Vibration Control

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Module - 7
Principles of Active Vibration Control
Lecture - 7
Magneto and Electrostrictive Materials

This is Dr. S.P. Harsha from Mechanical and Industrial Department IIT, Roorkee, in the course of Vibration Control, we are discussing about the Principles of Active Vibration Control, in which we discussed about that how you see. What the basic principles of the active vibration controls are in which we can sense, we can actuate and we can put the control unit through which we can amplify the things. So, we can put some kind of external source to actuate and to balance the, whatever the excitation forces are.

Then, we discussed about the smart materials under the active vibration controls, right from piezoelectric materials that how these piezo sensing, and piezo actuations can be acted for active vibration control. And also we discussed about under this category about the electro electrorheological fluid, the ER fluids they can exhibit a kind of damping features through which and also along with that, we can put in the actuation part. So that they can be acted effective, we can say way to control the vibration, and also in previous class, we discussed about the MR fluid, the magnetorheological fluid.

That how when we are applying this the magnetic field or the flux, all along you see this particle, which are being there in the carrier oil, like silicon oil or any non conductive oil. Then they can put by adding the magnetic field, there is a clear addition of the viscosity, and they can be just aligned according to the direction of the fields and it is just you we can say that, if it is perpendicular to the applied field part. And they are straightaway resisting that whatever the kind of vibrations are there, they can absorb the vibration excitation energy or the dissipation features can be acted.

So, we discussed about the three main modes in that, one was the flow mode, one was a shear mode and in these in all, and one was the squeezed mode. And in all three modes they are absolutely acted according to the kind of applications, so if you want just for normal operations in which the vibration controls are being there for the beam or something. The flow mode or we can say sometimes it is a wall mode, is quite effective even the shear mode is also very effective in such cases.

Then in this magnetorheological fluids, we discussed about that how we can simply locate the potential location where these fluids can be the placed, and we can get an effective vibration, we can say suppression part there itself. So, in last 2 lectures, it was mainly focused on the electric field with the particles which are being arranged, and they are just putting with the additive viscosity part. And also the when the magnetic fields are being acted and these things are there, and these all resistances are being provided by the fluids. So, the entire part was there surrounding with these fields, and the conducting oils the non conducting oils with the carrier part particular. In this lecture now, we are going to discuss about the similar feature like, if we have the magneto or the electrostrictive materials.

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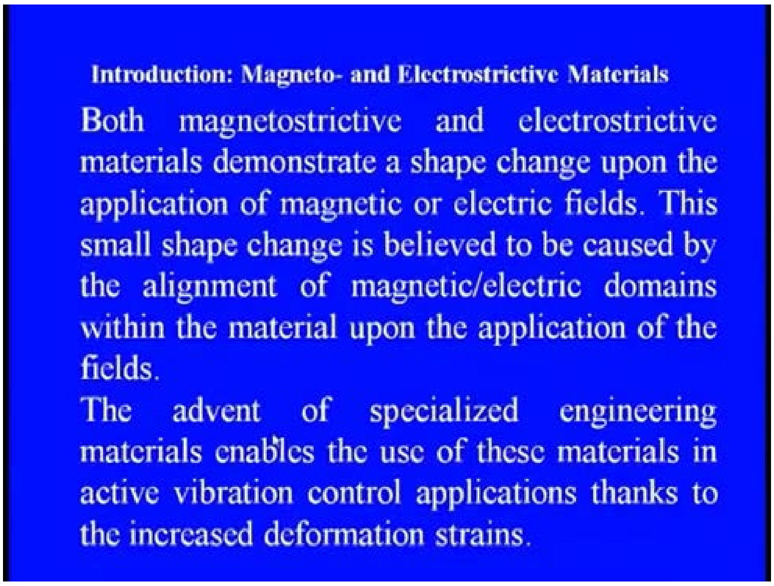

What does that means that you see here, that we means we are saying that both the magnetostrictive and the electrostrictive, materials demonstrate a shape change upon the application of these fields, the magnetic or the electric fields. And the shape change application is very sensitive to the, we can say the capacity or the intensity of these fields are the magnetic or electric fields. So, the small change is believed to be caused by the alignment of this we can say magnetic or electrical domains, within the material upon the application of these fields.

And the advent of the specialized engineering material, which enables the use of these material in active vibration control application, just because of the increased deformation strains. So, that is why when the change in the shape or the strains are there, correspondingly we can simply judge that how much these we can say suppression of the energy, or some kind of the, this force applications are there on that part.

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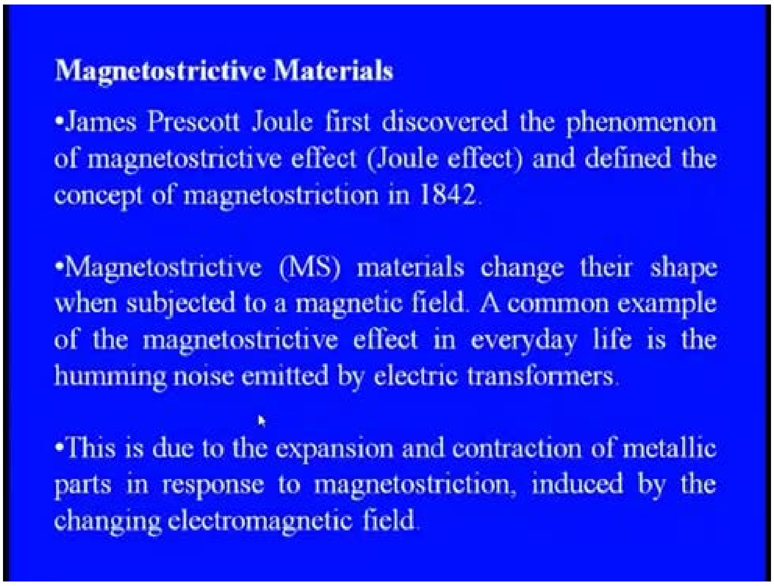

So, when we are talking first about the magnetostrictive materials, it is started from say the James Prescott Joule first discovered the phenomena of the magnetostrictive effect, means the Joule effect we can say and defined the concept of this magnetostrictions in 1842. So, this magnetostrictive material they are simply changing their shape, when the it is being subjected under the magnetic field just like, we simply see that there is a always humming noise is there, this humming noise is there, which is being emitted all the time from this electric transformers.

And this is due to the expansion and the contraction of the metallic parts, in response to these magnetostrictions which is being induced by the change of electromagnetic field. So, this every time when there is a change in the electromagnetic field, there is a clear change in the shape either the contraction or the expansion. And because of this thing there is a clear response against these kind of we can say the changing of this field, and we are simply getting a kind of a humming noise. So, this is a perfect example of these magnetostrictive actions on that.

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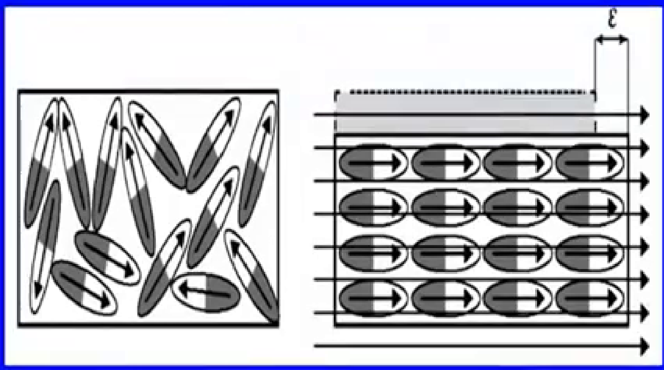

Fig. Randomly oriented magnetic field

As you can see on your screen, you will find that we have randomly oriented these magnetic field, so when we are saying that these randomly oriented, all the directions about these the atoms together. And when we are trying to apply these, what we can say this magnetic field then you can see that the entire material is just either the, we can say expanded or the contraction. So, here we are simply showing the expanded part this is what my the strain part and when they align, along with the direction of the magnetic field you can see that there is a clear expansion feature is there.

So, here there is a only change when we are simply applying the magnetic field and because of this application, you see all the particles along the layer, they are simply streamlined. And because of that they is a clear change in the dimension, and again this change, the strain part is absolutely depending on the flux intensity, that how much these electromagnetic forces are being generated; and because of that there is a clear change in that.

So, the most popular and simple model to explain the behavior of this magnetostrictions is simply a ellipsoid model, as you can see that as I simply showed you that, when they are randomly oriented, means there is no, the electromagnetic fields are there the H equals to 0. All the ellipsoid material they are randomly oriented and the direction even itself is just varying like this and then you see the magnetic field which is being applied in this direction, the H direction all these ellipsoid molecules. They are being arranged and because of that we have a clear strain or clear extension feature.

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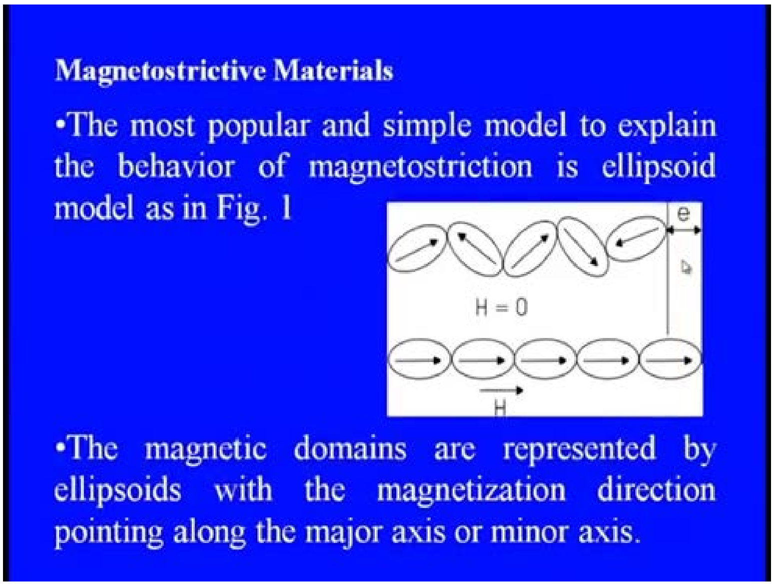

So, magnetic domains are being represented by the ellipsoid with the magnetization direction, pointing along the major or minor axis of this ellipse. And correspondingly when they are simply aligned there is we have clear, whether if they are aligned vertical or horizontal, there is a clear you see expansion or we can say the contractions are there.

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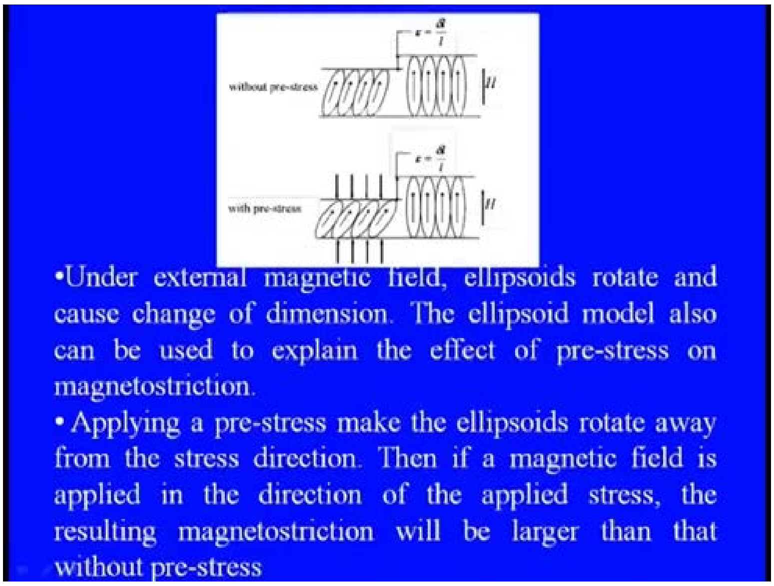

So, that when we do not have any pre stress, these things are being even that they are being arranged in this way, and when the pre stress, just like these pre stresses are being applied there, just to put in a compact way. Then you can simply see even under this what I mean to say this the magnetic field they are straightaway being arranged in this particular part. So, the pre stress is clearly causing the change in the direction even in the presence of we can say the magnetic field and in this case, there is a clear change, when the pre stress is there the change is even more significant along the major axis.

So, when we do not have any pre stress you see that, the magnetic field can generate the expansion certainly and this expansion can be encountered with respect to these strain part that is nothing but equals to change in length divided by the original length. But, when the pre stress is there that means, all the these ellipsoid elements, they are absolutely in the robust contact and when we now apply the magnetic field the expansion is even quite more. So, this is what you see the expansion size, and we have the strain which is quite significant as compared to the without pre stress concept, and we have you see delta l by l.

So, under external magnetic field the ellipsoid rotate, and because of this rotation there is a clear change in the dimension. So, the ellipsoid model also can be used to explain the effect of pre stress as we discussed here, and in this we simply got that, when the pre stress is being applied or when we have a pre loading feature, because of that some stress phenomena is there in the material side, we know that whatever the rotation is there, they are being away from the stress direction. And then you see when we are just trying to apply the magnetic field in the direction of these applied stresses or the applied force rather we can say the resulting magneto this action will be larger and then there is a clear cause of more extension than the without pre stress concepts.

So, we can say that these magnetostrictive materials, they are almost nearly all ferromagnetic material demonstrate these kind of property. But, the shape and the volume change is very small in ferromagnetic as compared to the magnetostrictive materials, because these ferromagnetic materials have the structure divided into magnetic domains, which can exhibit the uniform magnetic polarization.

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And this is what you see just bifurcating the ferromagnetic material from the magnetostrictive material, and when the applied magnetic field causes the rotation of these domains, then in return a slight shape change in their at the macroscopic level. So, that is why you see somewhat different feature is there in that.

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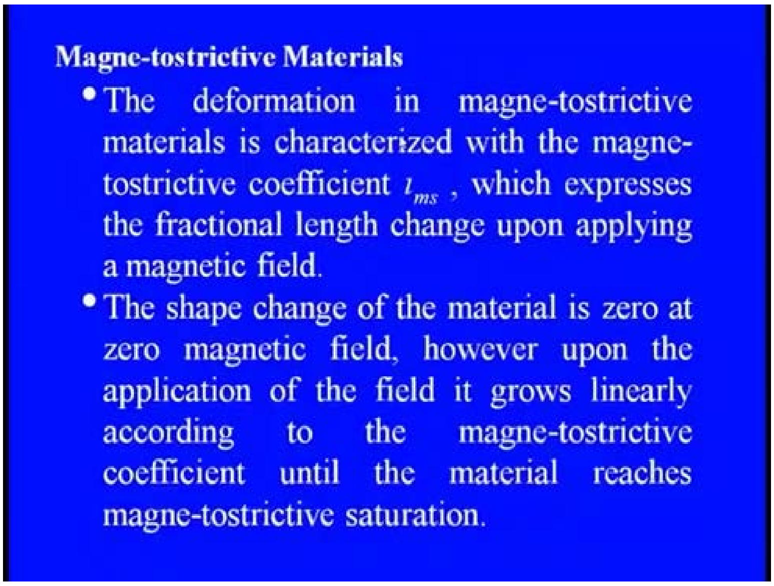

And when we just want to see the deformation in these magnetostrictive material, then we can simply characterize this with the magnetostrictive coefficient, which is straightaway coming from the fractional length change, when we are applying this thing.

So, we can say l this MS means the magnetostrictive part or something, but mainly you see here when the shape change of the material is 0 at 0 magnetic field.

We can say that the application of this flux on the expansion or on the orientation of these ellipsoid particles, it just grows linearly according to the magnetostrictive coefficient, until the material reaches up to the magnetostrictive saturation part. So, in this it is a clear feature that, it has to reach up to saturation and beyond that even we are giving the strength to our magnetic flux, there would not be any effect, means the H. We are increasing the H, but there would not be any effect in the contraction or the expansion of these materials.

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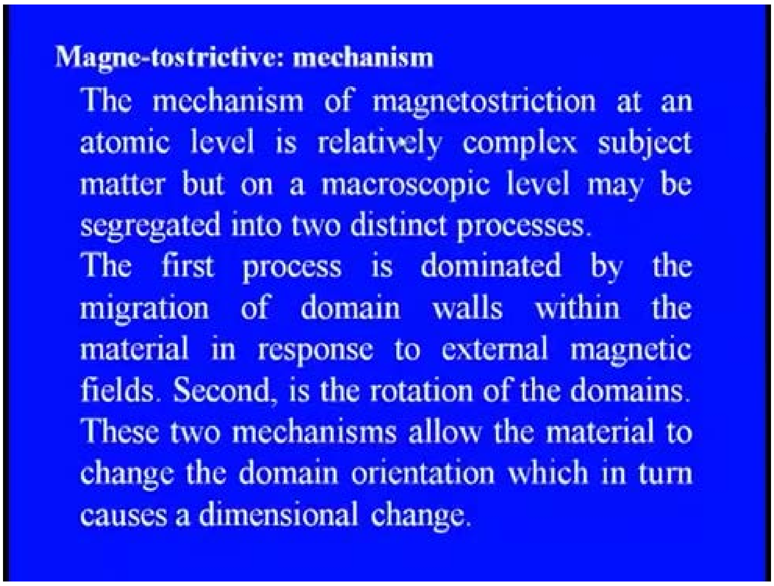

So, the mechanism of these magnetostrictions at an atomic level, is somewhat more complex, because at the macroscopic level we need to segregate this entire concept into two main feature. One in which you see this process are being dominated by the migration of this domain walls, within material in response to the external magnetic fields. So, we need to see that what kinds of migrations are being taken place at the macroscopic level of atomic part, when we are simply applying the magnetic field from outside.

And second we need to see the rotation of the domains, because we know that there is a clear rotation of the domains are there in which the molecules are being rotating towards that. So, these two mechanism in which one is the migration feature of the domain and one is the rotation feature of the domain, allow the material to change the domain orientation and because of that, there is a clear cause of dimensional change. So, we can justify the change in the shape of the domain, either by the migration feature of the entire domain or by rotational feature of the domain.

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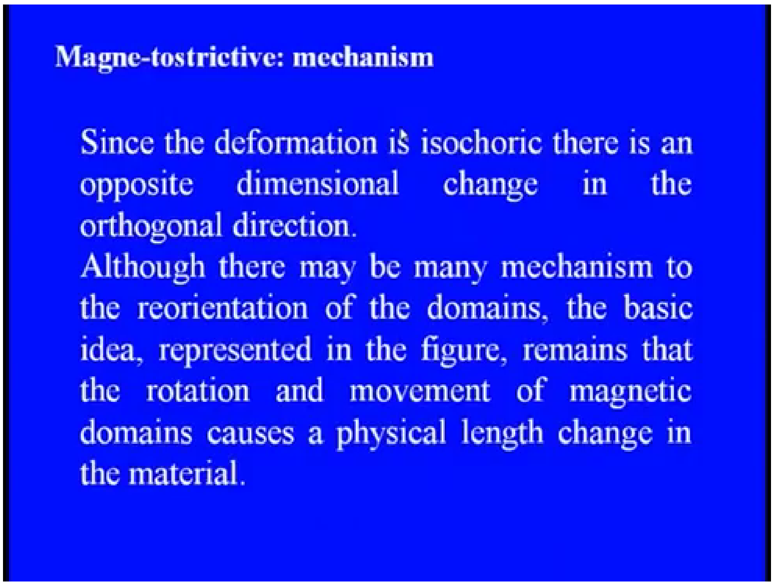

And since the deformation is isochoric, and there is we can say the opposite dimensional change is simply we can say in the orthogonal direction. Because, it is always being there, when we are applying the entire magnetic field, in the uniform environment, then whatever the changes are there in the special, we can say the deforming feature, it is always being there in the orthogonal direction. And even when it is being reoriented there are various mechanism, in which we are simply explaining that how the reorientation of the domains are.

But, here you see our main feature is to just give a clear understanding about that how the rotation and the movement of these magnetic domains are being there through, which there is a clear cause of the change of the physical, we can say the dimension changing in the entire material. Because, we know that these magnetic domains are always influencing the shape of the material, so that is why even for the this disorientation or the reorientation part, means when the magnetic field is being applied or when it is recovering part. There is a clear we can say this rotation or we can say the displacement, means the migration features are there of this domains, and we need to see that how this mechanism is working.

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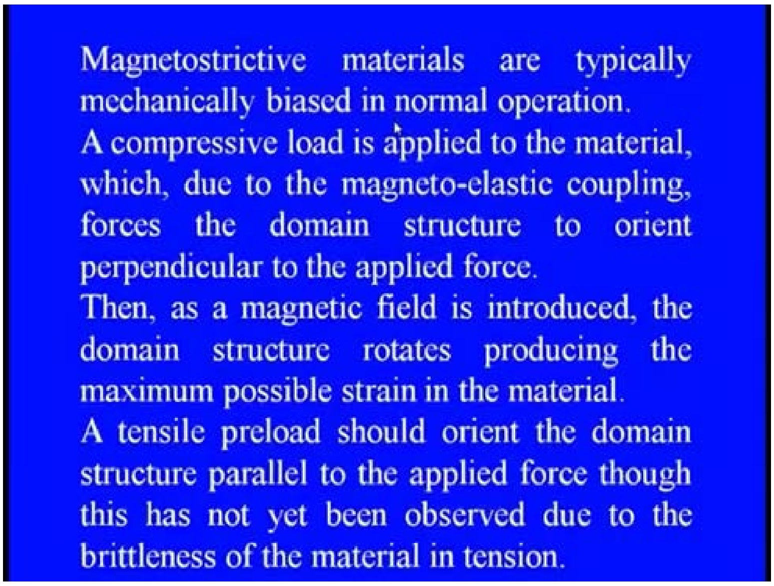

So, now we are taking that when these materials are being there under, we can say the normal operation and a compressive load is being applied to the material, which is due to we can say the magneto elastic coupling forces. And we can say when it is being magneto elastic coupling, whatever the forces which are being there in the entire structure domain, certainly being there they are acting perpendicular to the domain of these applied forces.

Or we can say whatever the main domain is there, so a magnetic field is introduced in this, and the domain structure rotates and producing the maximum possible strain in the material. So, a tensile preload should orient the domain, just we can say parallel to the structure and whatever the applied force is there, through which we can say that we cannot get the kind of the maximum strain in this. So, we can say that the brittleness or whatever the main property, makes this material more comfortable in the compression part and through which we can say that, we can generate maximum strain in these material rather than in the tension feature.

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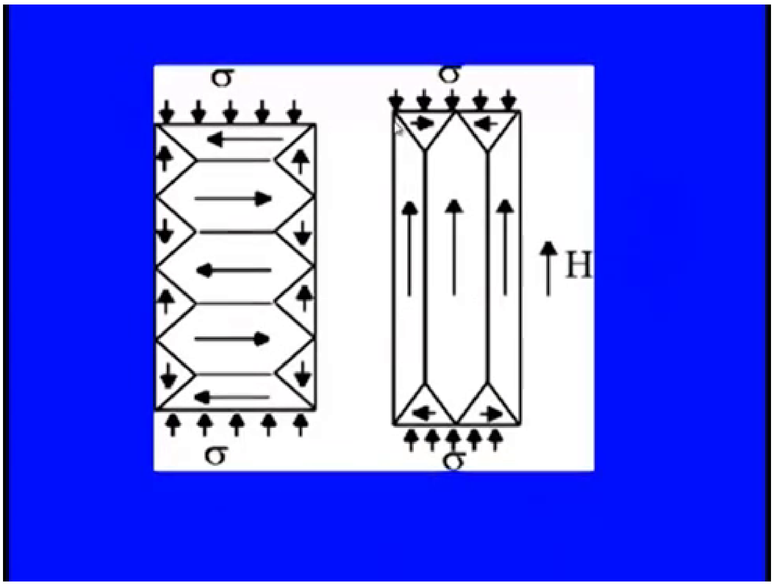

As you can see here this is clearly showing that, when you have these orientation the stresses are being like this. And when we are just making the compression, the first is showing the compression part and when the compressions are there, there is a clear the changes features are there. But, when even in both the cases, this is a well compression and whatever these shape changes are there they are quite significant in this cases. But, when we are applying the tensile feature, because of the brittle nature of the entire fibers or the material itself they are not exhibiting a maximum, we can say the strain feature in this. And in this cases you can clearly see that whether the orientation of these, the particles are like that or the orientation of these particles the ellipsoid or anything are these, we can get the maximum extension feature under this magnetic field part.

So, if you are just going with the basic principles, now this is what my the magnetic field which is being there either, we can say the AC or the DC part, these are the two clear features which are being showing. The AC, the AC strip magnetic induction which is BC, this subscript b c and when it is just targeting to the eddy current loops, these are all the my eddy current loops you can see that, which is clearly based on what the density part is there in the electrodes.

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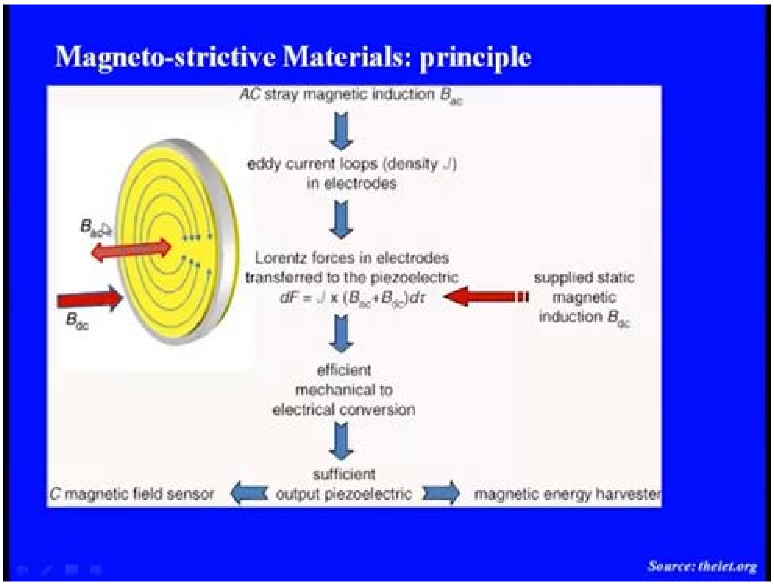

And because of this, then the Lorentz forces we can say electrode, transferred to the piezoelectric features by this formula we can say whatever the forces Lorentz force d F, just at the segment the d F is equals to j that is nothing but the density of the current into B this B AC plus B d c into d tau. So, we can say that this is being supplied the static magnetic induction, we can say B d c and when we have the Lorentz force with these, the electron electronic feature we can clearly exhibit an efficient mechanical and energy this conversations.

Means the exchange part right from the mechanical energy to the electric energy, along with these Lorentz forces can be efficiently exchanged. And when the things are being there, we can have the good output in terms of the piezo electric part and that can be create the magnetic field sensor, or we can say the magnetic energy transfer. This transfer features are being there, so both the things whether we are talking about the magnetic field we can say the sensor part, or it is being dissipated part can be immediately done by these piezo features of the entire. So, this is what you see the basic principle in which it is being working at the micro structural level, when the magnetic fields are being applied there. Then how the entire molecules are being worked, and the Lorentz force, which is being generated due to these they can be immediately transfer this in efficient way from mechanical to electric conversion.

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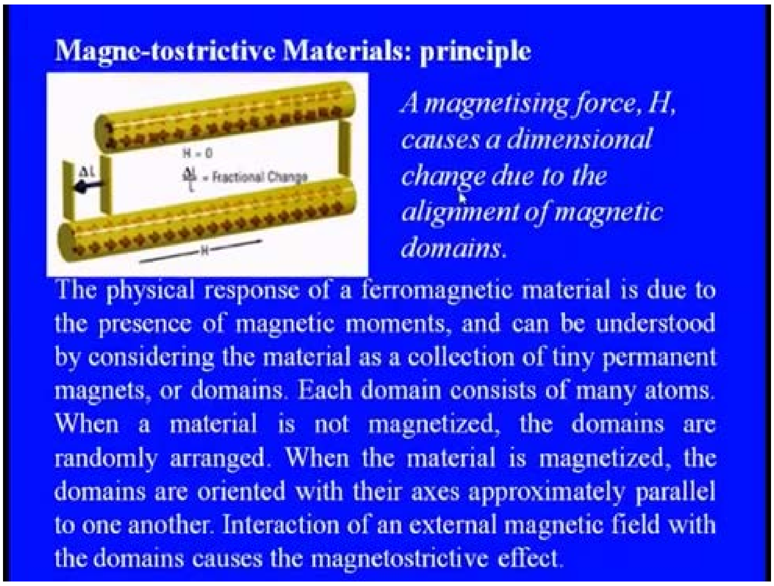

So, now in this particular diagram, it is a clear feature which is being exhibited there in terms of you see the magnetic force H, through which we can say that it is a clear change in the dimensional feature due to alignment of these magnetic domains. So, we have you see this part, if you look at this clear, we have you see this is the alignment of the molecules, there itself when there is. And then these are the different orientation, one is going like this, one is going like that and these, these all different orientations are there.

And you see the size of this entire is this l say, when the magnetic field is being applied say this one the H in this direction all these molecules are being this, we can say oriented towards whatever the this magnetic field is being directed. And then we have even the physical change in the entire parameter, so that is what we discussed, that you see this Lorentz force which are being there between these they are straightaway directed towards whatever these mechanical parts are there along with these molecules. So, the physical response of the ferromagnetic material is due to the presence of these magnetic moments and then we can say that it is all with consideration of all the material.

There is a clear collection of this tiny permanent magnets or we can say rather they are the domains, and when the material is being magnetized the domains are oriented with their axes approximately parallel to each other. Though you see right now we are showing through this diagram, that they are absolutely aligned, but sometimes you see according to the intensity and the effect on this micro structure they are approximately aligned in parallel to each other. And the interaction of this external magnetic field with the domain is clearly causing this magnetostrictive effect there.

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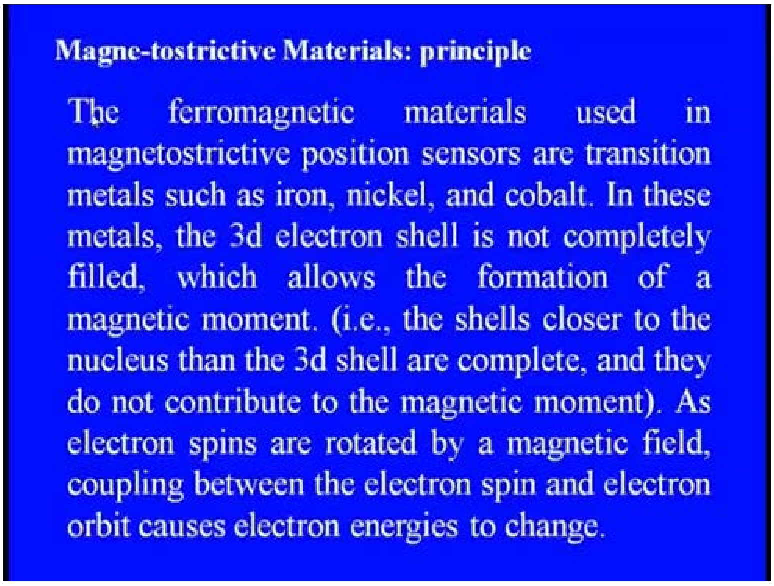

So, we can use these ferromagnetic material and these materials as the sensor, which are in the transition metal, such as the iron, nickel or cobalt, that can be the base metals are there. And in these metals the 3D electron shell is not completely filled, since they are all these 3D element they are not filled, they are allowing the formation of the magnetic moment, within this empty field. That means, you see the shell which is closer to the nucleus than the 3D shell which are being complete, they are simply, if they are being complete then certainly they will not contribute in the magnetic moment.

But, whatever the empty features are there, they will certainly cause the magnetic moment and they contribute in that. So as the electron spins and they are being rotated by this magnetic field a coupling between the electron spin, and the electron orbit, in the empty space. These spaces are certainly causing the electron energies to be changed, and then these changes on the energy is clearly showing by the exchange feature and since.

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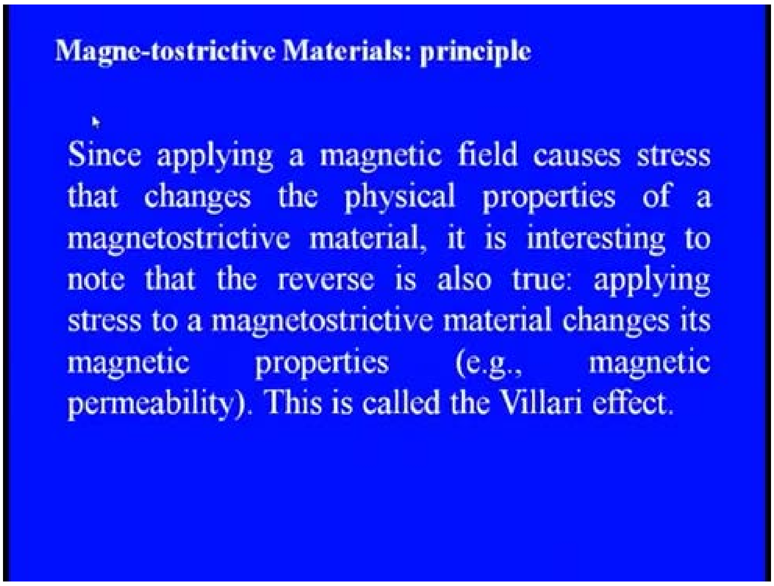

We are applying the magnetic field, through which there is a clear change means, whatever we are causing the stresses that through this, there is a clear change in the physical property of the magnetostrictive material. So, we need to see that, say if we are just going in reverse way, means when we are applying the stress to the magnetostrictive material and we need to see the changes, in it is the magnetic properties, like the permeability or the other things. We can say that what the reverse effect is there and this effect is sometimes is calling the, this villari effect.

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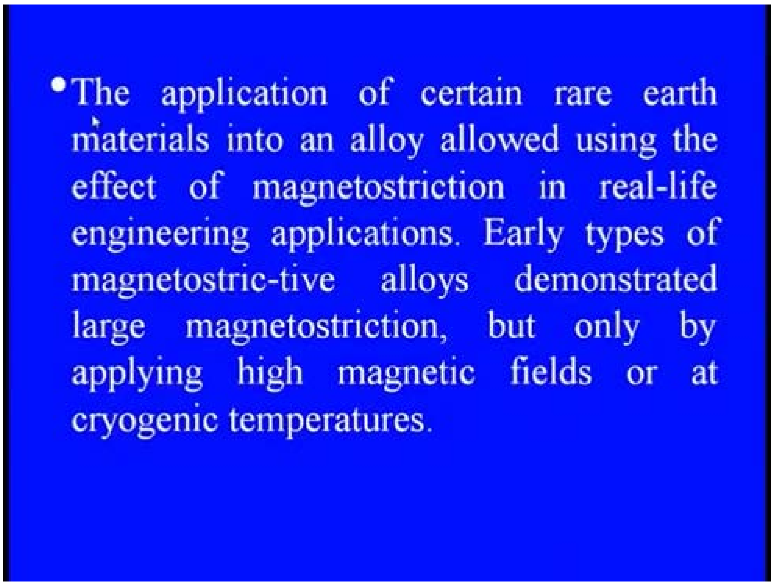

So, the application of certain rare earth material into the alloy allowed using this effect of magnetostriction, in the real life engineering application is really significant. So, we can say that they can even these alloys can demonstrate the large magnetostrictions, but again when we want to exhibit such things, we need to apply the huge amount of the magnetic fields. Or we can say we need to apply some kind of the cryogenic temperatures on that, then only we can see the feasibility of that.

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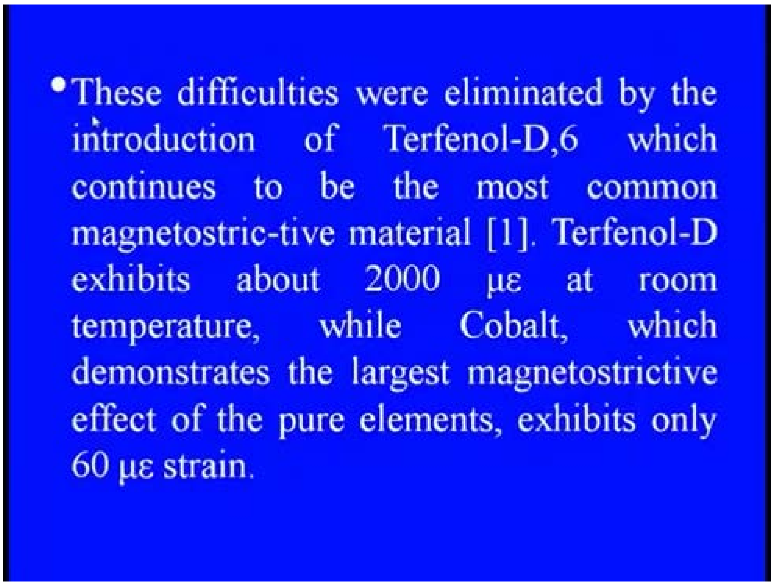

So, when we want to see these things, we can simply remove these difficulties by introducing the Terfenol-D, 6 which is we can say a continuous common type of the magnetostrictive material. So, Terfenol-D is always being exhibiting almost up to 2000 micron the strain at the room temperature, while we can say the cobalt which can demonstrate even large magnetostrictive effect of a pure elements, and they can exhibit you see almost up to 60 micro strain. So, we can exhibit you see right from 60 microns, we can say the shape change in the cobalt to 2000 micron shape change in the this Terfenol-D six.

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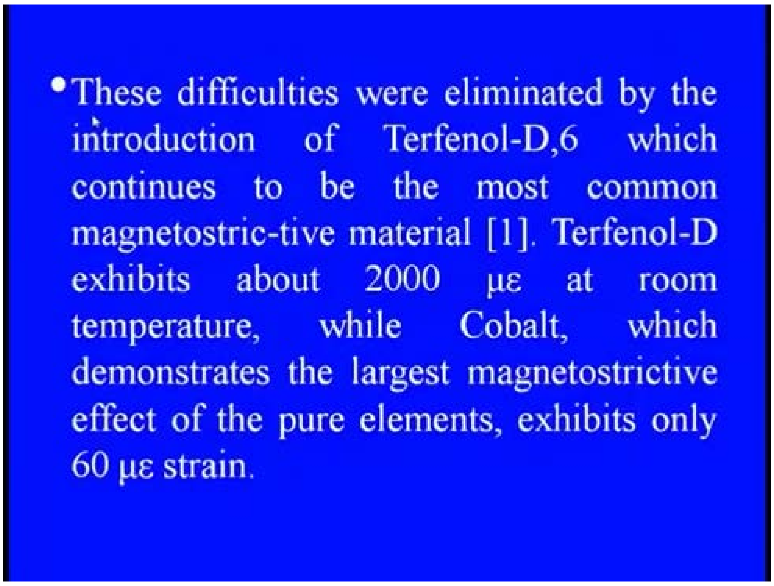

So, that what we have we have a clear this say Terfenol-D drive mode is there that means, it is here and then these the coils are there through which we can straightaway put together part. And then these are the permanent these magnets are there, this is what you see the preloading part, because we know that if you want an significant deformation or the shape change, certainly the pre loading springs are always being required and this is my output. So, when we are looking towards you see the piezo electric feature, then these are the we can say the arrangement of these our molecules.

And in these whatever the empty spaces are there, under the action of these magnetic field, there is a clear cause of the magnetic moment and because of that, with the electron spin. And with this whatever the rotations, and they are simply causing whatever the electric energies which are being changing into that, the shape part. So, these magnetostrictive materials which are clearly showing here that, when we are applying, this is what the alignment when we are applying the load, means the magnetic field there is a clear change in the length when they are being applied in a such a way that.

So, this is what my delta l and then I can get that what exactly the strain part is there, so this is the straight these Terfenol-D rods are there, that can be straightaway put here. And we can see a clear change even at the micro strain or at even this one, so you see even at the micro strain or the real structure, this is what the things are being happening, when the entire latest structure is being strained, according to the magnetic field is being applied there.

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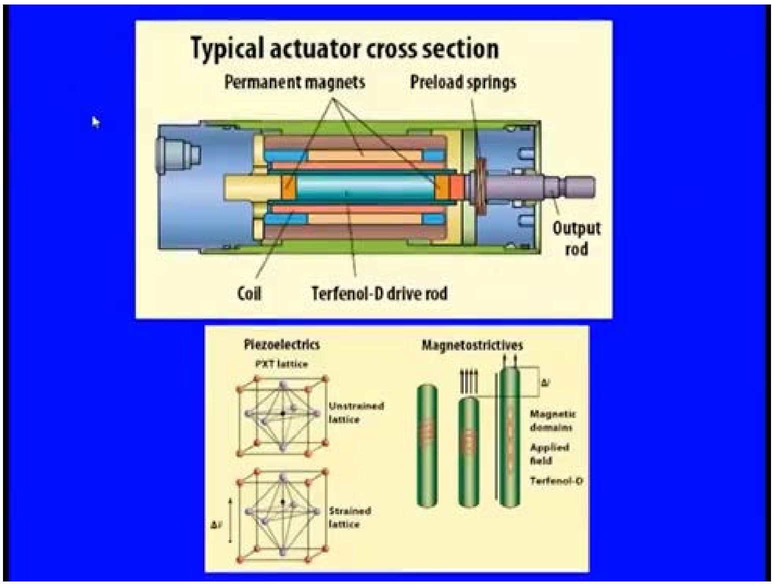

So, a typical this recoverable strain of the magnetostrictive material, just like for this Terfenol-D is in the order of almost 0.15 percent only. And the maximum response is presented under the compressive load is always being there, because of the brittleness. So, they are quite insensitive towards the tensile feature, and these magnetostrictive actuators have a long life span and that can be used for high precision applications. So, actuators which may be used in compression along with the load carrying elements are the perfect featured for this kind of materials. And in this the pre stressing the this actuators can also increase the efficiency and the coupling effect for this actuation features.

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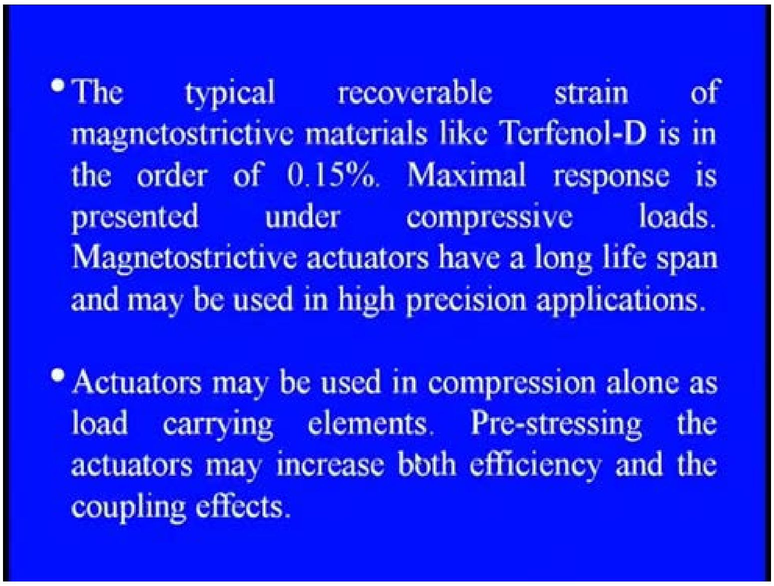

So, we can say that, these materials which have this anisotropic feature in the opposite direction, that can be straightaway shown either with the cobalt to we can say these Terfenol-D. Because, these material have a tremendous magnetic, anisotropic feature, and certainly it is required, because a very large magnetic field is certainly required to drive these magnetostriction features. So, we can say that you see when the anisotropic feature is there, so the recovery part is almost, irreversible as compared to whatever the extension features are there.

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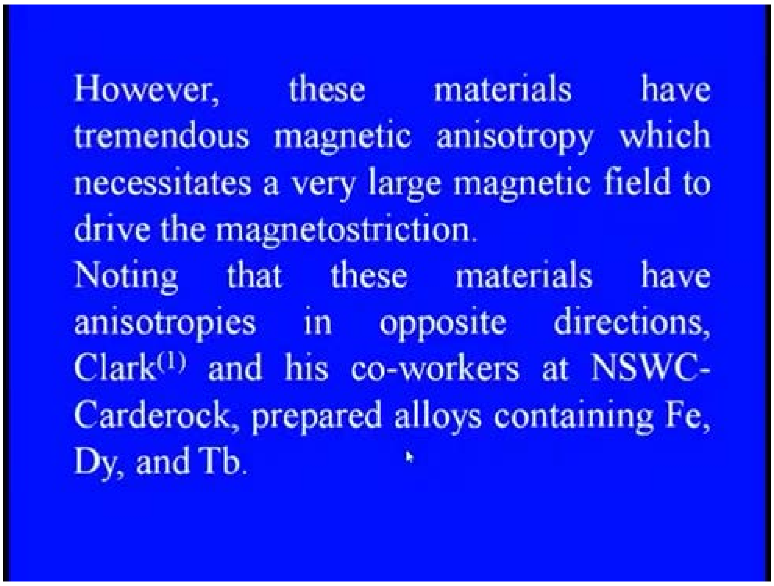

So, these we can say the alloys are generally a stoichiometry of the form of T b x D y 1 minus x F e 2, so that can be coined with the Terfenol-D, which is operating under the mechanical bias or the strain can be produced in the field of the 2 k O e at the room temperature. So, we can use this the Terfenol-D as a transducer or the actuator for many of the application, where we need the accuracy features.

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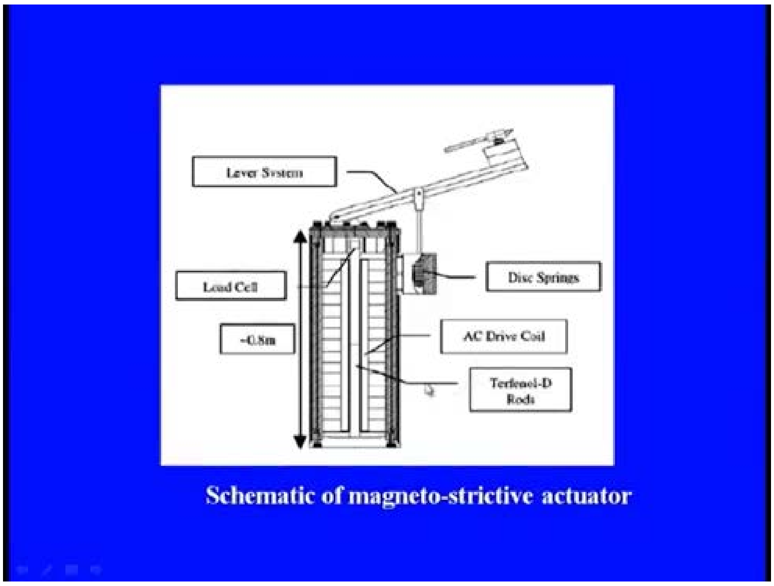

So, you can see that, this is what my actuator part is there, where the Terfenol-D is absolutely there in this middle, and we are absolutely applying this spring for pre stressed part. And then the through this load shell and these whatever the AC drive shell, now the field is being created, and it can be straightaway actuated towards that. So, we have a clear actuation feature there itself and this is almost in this particular arrangement we can say that, we can get in the actuation of the entire lever system which is being there on top of that up to almost 0.8 meter.

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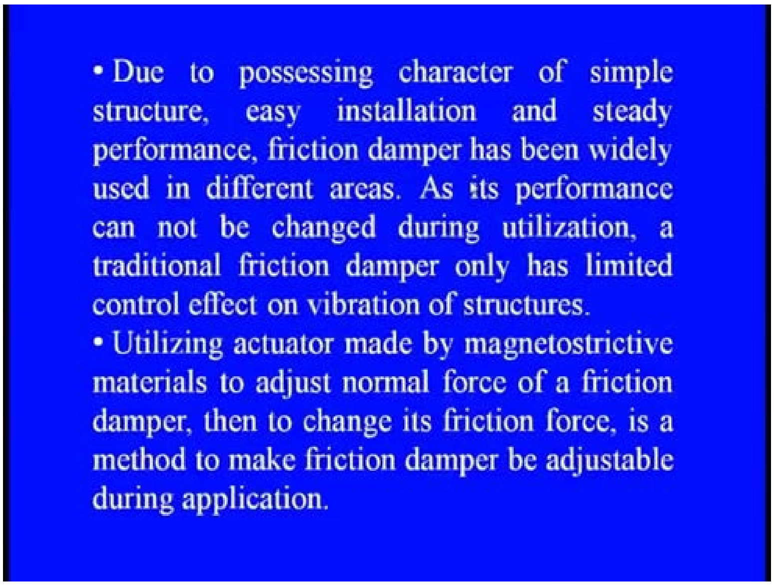

Because, due to possessing character of the simple structure, it is clear easy in installation as you can see that, and we can get you see the steady performance. They can also be acted as the friction damper, because when we are changing the orientation, they have the gap from where the magnetic moments are being created. So, the energy can be straightaway put there itself, so they can act as the friction damper towards that part. So, as its performance cannot be changed during the utilization and the part, so we can say that the frictional damper can be adopted there itself at the structure, where the vibration features are quite significant.

So, utilizing as the actuator made by this magnetostrictive material, we need to adjust the normal force of the friction damper and then we can say that, we can rather change it is, frictional forces which is something always adjustable, because of the simplicity feature in manufacturing of these magnetostrictive materials. So, this is the uniqueness you see here, they can be acted as the actuator part, they can be acted as the, we can say the damper part through which we can straightaway suppress, we can say vibration up to you see the low frequency part.

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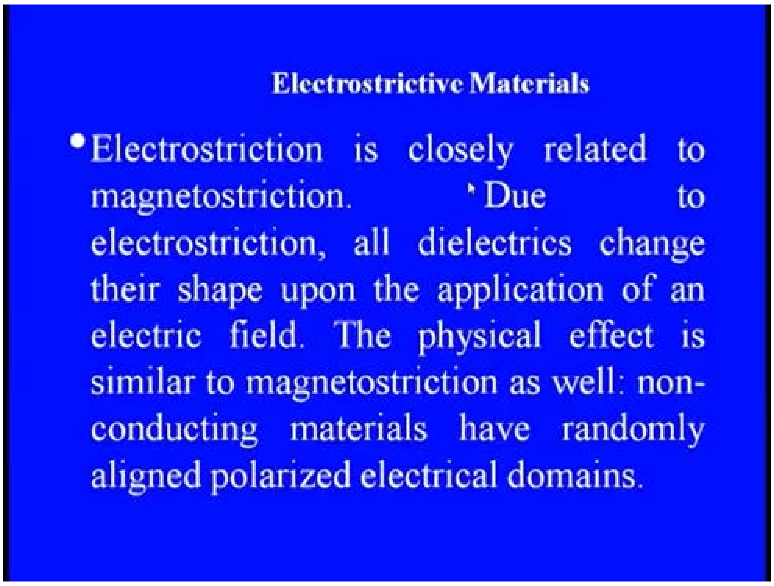

The second is coming as the electrostrictive material, the electrostriction is closely related to these magnetostriction, but due to this electrostriction all the dielectrics changes their shapes upon the application of the electric field only. So, we have the dielectric we can say these features are there with the elements, and they are changing their shape, when we are applying the electric field on the particular this specimen. The physical effect is similar to the same magnetostriction, where we can say that the non conducting materials have randomly aligned polarized electric domains.

That means, now we have a polarized feature with the electrical domain part in the particles and then when we are applying and even it is a non conductive material, and when we are applying these electric features then certainly there is a since outside there is a strong electric field.

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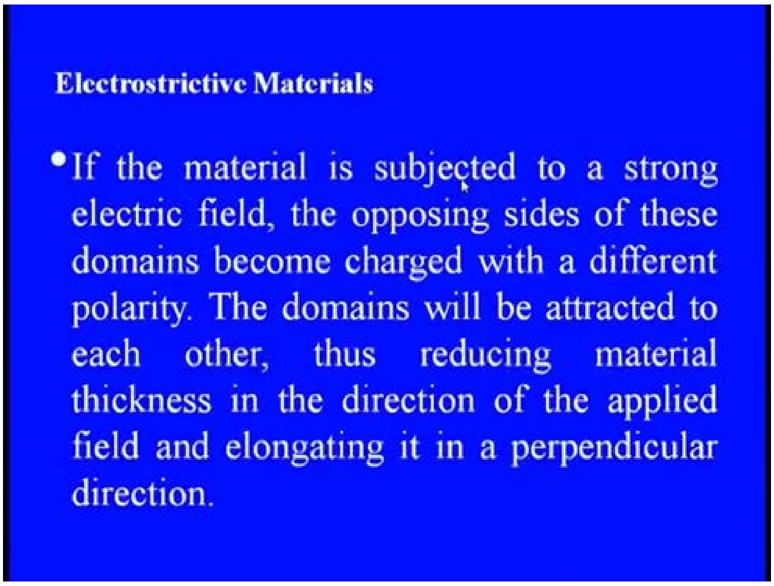

And the opposite sides of this domain, becomes now charged with the different polarity, so domains which are being attracted by each other, we can say that it is absolutely reducing the thickness of the material, in the direction of the applied field. Because, we are simply elongating, the entire we say the domains in a particular direction, where the field are being applied and there is a clear extension, but the thickness is, because you see here they are being randomly oriented. So, their thickness is being quite increase, but when they are being aligned along with the applied strong electric field, the entire elements are being we can say just approximately parallel to each other.

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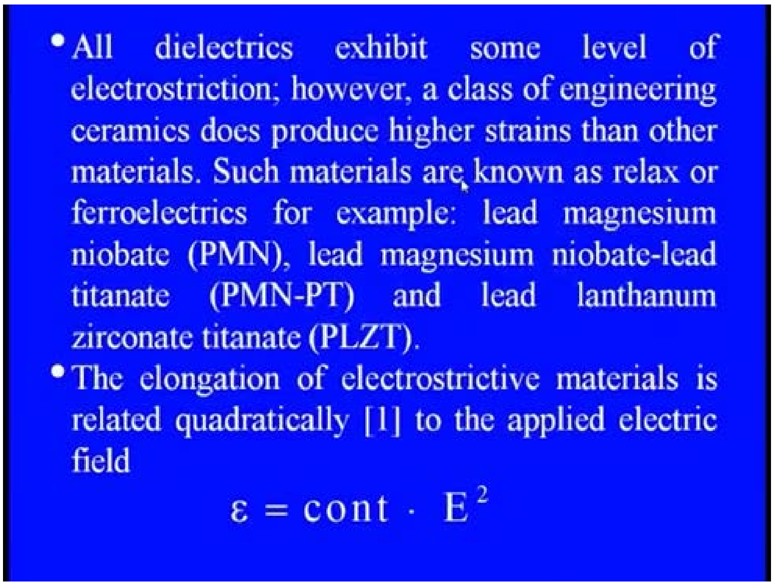

And all the dielectrics can exhibit the same level of electrostriction, and we can say that you see whatever the engineering ceramics, or the various features are there, in this ceramic part can produce the higher strain than any other materials or the polymers. And such materials, which are exhibiting such we can say the electrostriction feature, we can say they are somewhat the lead magnesium niobate, means PMN. Or the lead magnesium niobate lead titanium, because we need to when we are adding the lead titanium, the additional features, which can exhibit the strong part of the electrostriction part can be exhibited.

And also we can use the lead titanium zirconate, the lead lanthanum zirconate titanium the PLZT that can also be used as the electrostrictive material, because we know that when these ceramics which are producing the higher strain, even these materials can be known as the relaxed or the ferroelectric parts there itself. So, in this the elongation, which is being there under the application of this electric field of these electrostrictive material, can be explained by this strain is equals to one constant into E square.

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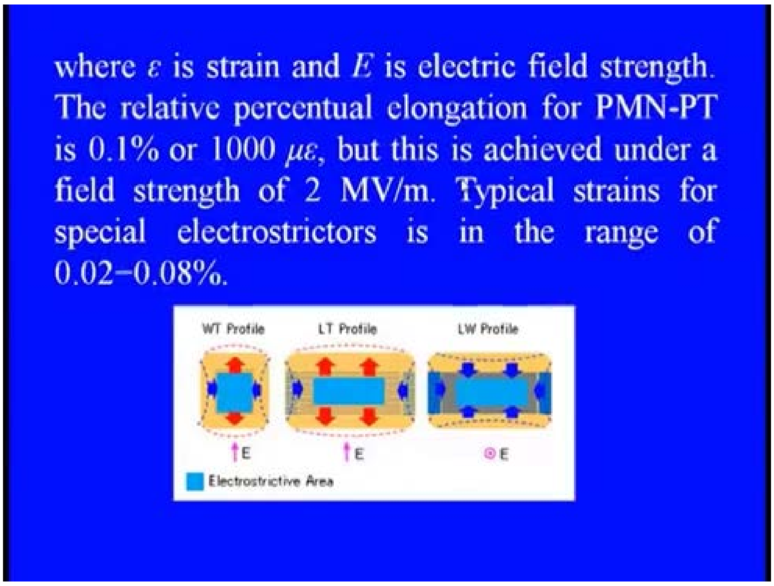

So, here you see whatever the strain which is being producing, we can say that it is showing highly sensitive feature with the non-linear impact of this electric field strength. So, we can say that, when the relative percentual elongation changes are there in PMN-PT, PMN-Pt is nothing but equals to the lead magnesium this niobate with PT means the lead two titanium. So, when the this PMN-PT is being using now, and we just want to see the percentual changes when the electric field is being applied, we can say it can be right from 0.1 percent to...

Or we can say it is almost going up to the 1000 micro strain. and can be achieved this much you see the strain when the field strength is of 2 Mega volt per meter. So, it is always being causing some kind of the electro strain part is almost 0.02 to 0.08 percent, so that this is what you see, this greenish area is clearly showing the electrostrictive areas when they are being under these the field part. So, this is what my electric fields are being applied in all three cases, and when we are going with the different profiles, then that we have a clear variation in the sizes of the electrostrictive areas.

So, when the electric field and these his WT profile is there, we have a clear variation in this direction, and when we have the LT profile there itself, then certainly you see here it is a clear extension part. And when we are simply applying you see the LW profile, then certainly we have these kind of features in which there is a clear the compression part, at the particular we can say electrostrictive area. But, outside this is a clear we can say these features are there, the compressive part. So, in all we can say, there is a clear change in the strains are there as we can simply see the whatever the profiles are being concerned with the electrostrictive areas.

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So, now, you see here when these materials in which we have both the magnetostrictive, and the electrostrictive concepts are there. We can see that there is a clear change in their properties, means towards we can say the deformation or the shape change, when the fields are being applied. And they can be simply act as the actuation feature rather and also sometime they can be acted as the damper part. So, magnetostriction is nothing but as we discussed the changing of materials physical dimension, with respect to the whatever magneto fields are being there, or we can say this is magnetizations.

Or in other word we can say that, a magnetostrictive material will certainly change it is shape when it is being there, under whatever the magnetic fields are there. So, as we discussed you see lots of he cobalt, to the Terfenol-D they can be straightaway shows this kind of this particular part. And sometimes we can say that one which is being achieved the giant magnetostrictive, under relatively small field we can say this is one of the specific part, which can be used as you see the vibration control feature.

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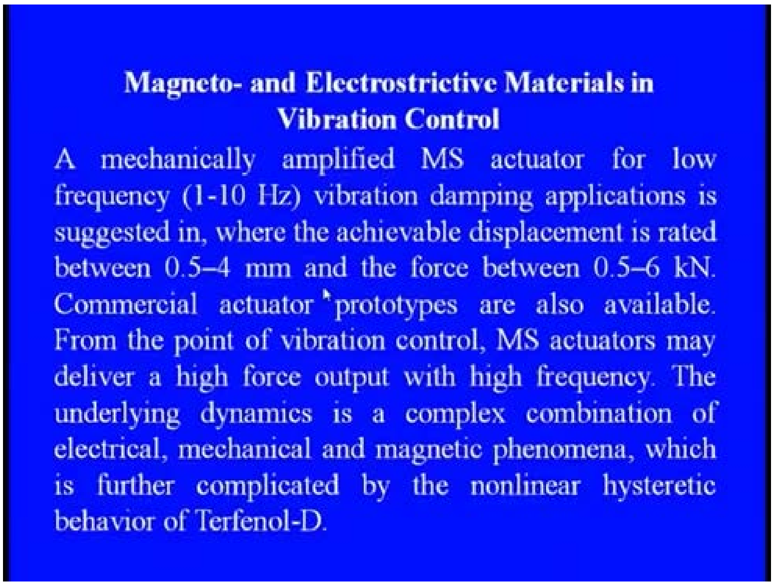

So, now we are just talking about the vibration control, we can say a mechanically amplified these MS, the magnetostrictive actuator for low frequency, just 1 to 10 Hertz. A vibration damping application is absolutely featured out from this, where we can achieve the displacement is almost rated between 0.5 to 4 millimeter, and we can even apply the force of certain 6 kilo Newton's. So, we can say that lots of these MS actuators are being available, which can deliver the high force output with the high frequencies also.

So, either whether we are going with the electrical mechanical or any this magnetic phenomena, we can simply use this concept the MS actuator, but we need to understand this with the using of the non-linear hysteresis behavior of the Terfenol-D. Because, we know that when they are being loading or unloading conditions are there, there is a clear loss is there and this loss is not the linear, this is the non-linear feature.

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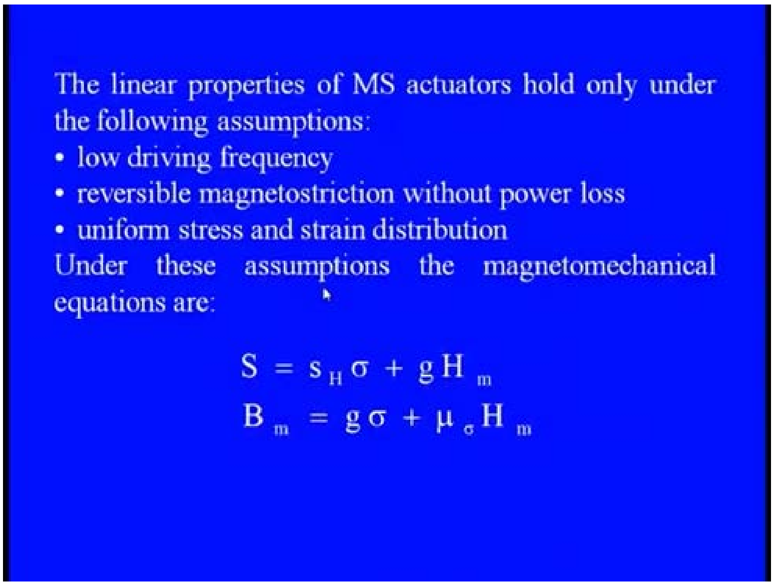

But, when you see when we are trying to set up the relation, we can simply assume the linear property of the MS actuator, and it is it can only be hold, when we are assuming the low driving frequency of the entire system, whatever the exciting frequencies are there. Then we need to assume that there is a clear reversible magnetostriction featured are there, without having any power loss, when we are just adopting the loading and unloading features.

And then it needs to show that is what you see we are assuming the uniform stress. and strain distribution. And when such things can be achieved, then we can say that, there are two main equations which can be clearly relating, the magnetic field whatever you see the frictional features there itself. And then you see here the this we can say, how these stress and strains are being there, so it is S equals to S H sigma plus g H m that is 1, one. Second is B m equals to g sigma mu into H m, where we are saying that the S H is nothing but the strain.

And we are trying to see the strain is nothing but equals to the stress into S H, S H is nothing but you see a constant, which makes the compliance feature, means we have you see what the compliance part is there when we are applying the constant magnetic field strength H. So, this is one part S H into sigma, the g which is nothing but the coupling part.

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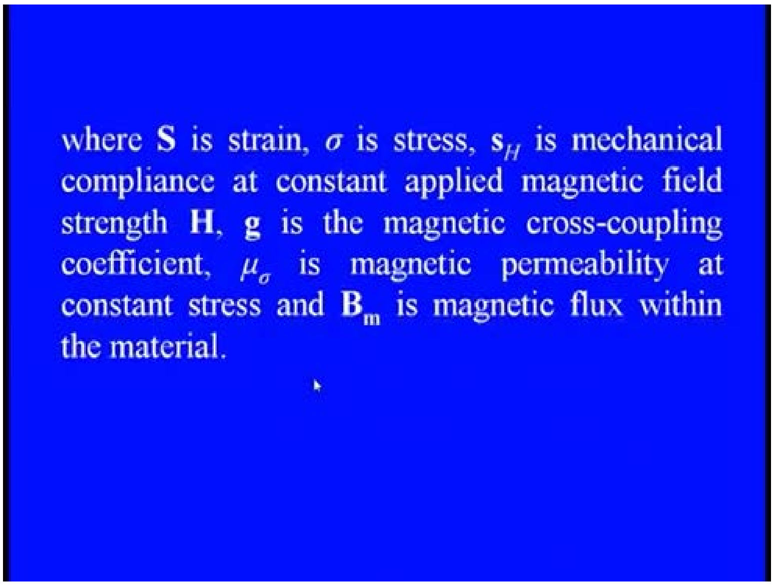

And this magnetic cross coupling coefficient is always being there, that how it is being attracted at the interfacing part and into H is nothing but equals to my what the magnetic field strength. So, the first equation is clearly making the relation between the magnetic field strength, to the stresses with these two coefficients. And second the equation which clearly exhibit that what is the magnetic fluxes are there within the material, is nothing but equals to the cross coupling feature into the stress, means how the cross couplings are there.

And then how the stresses are being generated within the molecular feature plus mu into H m, H m is my magnetic field strength and mu is the magnetic permeability. that is the inherent the material property, which always we are considering that, when the constant stresses are there the mu into sigma, constant stresses are there we can simply get the magnetic permeability feature of the magnets.

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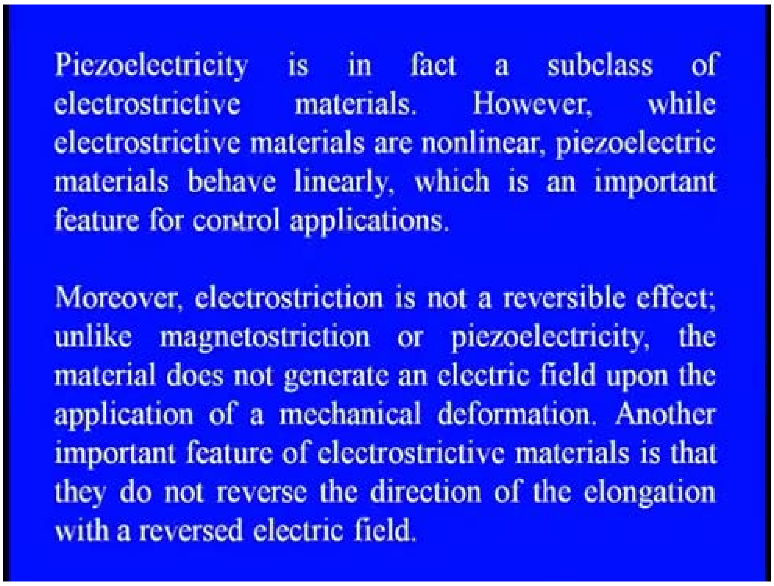

So, in this you see here, we can say when the things are being happening, the piezo electricity is being featured out which is in fact, you see a subclass of these electrostrictive materials. And when electrostrictive materials are non-linear, these PJT, materials, piezoelectric materials behave linearly and then we can say that we can straightaway apply this feature for the control applications. And also this electrostrictive concept is not a reversible effect, as just like the magnetostrictions.

Or even we can say, just like we have seen that this piezo electricity is there in which the material is always going in a linear formation. So, we can say that, the material which does not go under the deformation, when the electric field is being applied, we can say it is some kind of the restriction provided by this material against this one, and also this electrostrictive material. they do not reverse the direction of the elongation when we are reversing the electric field.

So, when we apply the strong electric field, and when the entire orientation is there we have the extension feature in these materials. But, when we are decreasing and when we are even going towards the reversing feature of the electric field, it is not going in the compression part, so you see here the reverse effect is not at all there itself.

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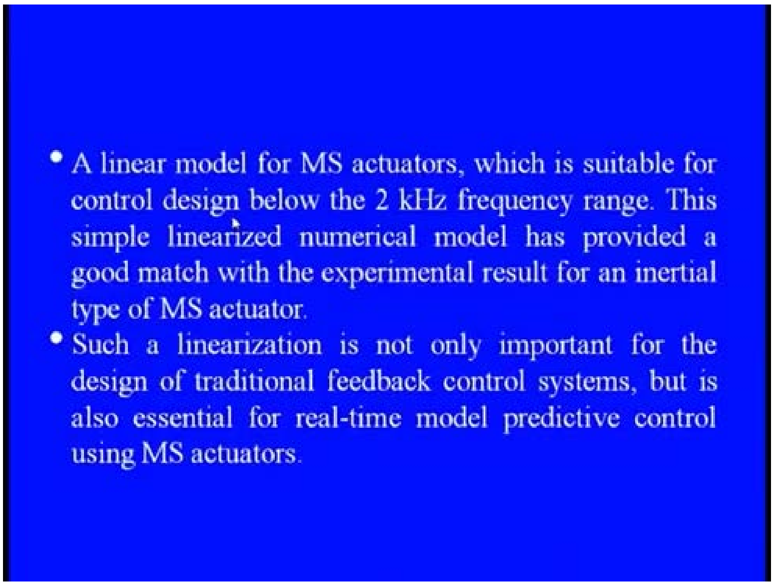

So, we can say that you see when we want to design, the controlling feature we can go up to 2 kilo Hertz frequency range to control that. And we can say that, we can straightaway apply in some of the experimental features for an inertial type of M s, M s actuators through which we can at least control or we can say actuate the things. And since, we know that the linearization is not the feature for these magnetostrictive or the electrostrictive materials.

But, when we are adopting the traditional feedback, control system, we can at least you see trying to reduce the error, whatever you see the desired and the actual outputs are there. And we can try to make proper control on this, so now we can say that, we can straightaway adopted these this M s actuator.

But, the main thing is that we need to couple with the hysteresis and the nonlinearity effect, when we are actually adopting this actuation feature or actuation displacement from this MS actuators. Because, we know that the MS actuator is clearly showing the linear actuations, so when we are trying to make this with the actual part, we need to coupled these thing with the hysteresis laws and the nonlinearity feature in this. So, the Li et al, Li and their associates, they simply exhibit the behavior of this MS actuator, in one of the composite shell experiment.

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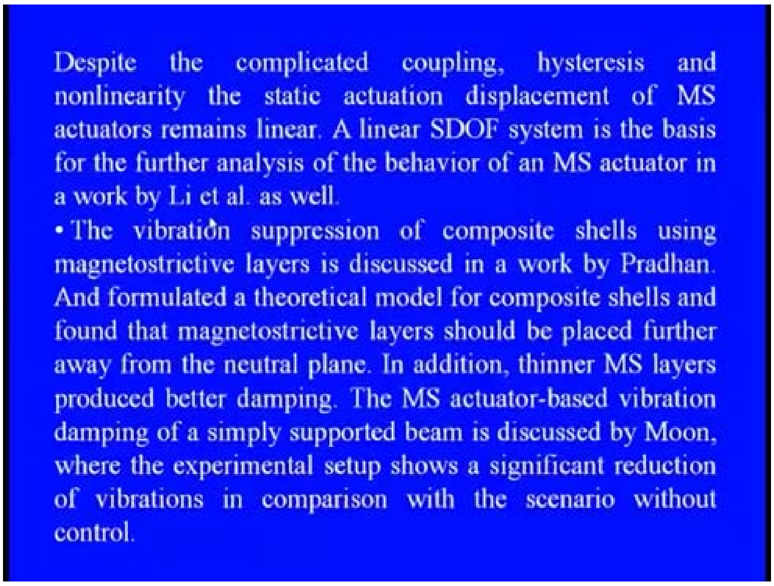

And even the few of the experiments have been done by the Pradhan and in they were simply showing, that what exactly the vibration suppressions are there, in their own composite shell. When they are using the magnetostrictive layers, in these shells and through that there is a clear suppression of the vibrations. So, they have framed the theoretical model for these composite shell, and they simply showed that, there is a clear along with the this neutral plane. When these magnetostrictive layer, when they are simply putting, in such a way that they are just away from this, this MS layer can produce a good damping feature there itself.

And MS actuator which is based on this vibration damper part of the simply supported beam, is also discussed by the moon, and in his work simply showed various experimental setup. Through which he simply showed that, there is a clear significant change means the reduction, in the vibration especially in the comparison of these other materials, with we can say the scenario without having this control. That means, you there is a clear effective control is there, in the beam part when the layers are being adjust with these magnetostrictive layers part.

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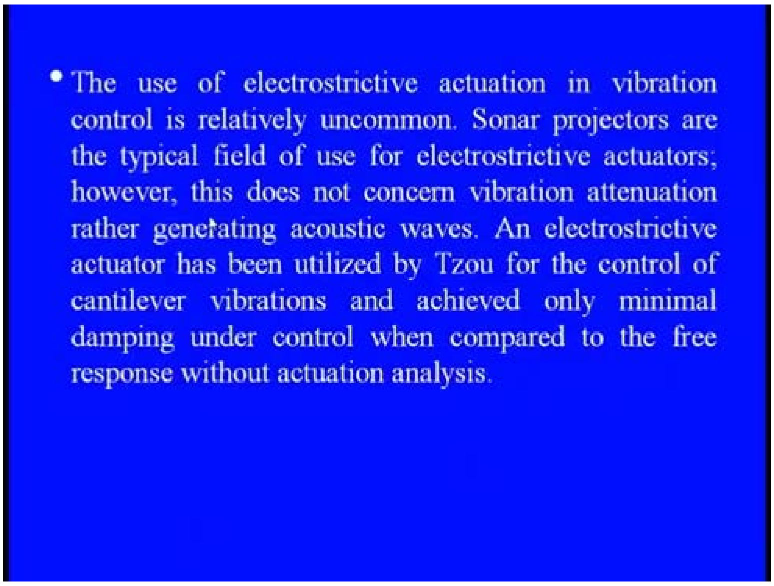

So, these the composites are clearly showing the vibration absorber feature in that, so we can say the sonar projectors are the typical field for the use of this electrostrictive actuators, in which the vibration attenuation, rather than the generation of the acoustic wave is a significant part. So, the lots of work has been done in this cases, and they are simply showing that, whether the magnetostrictive or the electrostrictive material, they can be successfully applied in the damping, as well as in the actuation part together.

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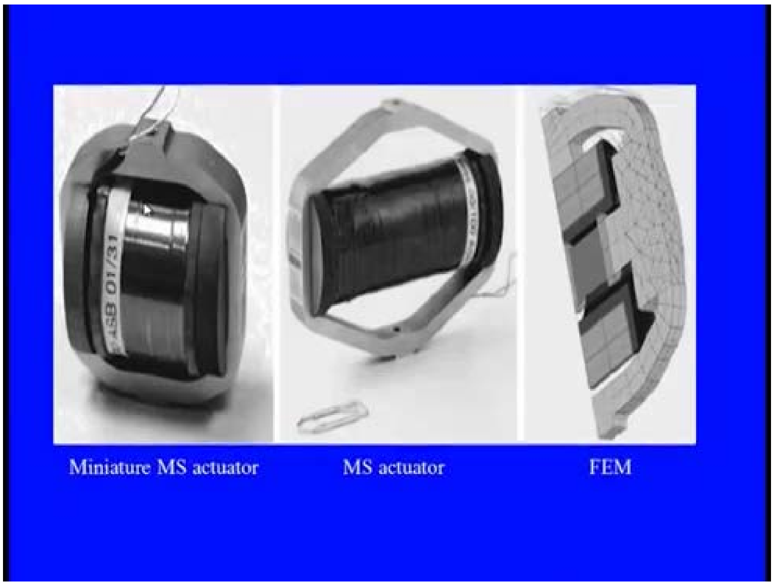

And then you see here, whatever the kind of say even for low frequency vibration or even we can say whatever the forces are being generated, through actuation it can be even amplified with this. So, as you can see on the screen, we have the miniature MS actuator, and these actuators are in the any of the forms, according to you see what kind of the applications are there, where the field and the load applications are required. And then you see it can be solved using the finite element method even, they can be mathematically formulated, the experimentation can be done using this magnetostrictive or the electrostrictive material layers composite feature. And then can be performed to see that how much vibration suppressions are there, for how much actuations can be formed from these parts.

So, in this lecture you see here, this still much of the research is going on and the materials are being framing, not only with the ceramics part, but also now they are simply checking with, whether it can be framed in the polymers and then it can be acted like that or not. So, this composite kind of a structure with the magnetic and the electric field, the magnetostrictions and electrostriction this concept can be explained and can be framed into the real materials, which is being there in the recent time.

So, this is all about this the magnetostrictive and the electrostrictive materials, how they can exhibit, what the concepts are there and then here, how we can use for specially the vibration suppressions. So, in the next lecture now, we are going to discuss about the new type of material this, which is also coming under the category of the smart materials, named as the shape memory alloys. In this we are going to see that how the shape changes are there, as we know that you see even, if we are applying you see any electric or magnetic field, there is the polarized molecules are there.

And accordingly they can be rearrange themselves and can get the shape changes, but the name itself speaks that the shape memory that means, these materials have their, they can memorized themselves pre and post effect of these part. Means pre and post applications, they can be refreshed or reframed them self into their original shape; so the shape memory concept and the shape memory alloys materials, are going to be discussed in the next class.

Thank you.