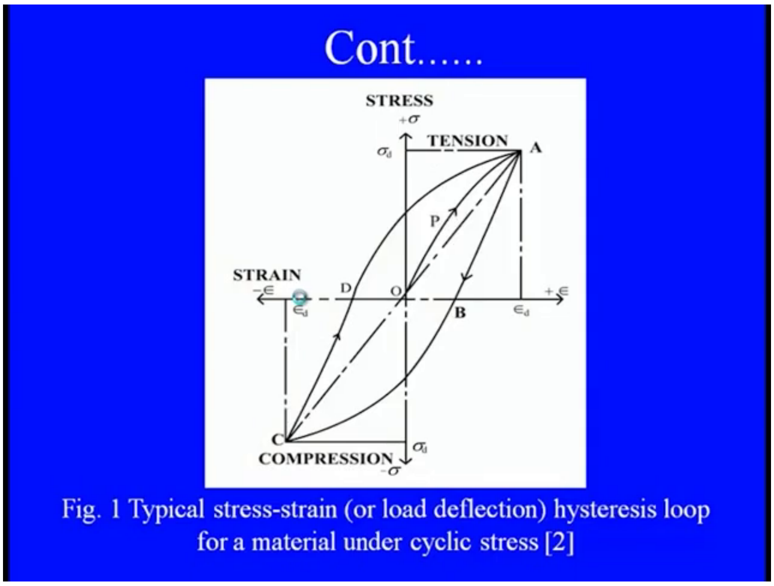

Fig. 1 Typical stress-strain (or load deflection) hysteresis loop for a material under cyclic stress [2]

So, when we are just trying to see these things what we have we have a clear loop of hysteresis under the stress strain diagram, so we can check it out this is what you see the stress sigma d this is epsilon d. So, what we have this is what the designed feature of that in both the category whether we are just going in the tension or in the compression under any cyclic fatigue. So, when the cyclic feature of the stress applications are there that even in the form of the tension feature or in the form of the compression feature in the back.

We could easily form that even in the loading condition, now it is approaching from A to B and when unloading is there it is approaching from C to D. So, when you see this is just forming the straight line feature A to just AOC that means it is a perfectly elastic material, but this is not always be there in any of the actual practices.

There is always a formation of this ABCD and then this entire cycle is clearly showing that you see how much the this, this is what you see the hysteresis loop that how much energy is to be loss during loading and unloading condition in the cyclic stresses. So, this is the stress strain diagram, typically we can say the load. We can say it a load deflection diagram which clearly shows that when the material is under cyclic stresses there is a clear loss of energy, which can be computed based on the hysteresis loop area under the entire curve in between the stress and strain.

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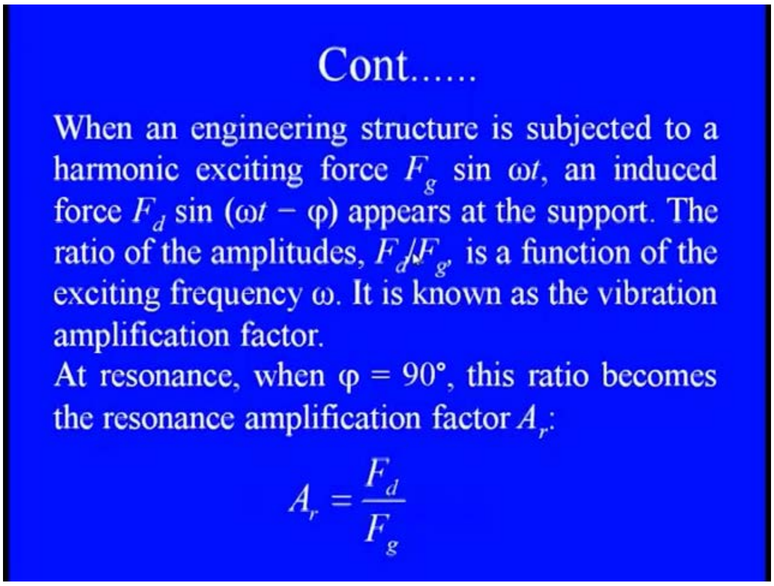

So, when an engineering the structure is being subjected by the simple harmonic excitation force which is nothing but equals to f sin omega t. The induced force whatever the induced forces are there due to this application of the material f d sin omega t minus phi always being interacted from the applied to the reactive forces. The ratio of these amplitude means the exciting two induced force means the action and do reaction force is a function of exciting frequency.

We can say that this is something the ratio of this row this the ratio of this force the applied force and the reactive force is nothing but the amplification factor. So, when we are trying to discuss this amplification factor which is just coming out, we can say in other term is the transmission when it is just transmitting. So, transmissibility factor then we can say that at the resonance when this reactive force which is nothing but the f d sin omega t minus phi.

The phase difference when this phi is 90 degree, the ratio becomes the resonant amplification factor. And this we can say the resonant amplification factor can be denoted by A r and this A r is nothing but equals to F d by F g the exciting this f d is nothing but equals to the induced force and F g is nothing but equals to the exciting force.

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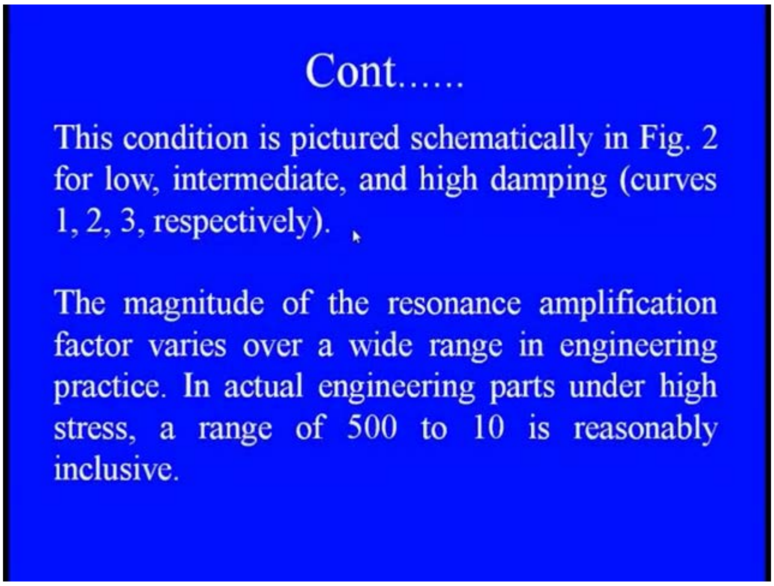

So, the condition you see which we can show in the later picture is simply showing that when you have a low damping feature. When we have a intermediate damping feature and when we have the high damping feature then how the amplification factor at the resonant condition is being varied. We could easily figure out that the magnitude of this resonance amplification factor is simply varies over a wide range of various practices where a clear application of these cyclic loadings are there. We can say that this is even starting from 10 this ratio means the F d by F g, the induced force divided by we can say the excitation force, this ratio can be in the range of under high stresses can approach up to 500 and up to 10 within the reasonably inclusive forces towards that. So, if I see that I could easily figure out that you see what is the A r means what is the resonant amplification ratio is and accordingly we can say exactly the other features or other properties of the systems.

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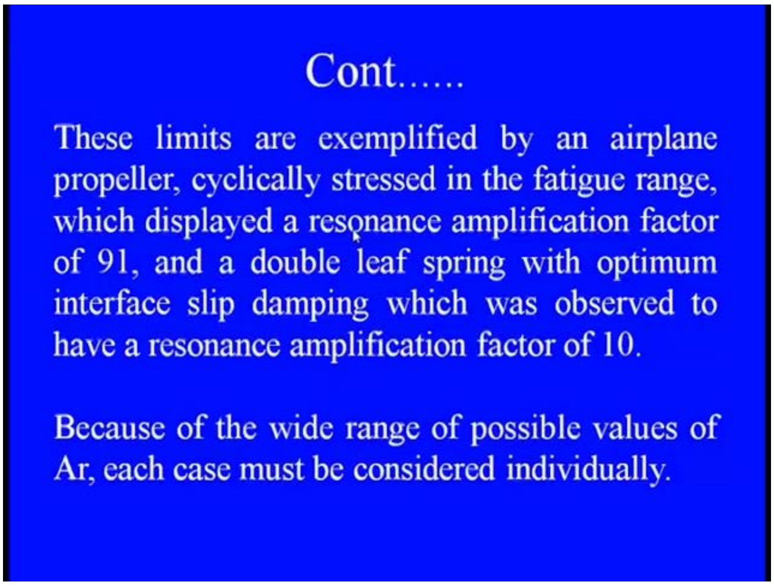

The limits are even sometimes just go beyond certain beyond certain things as if you are just considering an aeroplane propeller the cyclic stresses in is absolutely in the fatigue range. They can be displayed a resonant amplification factor is the maximum like the ninety one under double leaf spring with the optimum interfacing of the slip damping can be observed.

In that we have a clear double leaf spring and even in that, the damping the slip damping features are there even it has the amplification this factor at the resonance is of 10. So, it can be you know we can say that we can vary it right from 1 to 500 or even more than that. So, amplification ratio can be calculated based on that, so because of the wide range available here we can simply consider an individual effect of these application parameters.

So, you can see that how the effect of material and the slip damping is there on the vibration amplification curve. Now, you can see what you have you have a clear mass which is being associated with this particular bar of A. Then you see in this we just want to see that what exactly the effect of this pressure is there on the joint and then when we are simply applying. Here, the force which is nothing but the excitation force f g sin omega t. We can get you see the responses which is being we can say the inductive force f d is nothing but equals to the f into sin omega t minus phi.

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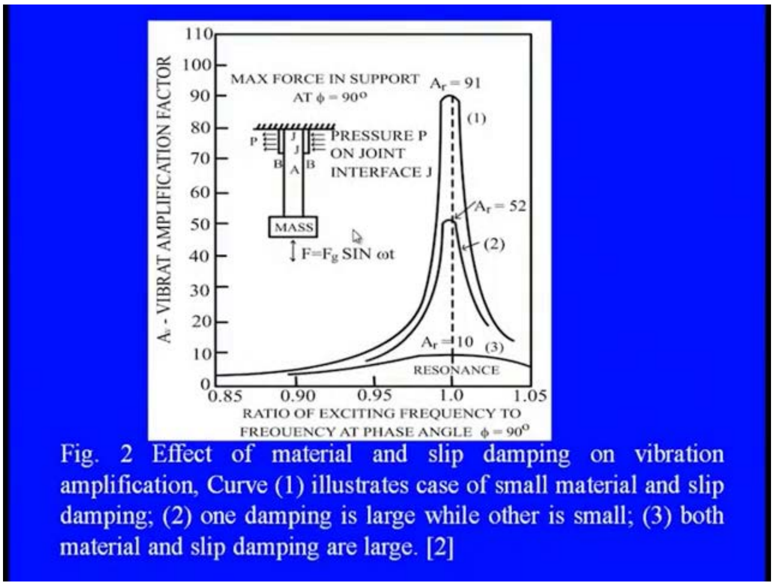

Fig. 2 Effect of material and slip damping on vibration amplification, Curve (1) illustrates case of small material and slip damping; (2) one damping is large while other is small; (3) both material and slip damping are large. [2]

So, this is the ratio of the exciting force F g to the specially frequency at the phase angle phi 90 is always giving you see the resonance and this dotted line is clearly showing that what exactly the amplification ratio at the resonance. So, in that we can simply say that this A r which is showing the resonance this resonance amplification factor is absolutely depending on the various parameter. The first what exactly the material part is there what is the slip damping is there and what exactly you see the kind of application in which, the cyclic loading conditions are being coming towards the structure.

So, when you see that the first curve which is just showing the A r 91 is nothing but the show of the small material and more slip damping. That means here as we discussed in the previous case when we are just going with the propeller design of the aeroplane, we know that the amplification is quite used because the exposure is with the small material. The slip damping is even for the small, but when one damping is large with comparison to the other we can say damping then we can say that somewhat we can control the amplification because of the damping available at the material side.

So, you see here the a r can be straightaway reduced half of that is up to that and when you see both material and slip damping are just large enough to clearly control the entire features of the excitation. In the previous case we discussed about the interfacing of the properties in the leaf spring the double leaf spring we could easily figure out that the resonance at this point is just 10. So, almost you see here the 90 percent reduction is there in the amplification by adopting a different methodology and the material properties in that.

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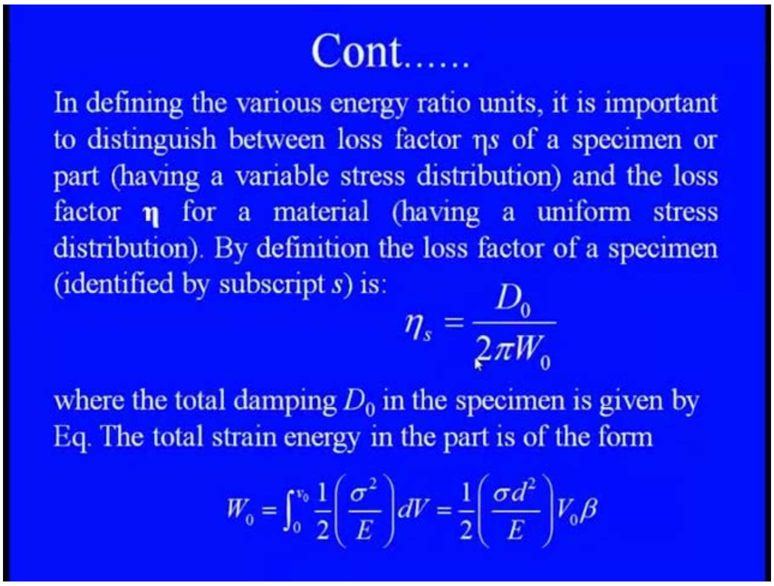

So, in defining the various energy ratios unit it is important to distinguish a loss factor of a specimen or a part which is having a clear variability in the stress distribution. This loss factor which we are considering eta here for material should be having a uniform stress distribution sometimes. The complications are there that we know that when you have the specimen part in which you see the variable stress distribution is there we need to keep n s the eta s. When you have the uniform stress distribution, we can simply keep the eta as it is and as we discussed in our first case that there are three main damping features are there the total average and specific damping.

So, for calculation of this loss factor we are simply going with the overall damping just showing the dissipation of energy in the entire specimen. So, we can simply define the we can say the variable stress distribution for the loss factor n eta s which is nothing but equals to the overall damping, which simply considered the overall dissipation energy in the entire specimen d 0 divided by 2 pi w 0 where we know that this is the overall damping.

The total damping in the specimen d 0 is there and then if you are going towards the total strain energy in the entire specimen, which is showing by the w 0 is nothing but equals. Now, based on that how much strain energy is there since we are considering a uniform material, so certainly you see it is showing the young's modulus elasticity under the feature. So, we have the integral of 0 to v 0 half of sigma square by e into d v or else even we can convert this into that how the entire volume is being changed.

So, we have the w 0 is nothing but equals to half sigma d square the sigma d is nothing but you see the designed feature where the peak stresses are being there, so sigma d square by e into v 0 beta. So, we know that when we are considering the peak stresses there is a corresponding the parametric features are there which is simply reflected by the beta. We know that until and unless if we not going with the dimensionless this feature then we cannot bifurcate the significant and insignificant features there.

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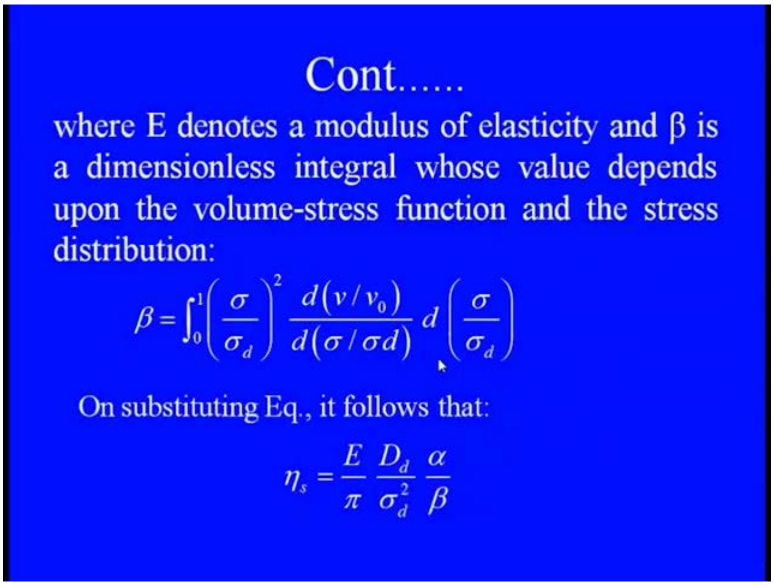

So, E is the Young’s modulus beta is the dimensionless integral whose values is specifically depending on the volume and stress relation which we discussed previously that beta is a simply the stress distribution. In this, you see we have the both the variation the sigma by sigma d sigma is the total stresses sigma d is the peak stresses which is simply relating the specific damping feature per unit cycle per unit volume into the variation. This beta which is one of the specific property is also showing the dependence feature on the volume and the stresses. So, we have d v by v 0 divided by d sigma by sigma d into d whatever you see multiplied with the variation of this stress distribution is d sigma by sigma d.

When we are trying to substitute these things into the uniform feature this the variable stress distribution for the loss vector. Then the loss vector eta with the variable stress distribution is nothing but equals to E d into alpha divided by pi sigma d square beta. So, here now we have one more parameter is the Young's modulus, d is the designed value means you see the specific feature where you see we are simply considering the damping dissipation of energy into alpha and beta. These are the two specific parameters and sigma d square is the maximum peak stresses relates to the d part it is not overall damping.

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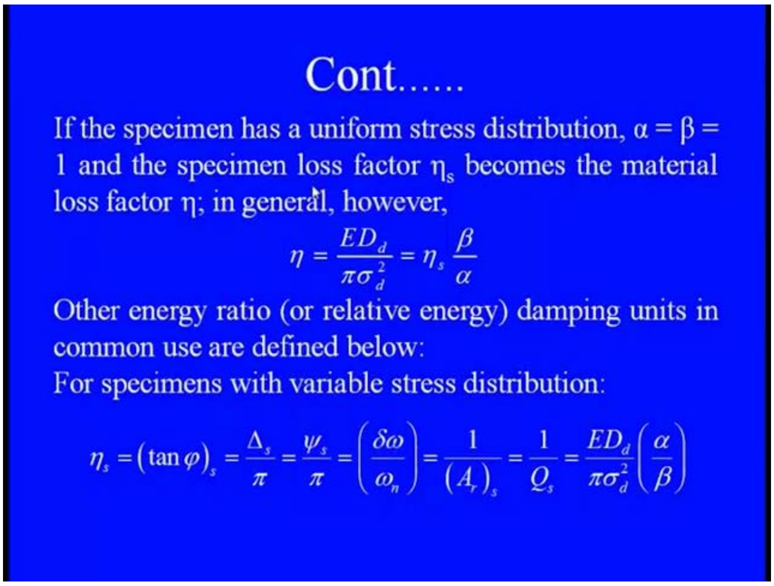

So, we can say that if this specimen is having the uniform stress distribution certainly alpha and beta will be the same and the loss vector becomes now the eta and this eta is nothing but equals to E into D d divided by pi d square. We can say it is nothing but equals to the non uniform stress distribution eta as loss vector into beta by alpha.

So, we can simply find out that you see when you have other ratios like you see the relative energy damping. Then certainly we can simply find out that how the uniform and non uniform stress distribution can be related. Now, these parameters where which are simply defining the stress distribution in the entire material can be specified accordingly means the beta and alpha values. So, when you have the variable stress distribution the loss vector eta s was there, which was simply the function of various parameters like beta and alpha. So, if I am saying the eta s is equals to tan phi or it is equals to whatever the variation this del s by pi or even we can say the phi s by pi.

We can also equal it for any specimen various you see the variety of specimens are there it is equals to the del w by w n or even it is the reciprocal phenomena of the resonant amplification ratio. We can say these different types of the stress distributions are means the non uniform stress distributions are or even it is nothing but equals to 1 by q s. Even we can say we can calculate as we discussed already the eta s is nothing but equals to E D d divided by pi d square into alpha by beta.

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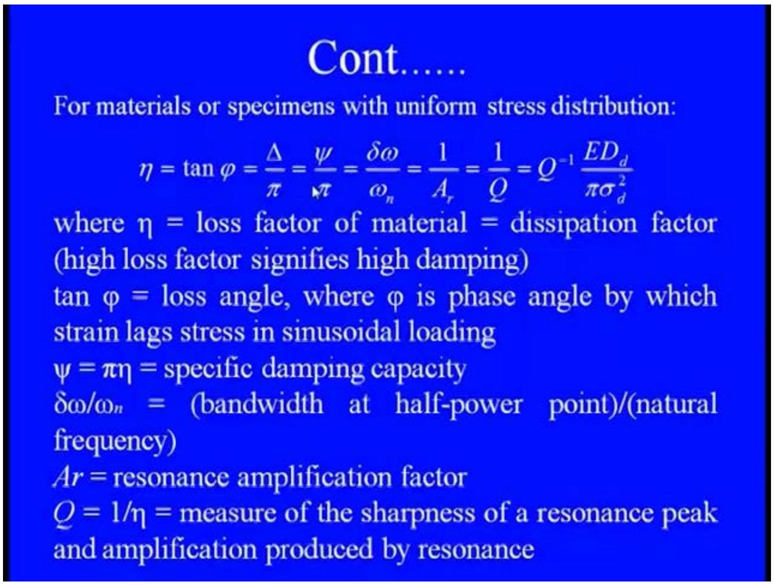

So, in these all variations it is clearly showing that there is a loss vector in the material because of the dissipation part under the high, we can say typically high damping certainly you see here. We can say as under the high cyclic loading if we are simply putting the high damping it will simply signify the high loss vectors are there in that. So, the tan phi which we discussed here is nothing but the loss angle which is simply computed here. The phi is the phase angle which is being there in the sinusoidal loading where the strain is lagging behind in the stresses because of this non uniform stress distribution.

So, in we can straightaway incorporate the effect of this non uniform distribution of the stresses in calculating the stress and strain feature in our material towards the loss factor. So, that is what the dissipation factor is clearly showing here the tan phi and phi is always being there as a phase angle difference. Even we discussed about phi over pi where phi is nothing but the specific damping coefficient which is being there according to the material property. We also shown there the del w by omega n which is simply showing that what is the band width is being there with respect to the natural frequency and when this the power is being dissipated through that means the energy dissipations are there.

We also discussed about the resonant amplification factor and this eta s which is nothing but the non uniform stress distribution loss factor is always reciprocal to that amplification. We can also find out the sharpness of this resonance peak and the amplification which are being produced by the resonance in terms of q. So, this loss factor because of the non uniform stress distribution is the reciprocal of this q, so it has a clear impact of all these variables with consideration of the stress distribution in a uniform or non uniform way.

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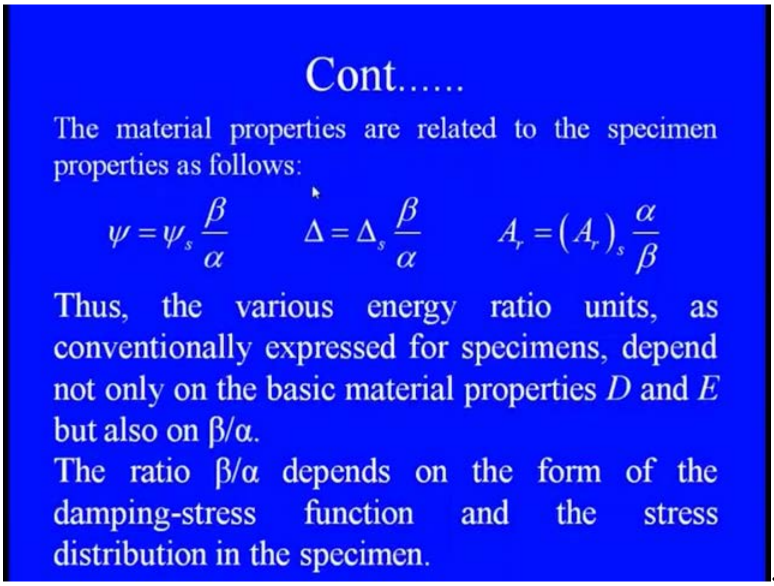

So, now we can go straightaway to the material properties that are closely related to this factor. So, we can say the phi is nothing but equals to the phi s beta by alpha the delta is nothing but equals to delta s beta by alpha or even the this amplification ratio is A r s alpha by beta. So, these various energy ratios unit as we are simply expressing with a corresponding the specimens are simply depending on the various basic material property like the damping Young's modulus. It is showing clear dependence on these two parameter beta and alpha the beta by alpha.

So, the ratio beta by alpha is absolutely depending upon the form of the damping and the stress distribution or the stress distribution in the specimen because you see here if you have a uniform stress distribution. This stress distribution is absolutely linked with the linear proportion of the damping is then we have a uniform stress distribution and beta and alpha becomes the same. If you see the material is not showing a uniform stress distribution along with the damping properties of the material, certainly we have a clear value of this ratio beta and alpha.

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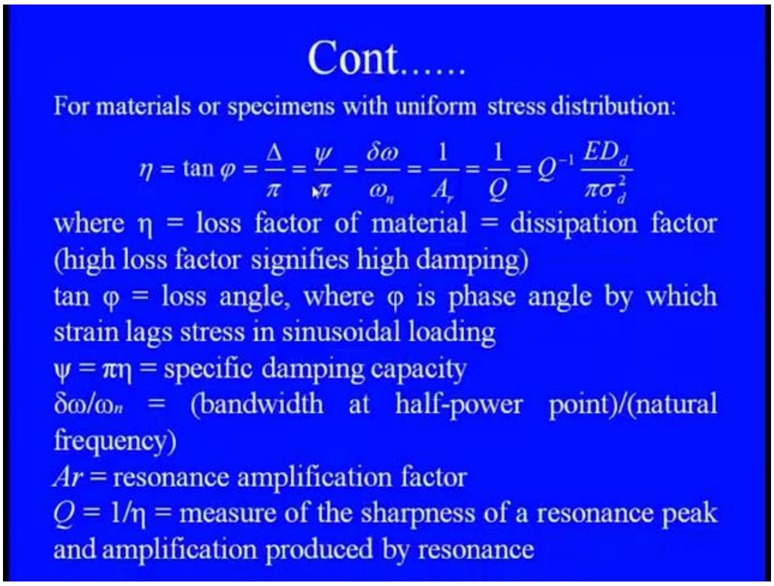

Due to that the various other properties like we discussed like the sharpness of the resonance peak or the resonance amplification factor or even the band width. Even we are simply discussing about the specific damping capacity in between the stress and strain. They are straightaway formed and they simply show their significance in enhancing the material damping, because of these two parameters.

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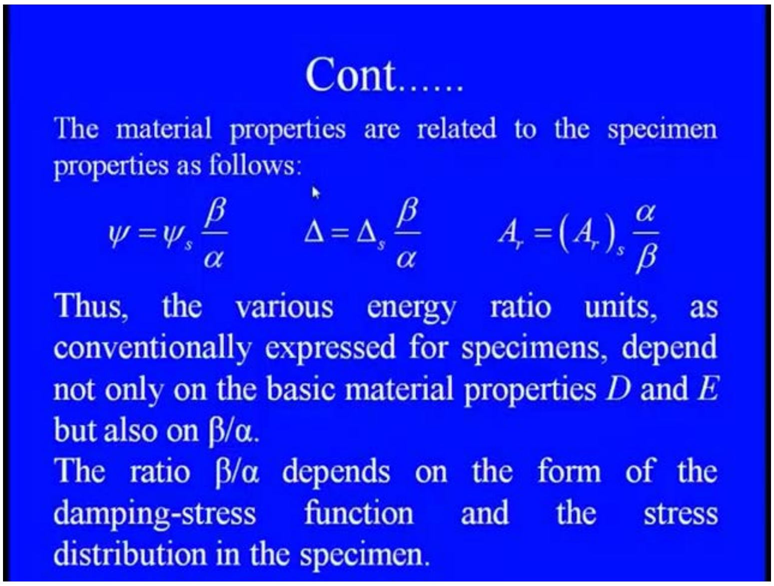

The stress damping function and stress distribution in the specimen.

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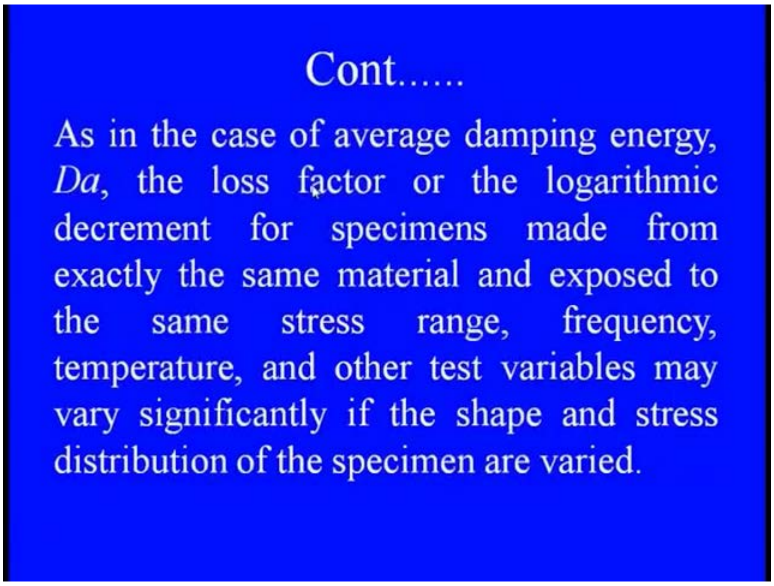

So, in this case generally you see we simply have taken the average damping energy d the loss factor or the logarithmic decrement for the specimen is exactly the same in such same material. These are being subjected to the similar kind of stress ranges frequency temperature, but we need to check it out that how the variables are being occurred when the shape or this we can say the stress distribution of the specimen is being varied.

When these being the variations are there, then certainly the loss vector is different for the even the same material or even they are under the same stresses. So, we need to check it out that how these parametric variations are there in terms of the stress when they are just passing through the material.

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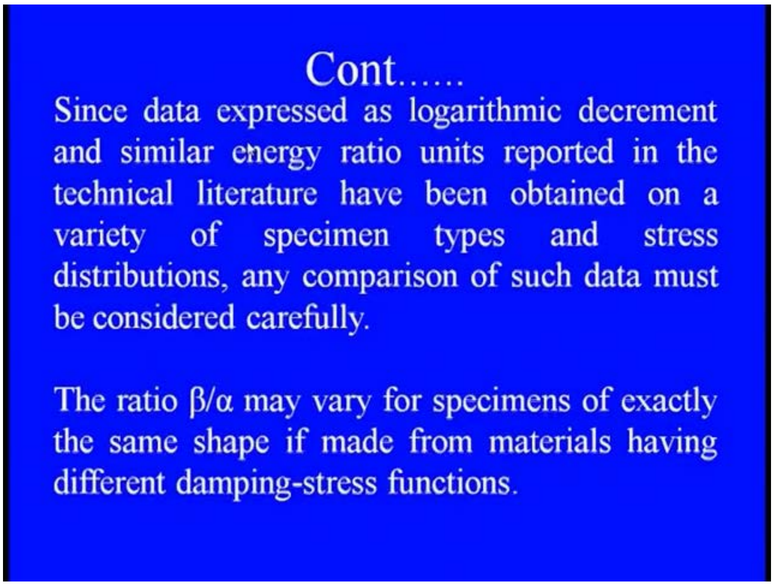

Since, the data expressed as the logarithmic decrement, similar energy ratios are just being varied in the same way with the same kind of you see the specimen types and the stress distribution. Then we need to see that how the material is being chosen so that we can keep these ratio and you see these logarithmic decrement in the similar fashion. The ratio which is simply showing the beta and alpha is absolutely one of the important part because you see, it is just showing the dependence on the shape which is coming out from the entire the feature and the material property with the damping stress function.

So, that is why you see here not only with the consideration of the specimen types and the stress distribution. We need to see that what exactly the damping stress functions are there means what exactly the interaction between the damping and the stress at the molecular level, so that we can simply choose the appropriate material for the damping feature.

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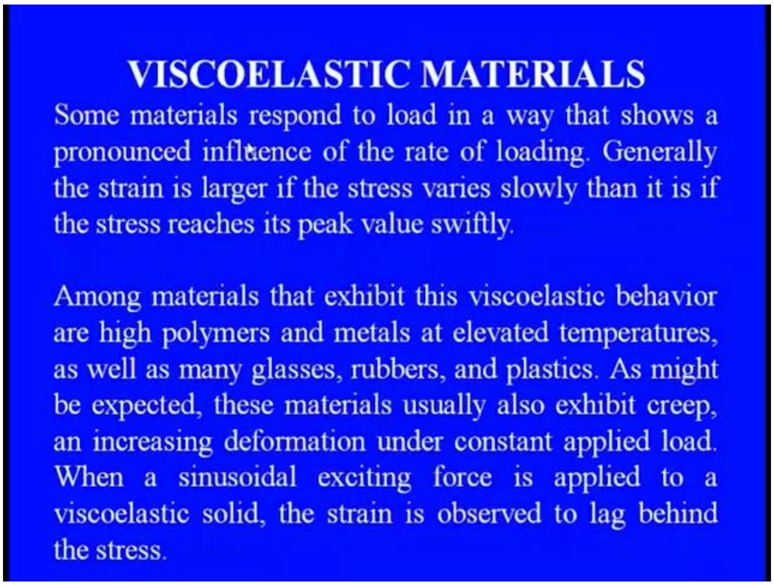

In other case you see as we discussed in the viscoelastic material we know that the system is somewhat influencing according to the rate of loading and also you see during the loading and unloading calculation. So, generally we can say the strain is very large if the stress varies slowly and then you see here it becomes reaches to the steady state feature in a very swiftly feature. So, among the material which exhibits the viscoelastic feature with the viscous and the elastic nature are simply the high polymers and the metals at the elevated temperature.

There are many glasses rubbers or the plastics which are exhibiting this, so when you see a sinusoidal exciting features are being there with the kind of viscoelastic material excitation. Then we need to check it out the strain and the stress whether the strain is lagging behind to the stress or not, if it is there. That means you see there is a clear indication of none this non uniform stress distribution and accordingly the loss factor is coming.

So, the phase angle between them which is always being there a measure of this loss angle in some kind of the viscoelastic material. Accordingly, the stress can be separated into two part one in which there is a phase with the stress strain in the loading condition and one when you have a different feature towards that in any of the quarter. So, the magnitude of these components is clearly depending upon the material and the exciting frequency omega for E 1 a homogeneous.

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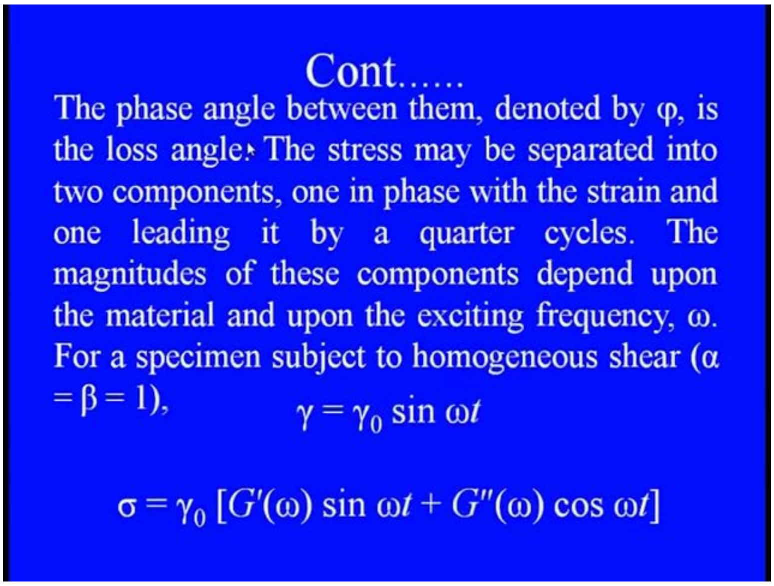

If we have homogeneous shear, then we can say that alpha and beta that this we can say the damping and the shear function is become same means 1. So, alpha beta is same we can say this gamma which is simply showing you see that how the stress is being varied towards that is gamma 0 sin omega t. We can calculate the total stress sigma is nothing but equals to the gamma 0 g dash omega sin omega t and g double dash omega cos omega t.

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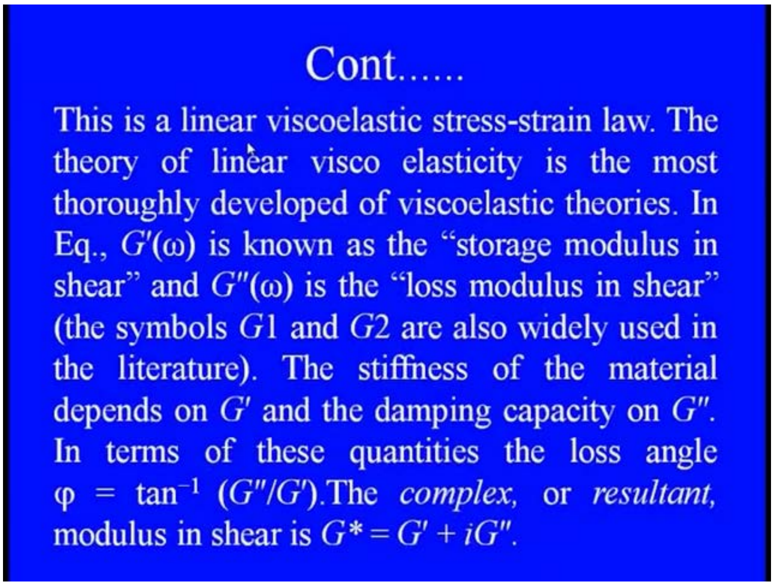

The g dash which we already discussed about the storage modulus shear and g double dash is the loss modulus in the shear feature. So, they are clearly showing the linear variation of the viscoelastic stress strain, so you see here sometimes we can go up to for the low cycle. The viscoelastic material can exhibit again it may exhibit a linear stress strain under the viscoelastic features of that. So, in this when we are calculating the storage modulus or the loss modulus of shear for the viscoelastic material the stiffness of the material is absolutely depending on both of them.

Then, you see here with the g and g double dash means the loss and the storage modulus we can calculate the loss angle phi which is nothing but equals to tan inverse of the certainly the loss modulus of shear divided by the storage modulus of the shear. We can simply get calculate the complex or we can say the resultant modulus because of both the feature g star is nothing but equals to g dash plus iota times g double dash.

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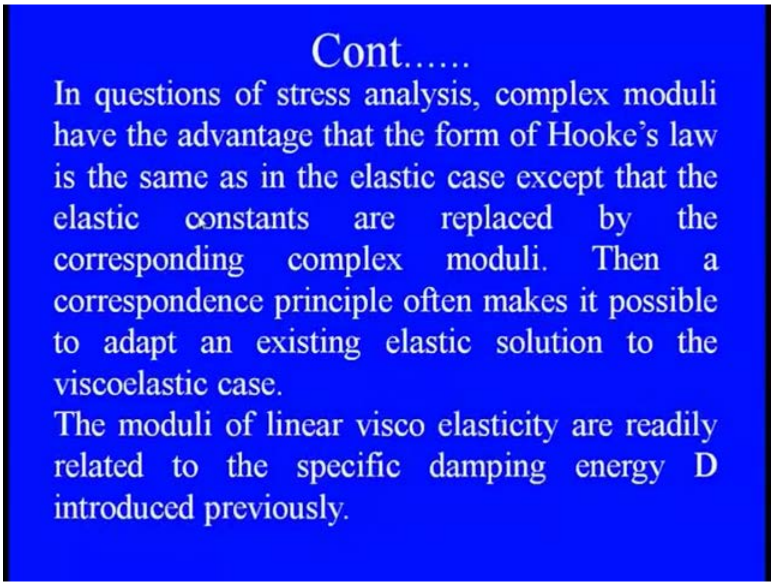

So, it is simply giving the complex modulus of these viscoelastic feature even when you have the elastic feature under the Hooke's law and it is being constrained by the viscosity feature towards that and which makes you see the complex moduli. Then we need to go with the corresponding principle feature which can be straightaway adopting the existing elastic solution within the viscoelastic range. So, the modulus of the linear viscoelasticity or we can say linked with the specific damping ratio in that case.

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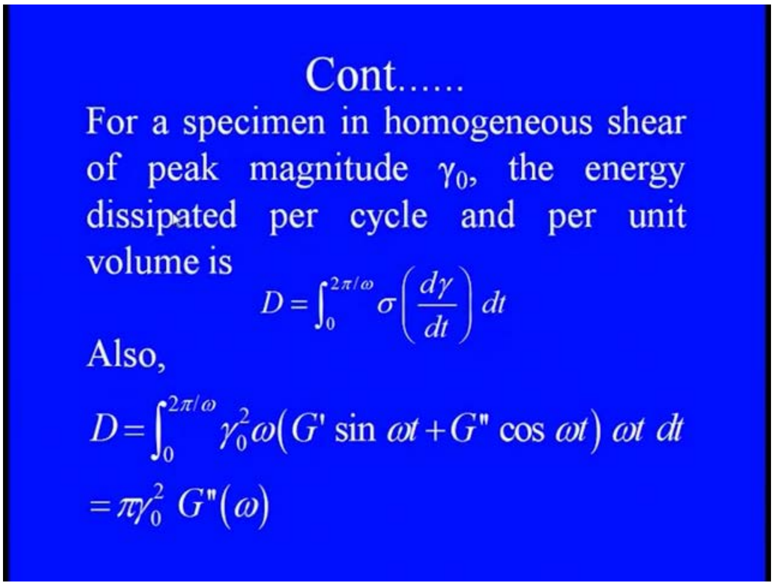

We can simply you know calculate for a homogeneous material under the shear stresses and we can say the peak amplitude say gamma 0 is there. Then the energy dissipated per cycle per unit volume d was there is nothing but equals to 0 2 pi omega sigma d gamma by d t into d t where the d is nothing but the energy dissipation per unit cycle per unit volume. It is nothing but equals to gamma 0 square which is nothing but the peak magnitude is there the shear stress.

So, gamma 0 square shear strain, sorry the gamma 0 square omega g dash sin omega t plus g of double dash cos omega t into d t or we can say that this is pi gamma 0 square g double dash omega. So, this is we can say the energy dissipation in those things under per unit cycle and per unit volume, it can be clearly calculated with those particular features.

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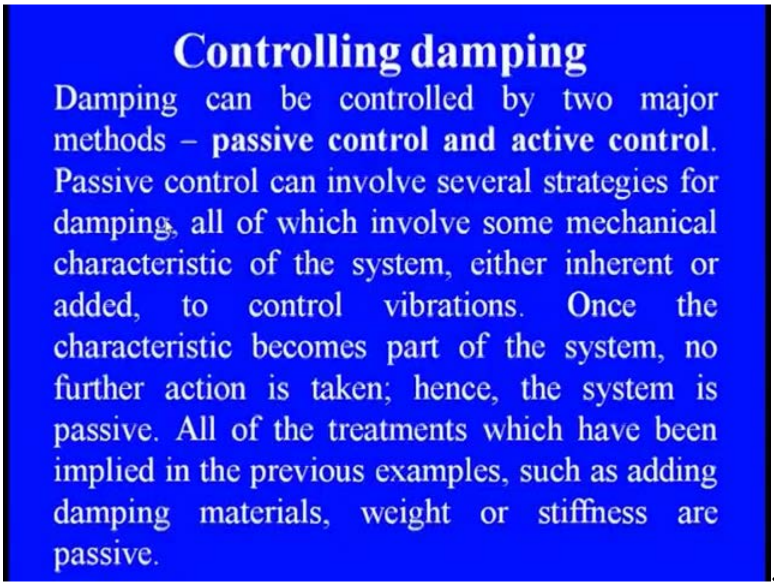

When we are going towards the controlling damping then we need to go with the two consideration the passive and active control. The passive control as we discussed already that it needs you see a certain kind of the external material just to keep there. This simply involves some mechanical characteristics of the system either to be inherent or to be added to the control vibration. Once you define the characteristic feature of the vibration then you cannot take the further feature in the passive part. So, that is why it is a passive once applied it to be applied and all the treatment which have been implied in this is simply adding the damping of the material mass of the mass feature of the material or the stiffness feature. Since these three, the damping materials weight and stiffness's are nothing but the key components of the passive vibration control.

So, passive vibration control is always being included in the discreet devices like the just like you see adding the shock absorber or just adding some kind of features through that we can simply put the energy loss. So, material with the high the mobile molecules such as the elastomers and all they are always showing a high damped features in their molecular feature of the material.

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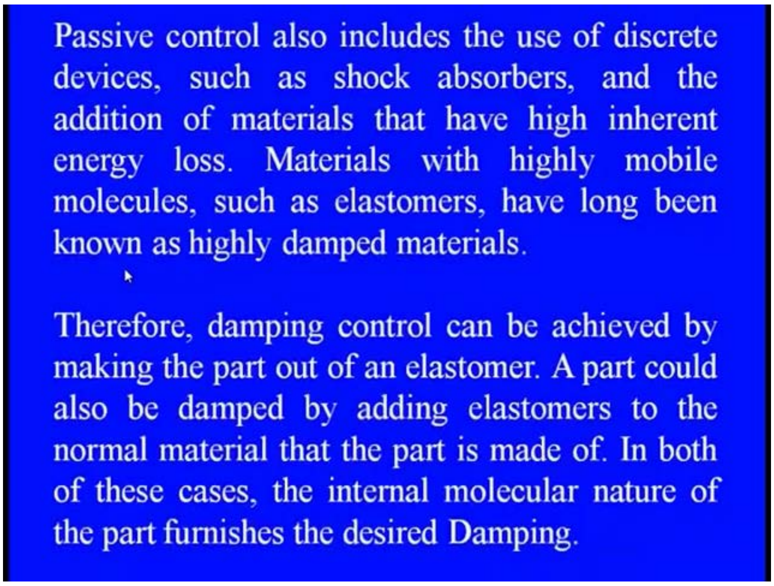

So, the damping control can be achieved by making the part out of the elastomers and the part of that can be simply added as the elastomers to the normal material and that part can be framed out as a composite feature. So, in these cases we can say that the intermolecular nature of this system and the outer feature the surface finishes, both can simply provide the desired damping phenomena in this.

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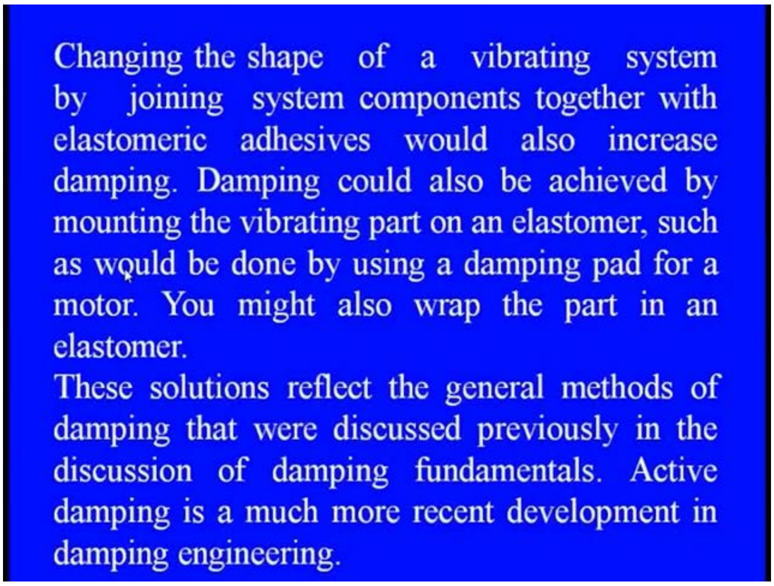

By changing the shape of the vibrating system by joining the system with other component you see here with the elastomers adhesive and all these things will certainly increase the damping feature in that. So, the solution which is reflecting the general methods in the damping was here discussed with the basic fundamental principle of the material that how we can enhance the material damping with the addition of this part.

So, if you are saying that we require the system in which you see some additional damping is to be added to just control the vibration or the amount of vibration we need to simply see that how the molecular features are to be added. This means at this molecular level how it is to be added so that it can dampen out the molecular movement when it is being excited.

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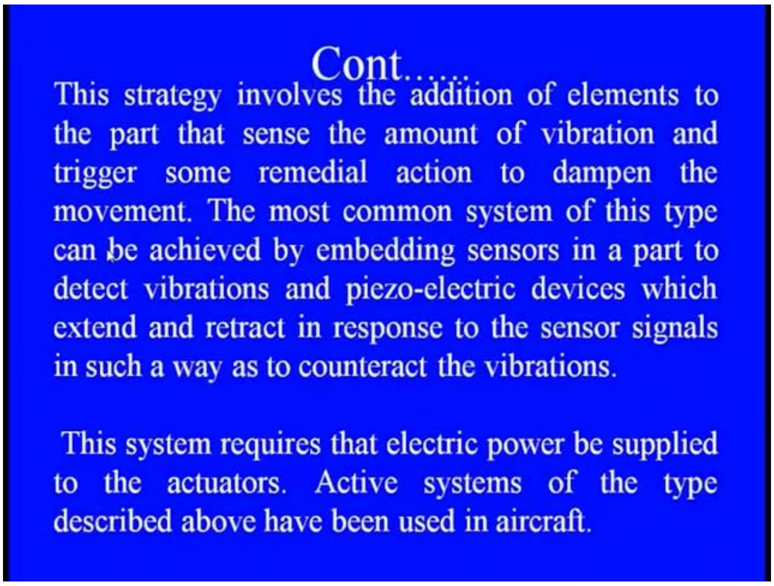

So, the most common type is just you see embedding just embedding the sensors as the part or to detect the vibration by putting the piezoelectric devices or something like you see here. Then it can simply extend and retract the responses to the sensor signals and then by that way we can simply put counteract to the vibration and such systems. That requires the electric power to supply to just act as an actuation anti sensing feature is just coming under the active vibration control towards that. So, these systems can be straightaway associated there in the fly, the air fly.

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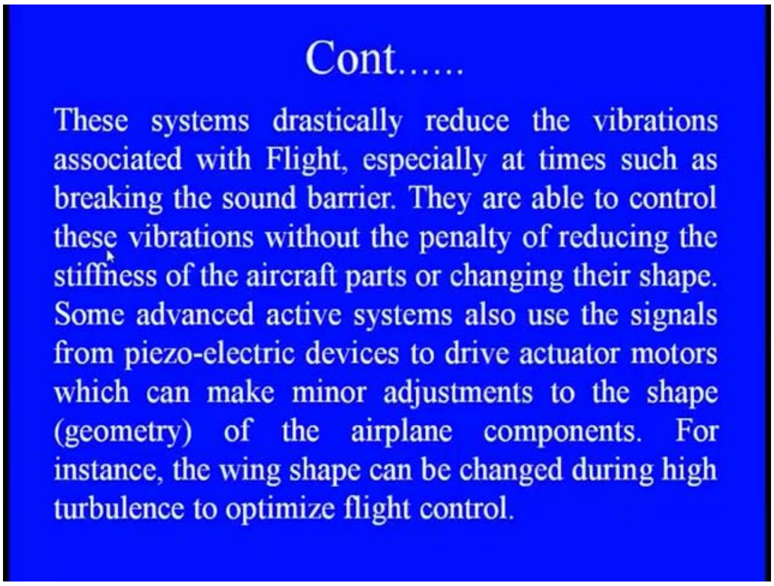

This aeroplane and somewhere you see here or in the flight particular there is a drastic change in the vibration is there just in the automatic way and they are able to control these vibration without the penalty of reducing the stiffness of the aircraft part. By changing even their shape and some of the advanced active systems are also used as a signal for the piezoelectric devices to drive the actuator motors which can even make some minor adjustments in the geometry of the aeroplane components.

So, that is why sometimes when we are simply viewing the wind shape the wing shape is being changed during the high turbulence to just optimize the fire flight control. So, these are some of the actuations from the piezoelectric feature and when they are simply sensed and simply you known like sending the signals accordingly the actuation features are being appeared in that.

There are various other methods in the active control just using the embedded fibre optics and these fibres can sense the gross vibration just like you see the electronic sensors are. This fibre optics can be monitored for changes in the cross sectional area of the fibre which can even cause the change in the light transmission and then can be indicated whatever the vibrations which are being occurring.

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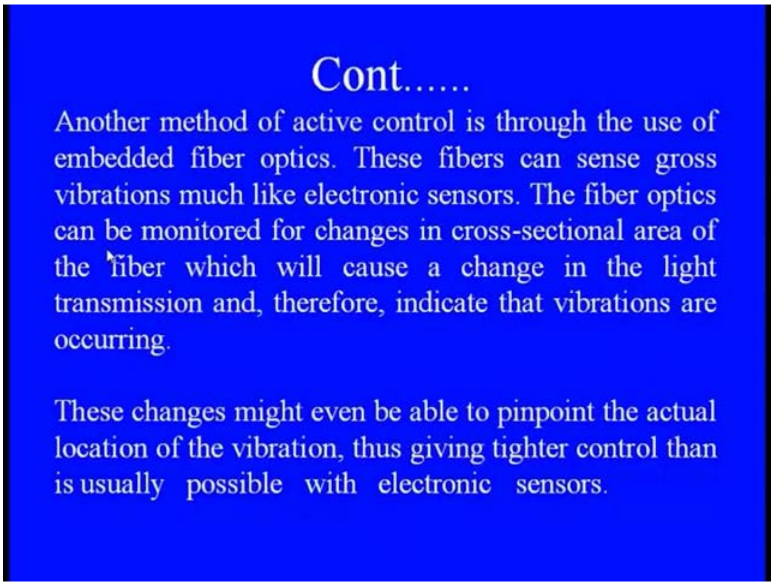

So, these changes can be able to point out the actual location of the vibration the optimum location of the source of vibration, and simply giving a tighter control than the usual possible whatever you see the electronic controls. So, this is you see one of the significant criteria that where we need to go to choose you see here the passive or active control. The significant criteria here means that you see here how we can enhance the material property which can enhance the material damping you see here and through that we can control the excitation feature of the vibration.

So, this was the introduction especially about the passive and the active vibration control because ultimately our theme was to see that what exactly the design considerations are there when we are simply choosing the material for our vibration control. Now, you see in the further lectures we are going to discuss about the passive control feature of the vibration what are the basic theories involved in that, when we are talking about viscoelastic material and other materials, then how you see the location and when you see the source of vibration which is being transmitted how we can deviate the path there itself, so from the source or the path how the deviations can be there in the vibration excitation by adopting an appropriate passive controller.

Thank you.