Vibration Control
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Module - 7
Principles of Active Vibration Control
Lecture - 4
Piezoelectric Accelerometers

Hi, this is Dr. S.P Harsha from Mechanical and Industrial Department, IIT, Roorkee the course of Vibration Control, we are mainly discussing about the Principles of Active Vibration Control. And in that you see the further category is the Piezoelectric part, so we discussed about that put exactly the piezoelectric materials are in which you see, the integrated feature means you know like we can say that, it can be act as a sensor it can be act as a actuator.

And the material itself has this potential to even the part of these even in the sensing or like the sensing of the acceleration or any part you see here can be immediately judged out. So, in the last lecture we mainly discussed about the application of these piezoelectric materials, right from even the generation of high voltage or the power source, to the sensors or the actuators or in for many other applications. Where there is a direct coupling of these piezoelectric materials are being suitable or we can say they are more compatible to that.

And even we discussed about the piezoelectric accelerometers, and there are lots of you see you know like we can say, the properties are there through which we can say that they are more compatible. This shear mode system in the piezoelectric accelerometer is one of the most significant for measurement of the vibration at the sensitive level, the high sensitivity level. And also when even the environment is of more severe from the acoustical way or from you see here, the humidity way or from even the temperature transient features.

So, we discussed all three types whether we are just talking about the shear or whether we are talking about the flexural or the compression mode of this accelerometer, under the piezoelectric material category. And then even we discussed about that how we can use these piezoelectric accelerometers, right from their application point of view means what is the criteria, and what kind of you see the property which we can look, while we are choosing the piezoelectric accelerometers. So, now even you see in this chapter we are further you see you know like categorizing, the various other properties of these piezoelectric accelerometers, based on these piezoelectric actions of the material under active vibration control.

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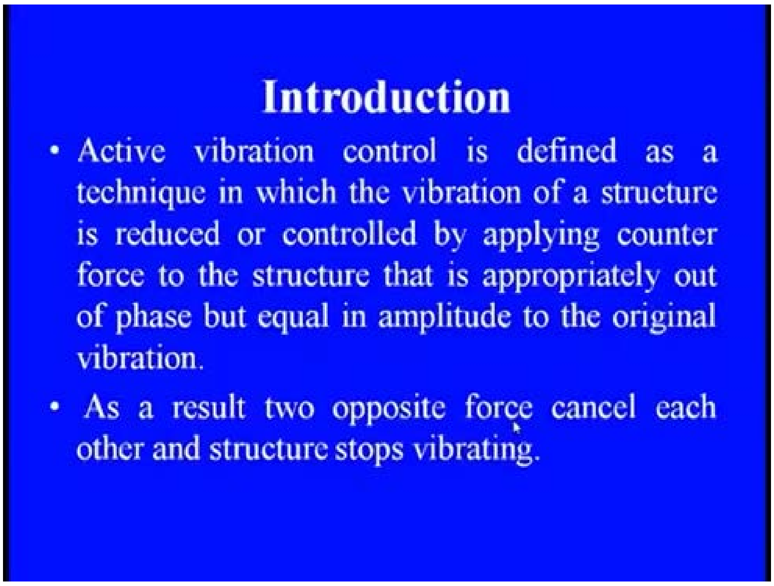

So, as we know that this active vibration control is nothing but you see it is absolutely based on the technique. In which the vibration of a structure is reduced or controlled by applying a counterforce to the structure that is appropriately out of phased, but in equal in magnitude to the original vibration. So, ultimately you see we need to just put up two opposite force which are cancelling each other and the structure is just stropping through this, you know like the oscillation or vibrating features. So, we can say that, that how we can sense this force, and how we can produce this through the actuations, the you know like the negative force that is basically coming under the smart structure technology or we can say some intelligent technology.

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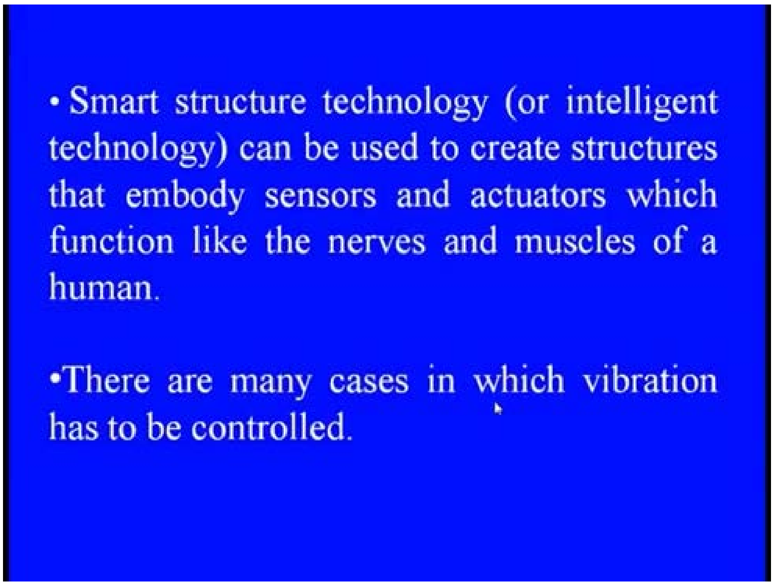

Through which we can create the structure that embody sensors, and actuator which functions like the nerves and the muscles of the human. Because, we know that both are just based on the sensing feature, and the actuating feature from the muscles itself in a human body. So, there are many cases in which the vibration can be straightaway controlled using this concept. So, we are saying that the smart structure which is a human body is a smart structure straightaway, when any sensing feature is coming immediately the actuation part is there. And we can simply find out that you know like, the action which is to be required there itself, and that is there in the you know like almost you see 1000's of the micron seconds.

So, when we are talking about the smart structure they have been actively studied, not only in. You know like these static or these you know like the simple machines, where it is there in the production floor from the power sector, to even the aeronautics and the space field, where one of their constrained feature is the weight and the space. So, the solid actuators can be used in these fields, generally produced only a small displacement, but when the force is very high. And by incorporating these actuators in the main structure, the variety of application just like you see, like we can say for the facilities, the building, transportation can also be you know like an integral part with these incorporation of the actuator with the structure.

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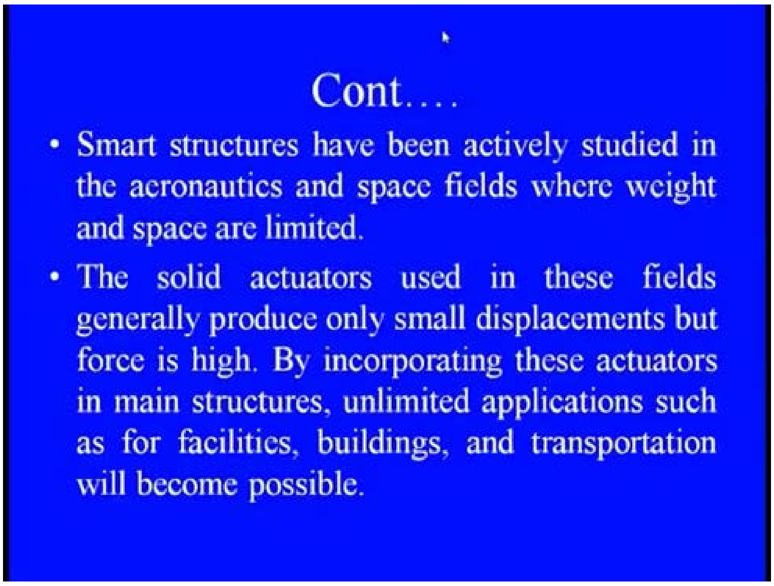

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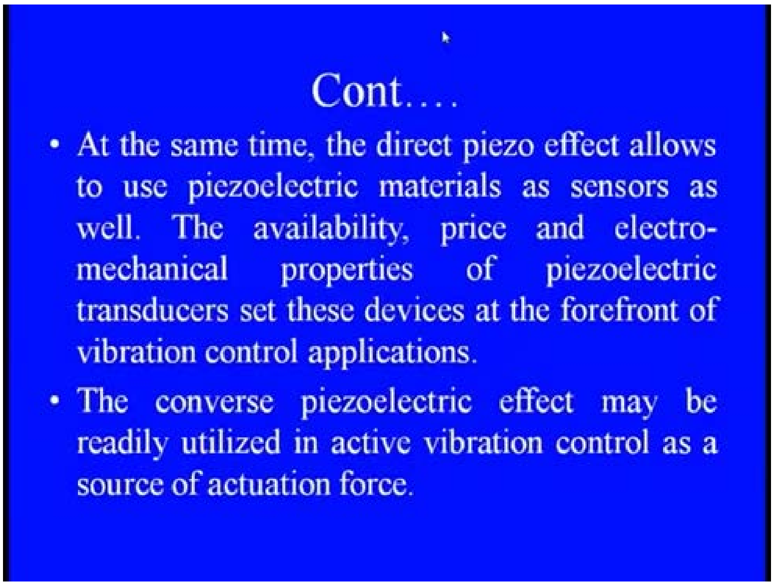

And the same time, the direct piezo effect which allows to use the piezoelectric materials as the sensor, can also one of the specific part of this piezoelectric feature. And we know that, you know like because of these availability and their wide range of applications and you see the sensitivity part, nowadays for vibration control, this piezoelectric features are being on the top most. And the converse piezoelectric effect may be readily available and they utilize in the active vibration control as the source of this actuation force.

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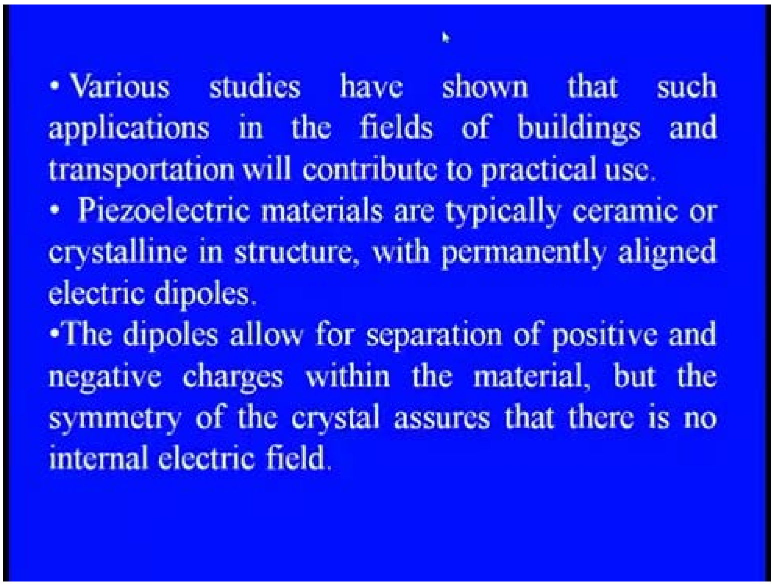

So, we can say that, that can be immediately apply to various buildings or the transportation that is being used for that. And these piezoelectric materials are typically we can say, the ceramic which we discussed or the crystalline in the structure with permanently aligned with the electric dipoles. And then through that you see here, both the actions can be carried out together.

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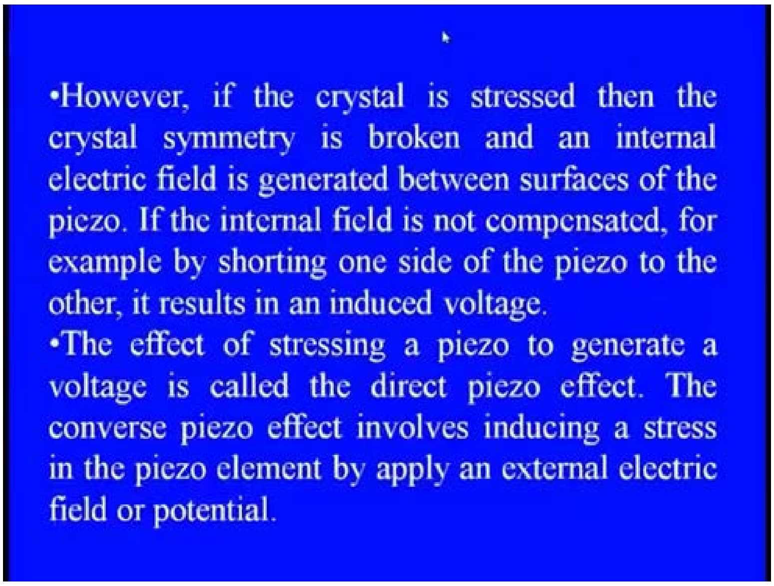

But, if the crystal is stressed then the crystal symmetry is broken, and the internal electric field is generated between the surfaces of piezo. And if the internal field is not compensated say for example, the you know like the sorting one side of piezo to other it result an induced voltage. And the effect of these you know like we can say, stressed the effect of this stressing a piezo to generate the voltage is sometime, we are saying that this is the direct piezo effect. And the converse piezo effect involves inducing the stress, in the piezo element by applying an external electric field or we can say the potential part in that.

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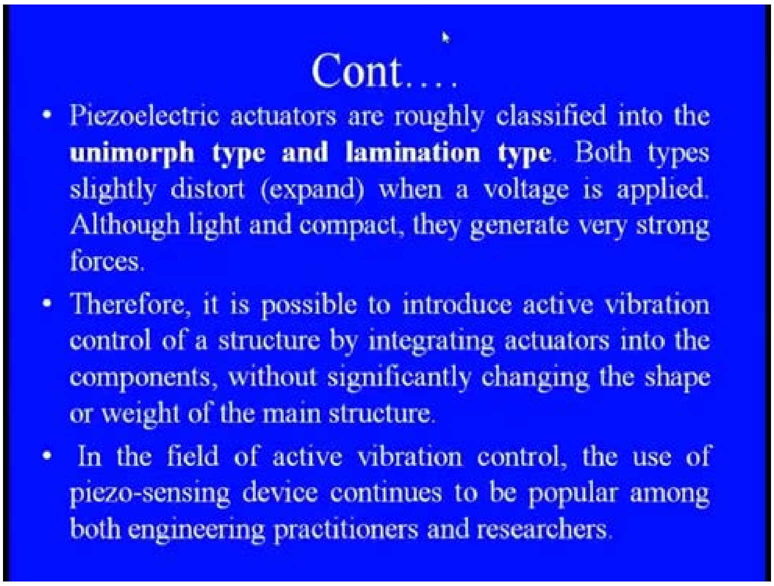

So, piezoelectric we can say actuators are roughly classified into the uniform type, means you know like we have the unimorph in which you see you know like the things are being different, and we have the laminated type. And both the type, slightly we can say you know like the distort or expand when the voltage is being applied to the system. Although light and compact, they can generate a very strong reactive force, and that is why they can be act as a actuator part. So, we can say it is possible to introduce the active vibration control of a structure, by integrating these actuators into the components, without significantly changing the shape or the weight of the main structure. So, we can say in the field of active vibration control the use of piezo sensing devices, continuously to be popular in both part whether we just want to be act as a sensor or actuator right from, the researcher point of view or practising engineer point of view.

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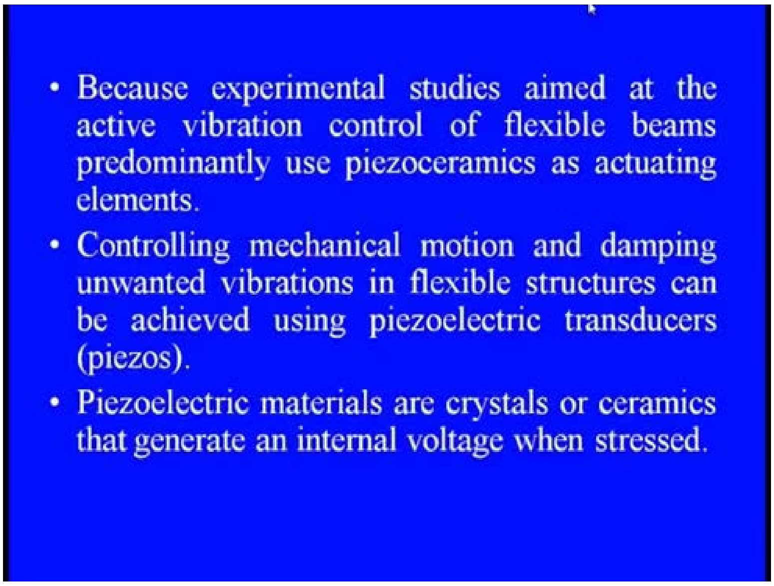

Because, we know that the study shows that active vibration control of the even flexible beams, predominantly use piezoceramics as an actuator element. And controlling this mechanical motion and dampen out the unwanted vibration, in the flexible structure can be even achieved accurately and within the sensitive feature, using this piezoelectric transducers. So, piezoelectric materials are the crystal or ceramics through that you see here, we are just generating the voltage when they are being under stressed.

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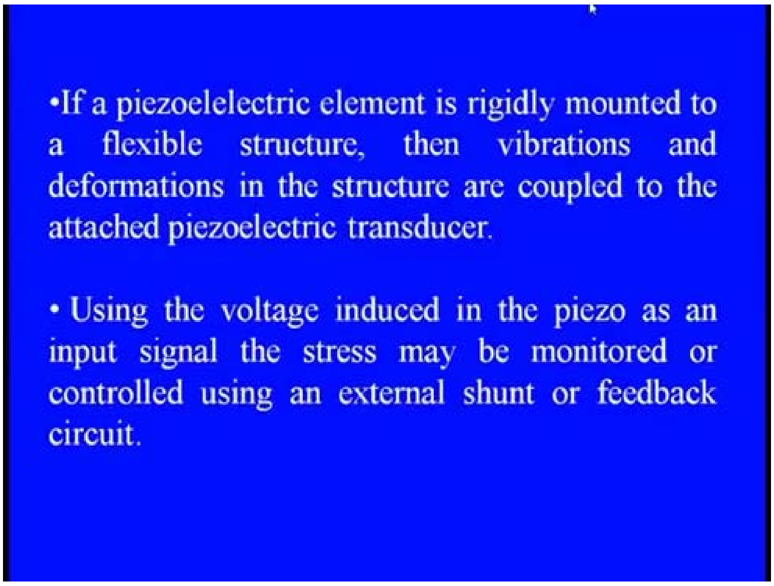

And when we are simply you know like mounting on the flexible structure, the vibration and the deformation in the structure are coupled to the attached the piezoelectric transducers. And using the voltage induced in the piezo as an input signal, the stress may be monitored or controlled using this we can say external shunt or we can say the feedback circuit. So, this is what you see one of the specific application point of view, where we can directly coupled this system together.

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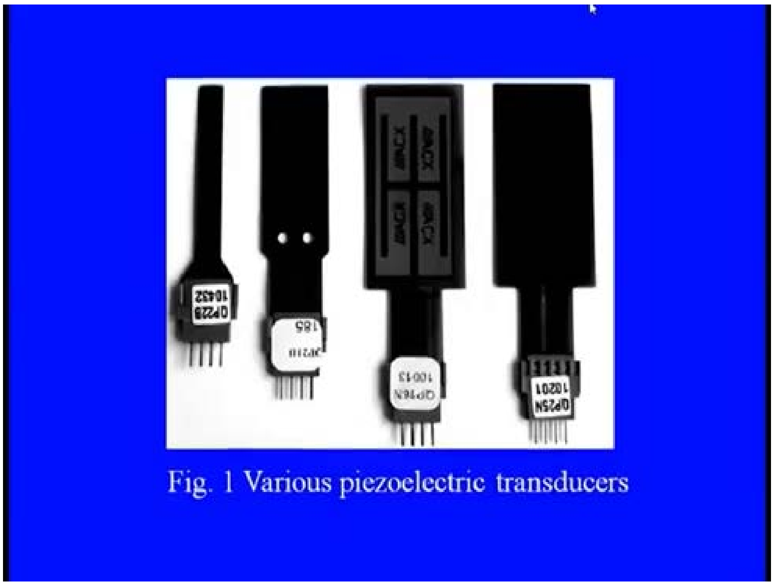

Fig. 1 Various piezoelectric transducers

So, you can see that these are the various transducers which are being there, and which are being straightaway applied to these surfaces. So, you can see this is what you see the first part, which is simply you know like a thin based plate is there, and then you see these are nothing but you know like the piezo featured part is there, which can be straightaway coupled the entire surface. So, whatever the mechanical motions are being there, the deformation can be straightaway sensed out.

So, either of that whether you see you know like you can see that, they are all been manufactured by the companies of various dimensions. So, that whatever the deformation of even microns level to macro level, the voltage of low level to high level can be immediately sensed out, and can you know like generate the whatever the required features are.

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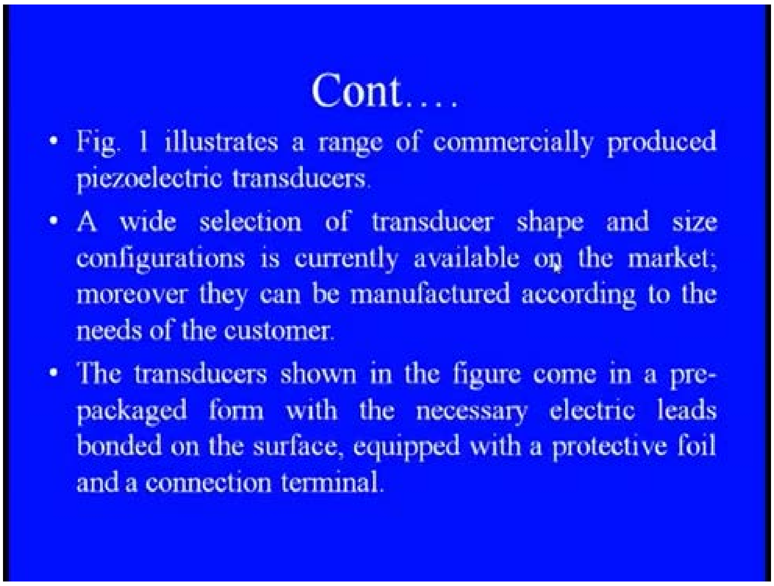

So, wide selection of these transducers are just you know like either, we can say shape and size configurations, can be straightaway adopted. And you see what the mounting features are there of the machine, they can be immediately adopt. So, we can say you know like these transducers which I just shown previously, in a pre packaged form with necessary electrical leads, which are being bounded on the surface are simply equipped with the protecting foil and the connection terminal. So, that you see you know like a whatever the these sensing features are there, immediately sensed out may be in terms of the strain or in terms of the voltage. And immediately transmit to the we can say recorder or for analyzer.

So, the longer transducer pictured at the bottom which was marked by Q P 4 5 N, and the transducer on the right side which were marked by the Q P 2 5 N contains two layers of piezoceramics. And these layers can be used either with the same input signal, to achieve the larger actuation force or one layer can be utilized as the actuator, while other can be used as the sensor to achieve near perfect collocation part. So, this is the beauty of these things you see here that we have the two different layers.

So, in that since you see here the one layer can be acted as the sensing feature, and other layer can simply you know like actuate the system at the same time. And to use the piezo as the either a sensor or actuator for vibration control device, we need to see that it should be rigidly mounted to the vibration sensing part.

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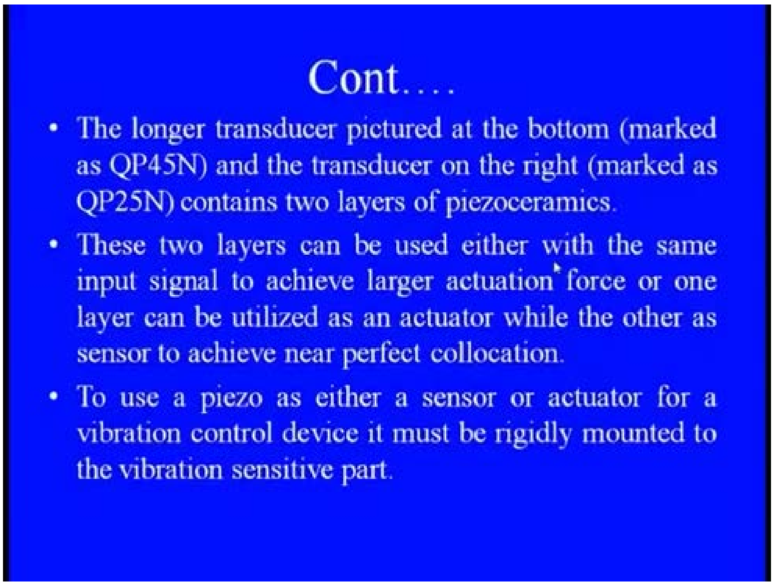

So, that there should not be any transmissional you know like we can say error is there, on then you see here we need to check it out that whatever is the transmission through the metallic surfaces are there when the vibrating mass is there, it can be immediately sensed out in the sensitative level. And then you see here the proper correction through this actuation force, through this actuator can be acted to the system for effective vibration control on these vibrating sensitive part.

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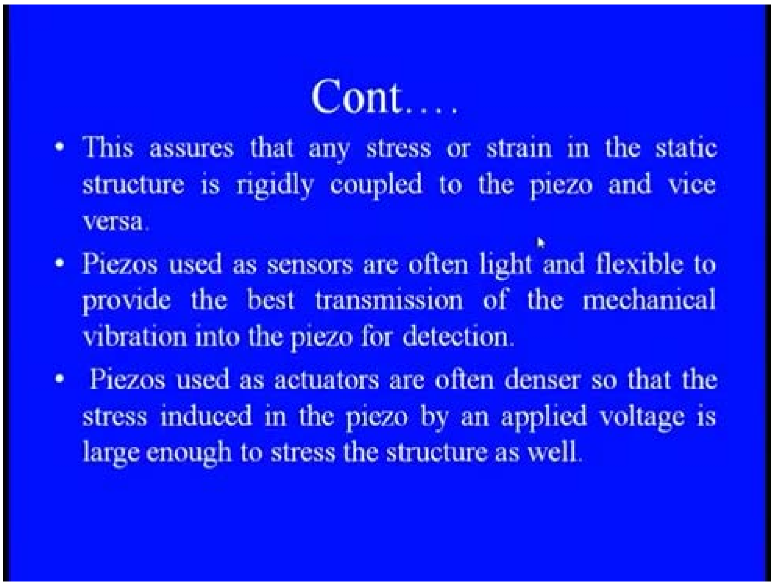

And we know that this assures that any stress or the strain, in the static structure is rigidly coupled to the piezo. And then proper electric field can be generated or else you see here, it is rigidly coupled with this entire structure when the voltage, you know like generated fields are there, so that properly mechanical strain can be generated in that. So, piezo used as the sensors are often light, and flexible to provide the best transmission to mechanical vibration, into piezo for detection of the accuracy of the exciting frequency or the amplitude towards that.

So, piezo used as actuators are often denser, so that the stress induced in the piezo by applied voltage is large enough to the stress structure as well. So; that means, you see here we need to check it out, that the piezo which are using as the sensor certainly often, the flexible and the light part for the proper transmission, and when the piezo used as the actuator often denser, so that the proper we can say you know like the stress to you know like provided towards the entire structure. So, this is the beauty of the piezo's that you see, how we are applying how you see the application are being featured out, with the sensor and actuator part.

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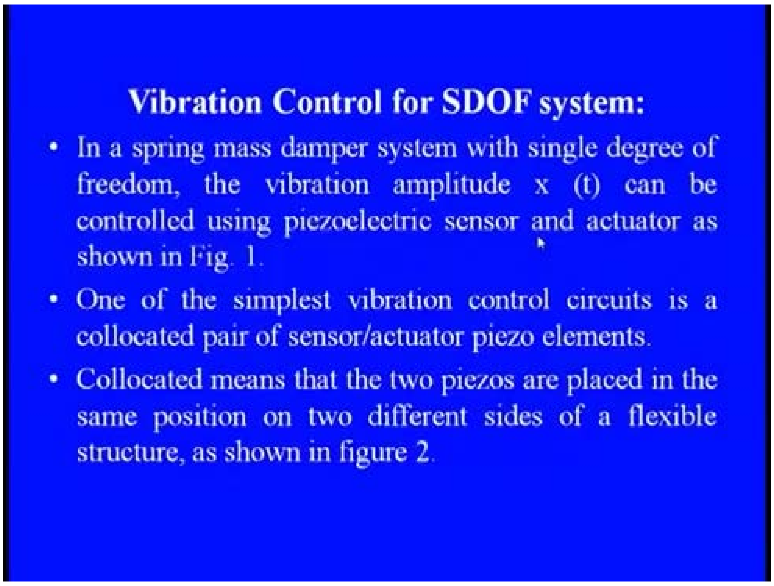

So, when we are trying to control the vibration for single degree of freedom system, we know that in the spring mass damper part. In the single degree of freedom system there is a clear single degree of freedom say x of t is there, in which the vibration amplitude is being featured out with the displacement part, and if we want to control this x of t because now since we have only one orientation where the vibration is being allowed the entire mass.

Now, if you want to control this using piezoelectric sensor and actuator, which I am going to show you the next you know like diagram. The simplest circuit is to be provided just to collocate the pair of sensor and actuator, piezo elements and also with the entire control units. And this collocated means, the two piezo's are being placed at the position the same position on two different side, on the flexible structure. So, that at one point we can sense, and on other point that can be actuated that can be you know like the force can be actuated from that part.

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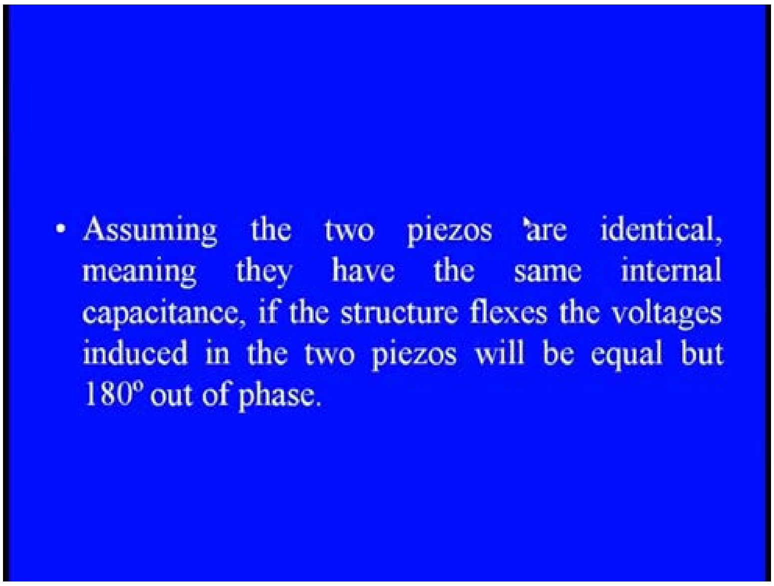

And we are assuming that the two piezo's they are simply identical, meaning that they have the same internal capacitance. And if the structural flexes are just you know like the voltage inducing, then in the two piezo's will be equal, but since we are just acted these things as a sensor actuator, they should be 180 degree out of phase. And we can keep you see in a two opposite directions on the same part.

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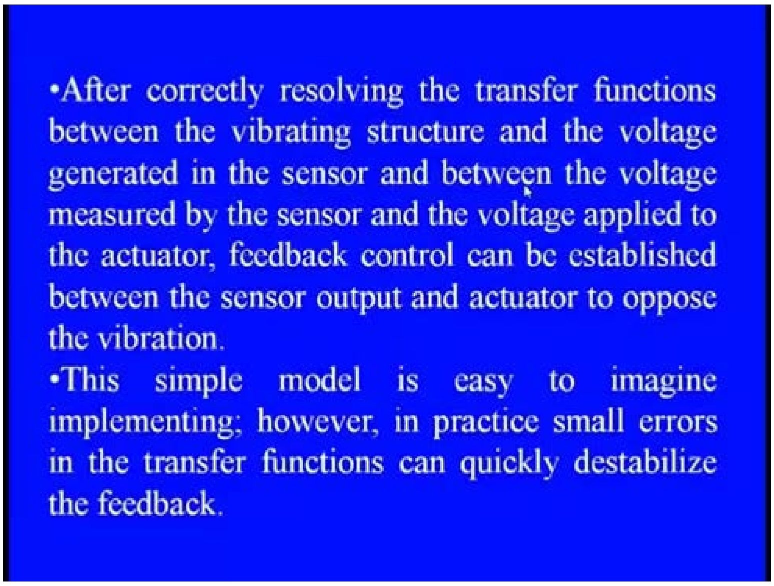

So, after correctly resolving that transfer functions between the vibration structure and the voltage generated, in the sensor between the voltage measured by the sensor. Then we can say that the similar voltage applied to the actuator, the feedback control can be established between the sensor output. And the actuator to oppose the vibration to cancel out the vibration excitations, and this simple model is easy to imagine implementing.

However, you see you know like we can say that, there are you know because it is when we are framing the system. When the entire actuation part is there, and the sensing part is there and we can simply frame the feedback control to establish between the sensor output, and you know like we can say the actuator input part. Again you see here there are lots of we can say the practicing smaller errors are there, in the transformation function. And which can be even you know like we can say, stabilize or we can say destabilize the entire feedback system. So, we need to check it out that what exactly the error functions are being generated, when such actions are being happened during that time.

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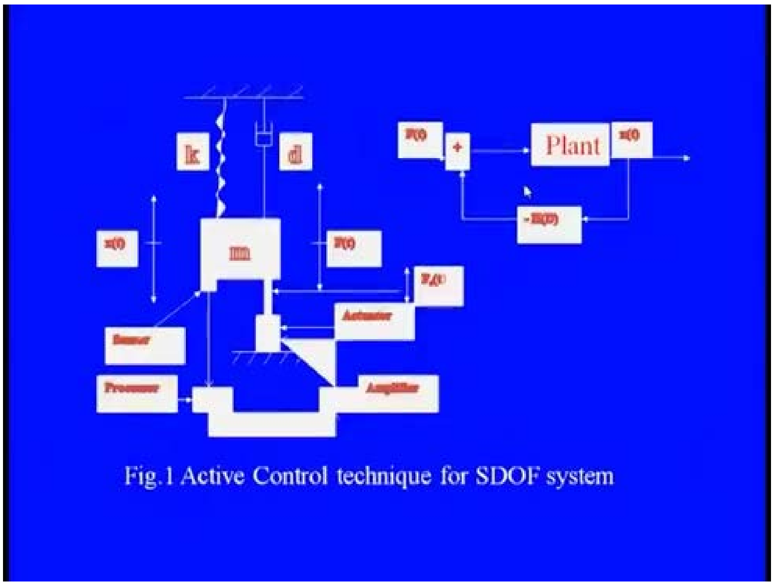

Fig.1 Active Control technique for SDOF system

So, this is what you see the active vibration control technique for single degree of freedom system, where you can say that this mass which is being oscillated. And we have the displacement of this x of t, as you can see here, and this is what the force we can say, the excitation force which is being there along with this part. So, when such things are happening this is being effectively controlled, mainly by the stiffness and the damping part here.

So, this is my single degree of freedom system mass spring damper, and when these displacements are being there, the sensor is straightaway coupled to the vibrating mass. So, that you see whatever the signals which are being coming, it can be immediately sensed out here, and then you see here it is being coming to the processor, where we need to check it out that whether we are really you know like require the amplification or not when we are simply you know like processing this entire signals.

So, in this you processing unit we have the amplifier, once it is being amplified then you see here, it is absolutely in opposite part you see this is what my you know like the actuator thing. We are simply sending this to actuator, and this actuated this entire thing is actuated this force, so this force is being generated in the actuator. And then you see here, this you know like we can say this dynamic force which is being there, again just put the repulsive force to suppress the vibration.

So, this you see you know like the displacement which is being there is just forcing this in the lower direction, and this actuation force is being there on the this we can say upward direction. So, you see you know like the repulsive forces are being generated, in equal and opposite manner to suppress or to balance the entire motion of the vibrating mass or else if you want to put the analogue of this you see here. We have this part you see this is what the control system, we have the entire plant or this we can say the system.

In which you see here, this you know like the vibrations which is being you know like the sensed out at x of t is simply said sending two my, you know like this entire unit. The processing and amplification unit, and when it is being you know like there the f of t which is you know like the forcing factor is being coming out through this actuator part is being now, sending back to you know like with this correction part. And then you see here it is being you know like sending to the entire plant to suppress the vibrations.

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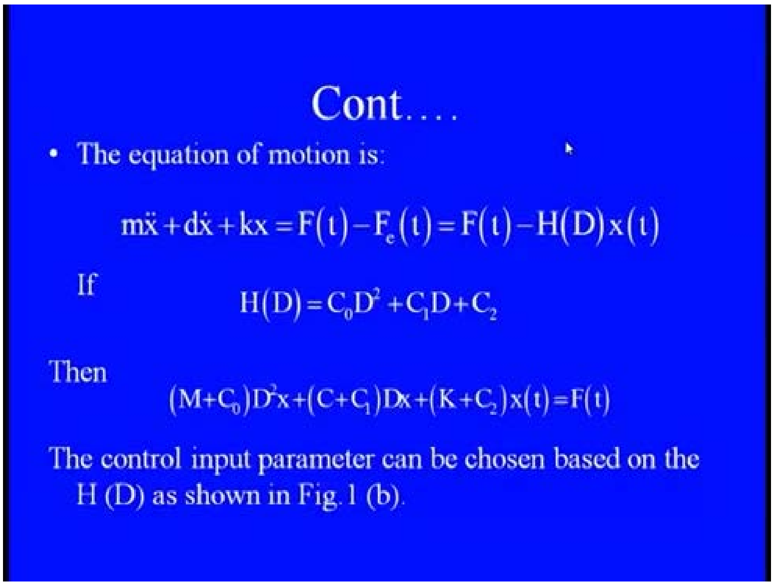

So, we can even generate the equation of motion for this, when mass spring damper is being excited we know that the three forces are being generated, the inertia force, the spring force, means the restoring force and the damping force. So, this is what you see on one side we have all the summation of the linear summation of these forces, which is being equal to the exciting force f of t. And you see here, whatever you know like the forces which is being there, at that point when the excitations are being there at the actuator part.

So, F t minus F e or else we can say that, the force which is the exciting force minus the force which is being generated at the actuator. So, H D x t and if you are saying that this H D x t is the integration feature of C 0 D square plus C 1 D plus C 2, where the D is the differential operator. Then we can now couple this actuator, in such a way that we can control the vibrating mass in all the proportionate feature, means with the differential operator second degree, with a single degrees differential operator and without this.

So, when we are now putting together, we have now the coupled equation along with the sensor and the actuator part. So, it is M plus C 0 D square x plus C plus C 1, which is being now you know like the added feature from the actuator into D of x K plus C 2 x of t equals to F of t. So, this is my you know like the control input parameter, which can be chosen based on this H d. So, this is what my the design parameter, which can be immediately find out that you know like what exactly the sensing and actuator features are being added, so that we can have a controlled entire unit.

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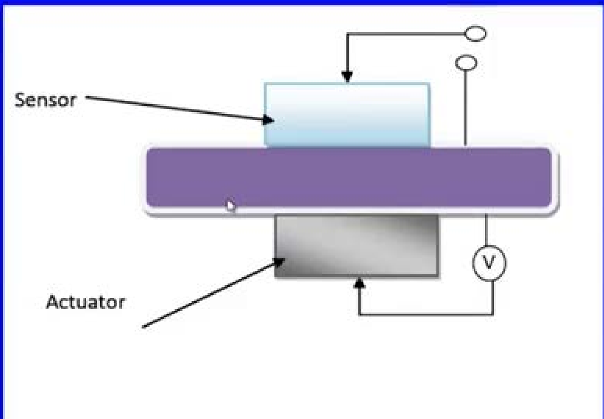

Fig. 2 Structure with piezo sensor and actuator

So, we can see that this is what the actual feature, in which we have the structure, and this a structure is being excited through you know like any exciting feature, and vibrating mass it can be sensed out here immediately. And because of you see these voltage differences in between that, you see here you know like whatever the sensor part is there, it can immediately sense these things. And in the opposite exactly opposite direction, which we can say that 180 degree phased out the actuation is there. So, through that you see the actuations can be happened there itself.

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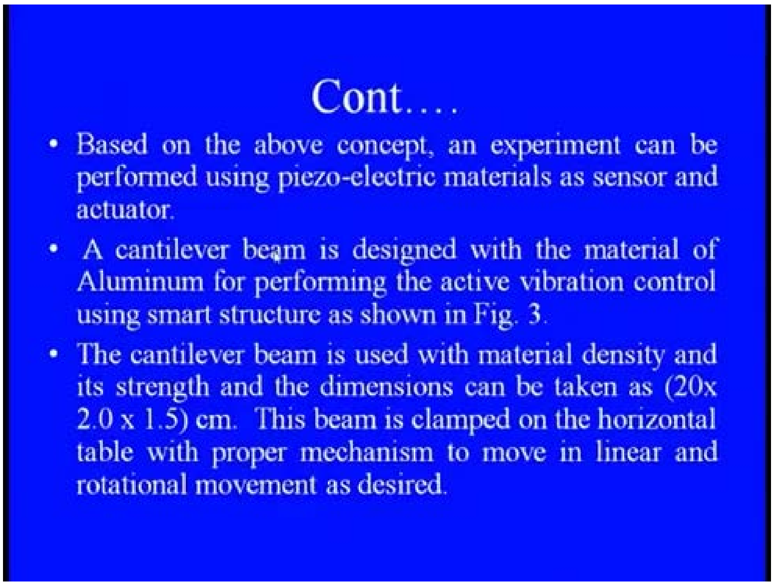

So, based on this concept an experiment can be performed using the piezoelectric materials, as the sensor and actuator as we have seen in the previous diagram, where a cantilever beam is designed with the material of aluminium for performing the active vibration control, using the smart structure as that. And this beam is used with the material density and it is strength and whatever the dimension, which we can you know like which can be taken, with the feasibility of that. And this beam can be claimed on the horizontal table, with the proper mechanism to move the linear movement and the rotational movement as desired you see that. So, this is one you know like part can be designed, and there you see here we can put the sensor and actuator together.

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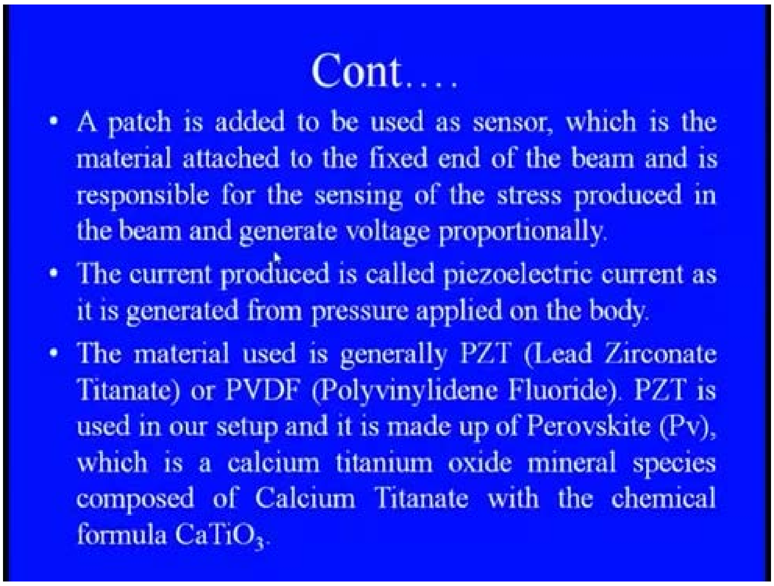

So, when we are designing this a patch can be added, which can be used as a sensor, and whatever the material which is being attached to the fixed end of the beam. And is responsible for sensing whatever the stress being produced on the beam, and you see what are the voltage, which is being generated proportionally according to the strain part. So, the current which is produced in that is you know like we can say, the piezoelectric current and as it is you know like generated from the pressure applied to the body.

So, material generally which we are using in all these types of nowadays, all these types of vibration control devices, and the sensing part is the PZT patches. The Lead Zirconate Titanium or even you see when we are using not the ceramic material, if we want to use the polymer material. Then even we can use the polyvinylidene fluoride you see here; that means, PVDF part.

And in this can say that the PZT is used in our setup you know like, which we can even put that. And it can be you see you know like sometime even it can be made up of this the perovskite, which is you know like nothing but the calcium titanium oxide mineral species, which is composed of the calcium titanium with the chemical formula we can say C a T i O 3. So, I means to say that any of these either because nowadays in most of the labs even in our IIT Roorkee lab, we have this setup in which you see we are using the PZT patches in actuation or even the sensing part of the inflatable materials. So, for such kind of material also we can be immediate actuate or even when we have, you know like a rotor bearing system of a cantilever, we can be immediately adopt either PZT or PVDF or even the P v kind of a smart materials there itself.

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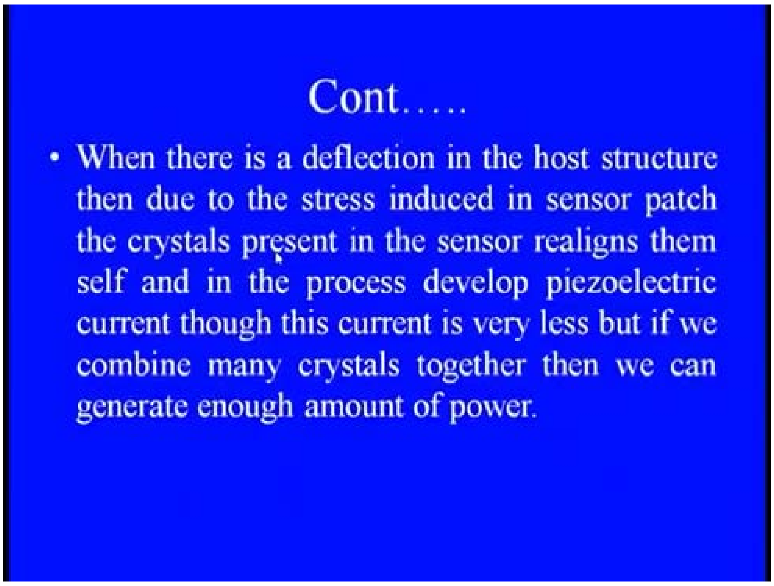

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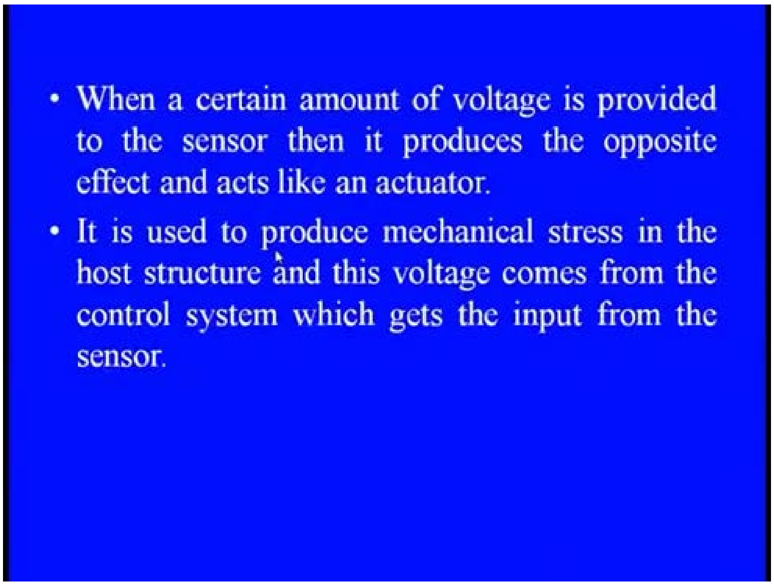

So, in this concept when there is a deflection in the structure, the main structure the host structure due to stress induced. In the sensor patch the crystal present in the sensor, realign them itself you see here and in the process development of that, the piezoelectric current through this current it is very less. But, you see, but you know like even if we combine many crystal together, we can generate enough amount of power just for sensing and actuation features.

So, when a certain amount of voltage is provided to the sensor, it produces an opposite effect and acts like a actuator part. So, it is used to produce the mechanical stress in the host structure, and this voltage you just come across you see from you know like the entire control system, which gets you know like just the input from the sensor. And the proper actuation functions in the opposite direction, can be acted by the same structure with the you know like the piezo sensing part and the actuation part.

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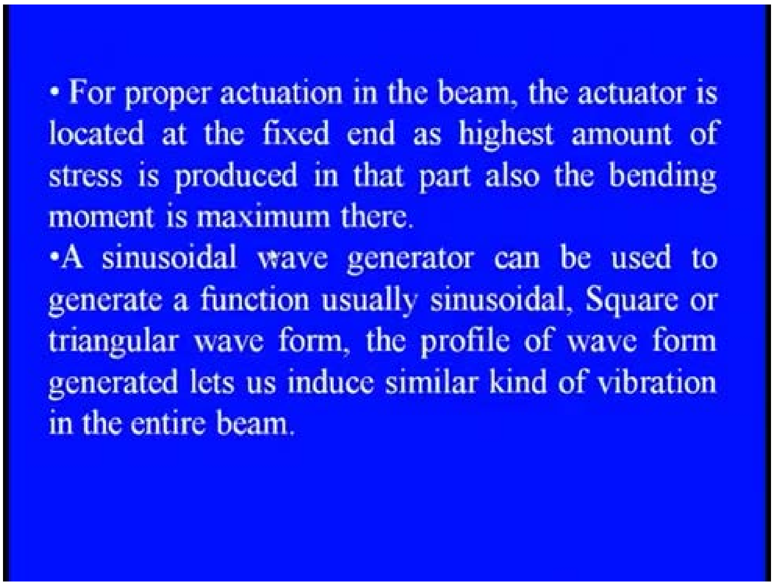

So, for proper actuation in the beam, the actuator is located at the fixed end at the highest amount or stress which is being produced and then you see here. Sometimes of the bending moment is also maximum there, so whatever the deformation which is being you know like, there at that point it can be immediately you know like sensed out with this. So, a sinusoidal way which is generated can be used, to generate the function whatever you know like we can say in a sinusoidal part or the square or triangle wave, and the profile of wave from the generated, which will induce a similar kind of vibration in the entire beam, through the actuator part. So, you see whatever the type of inputs are there, may be it is in the you know like the periodic feature the sinusoidal or if we have the square wave or even if we have a triangular wave.

According to the wave function the you know like whatever the vibration which is being generated, through this wave and in the piezoelectric part the similar waves are generated. And that can be supplied back through this amplifies to the actuator, and the corresponding force in terms of these waves can be immediately fed.

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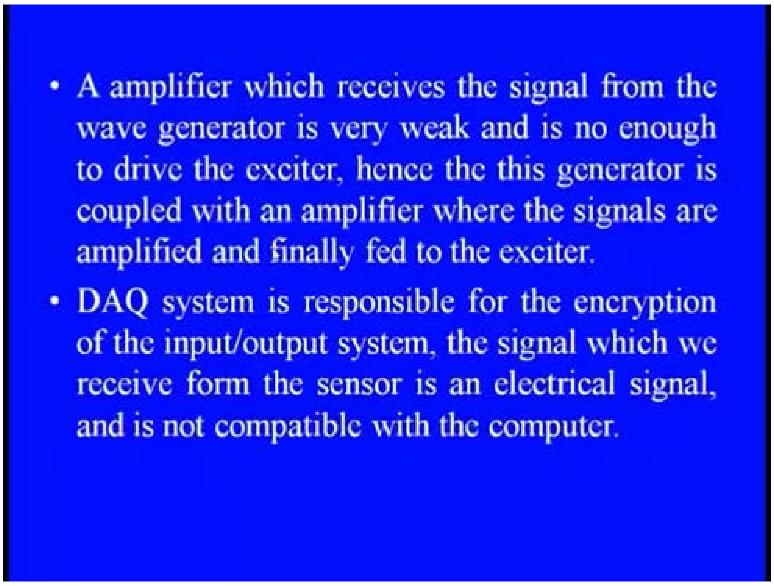

An amplifier which receives these signals from the wave generator is even very weak, and even it is not enough to drive the exciter. So, this generator is coupled with the amplifier which is what you see I told you that is a requirement, and where the signals are being amplified and finally, you know like we fed to the exciter, so whatever the data acquisition system which is being responsible for the encryption of the input, output system. The signal which we receive from the sensor is electrical signal, and we need to check it out that directly we cannot feed it to the computer because we know that it is not compatible towards that.

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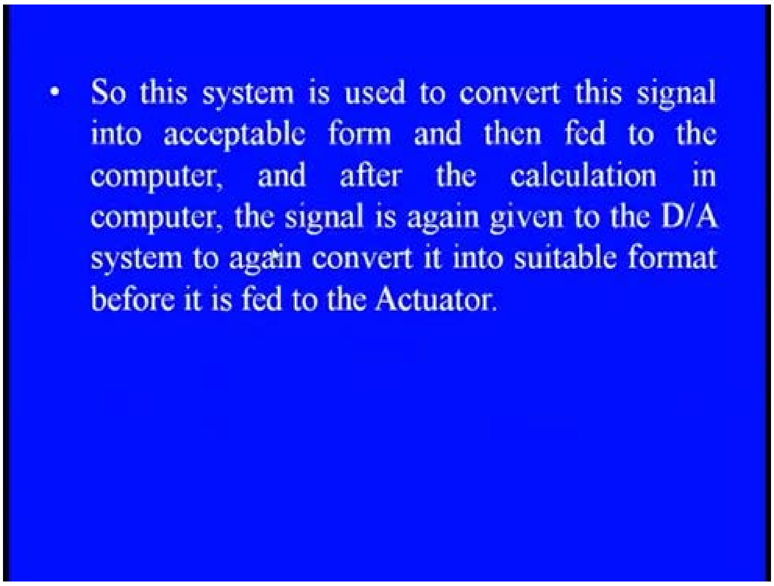

So, the system is used to connect this signal into acceptable form, and then feed it to the computer, and after the calculation the signal is again given to the data acquisition part. In which you see you know like all the conversions are there, and then we can fed this entire part which is you know like in terms of the force is you know like fed to the actuator part.

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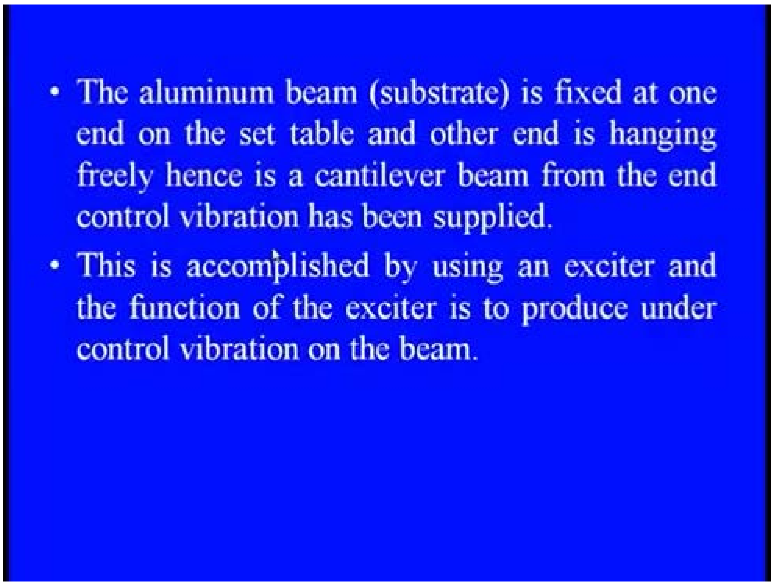

So, when we are talking about this you know like the substrate that is nothing but the an aluminium beam, which is fixed to one end and you see the other end is hanging freely.

A cantilever beam can be you know like just we can say, putting for the control of vibration, and in this part you see an exciter which is being there you see you know like the system, can be immediately coupled with this particular part.

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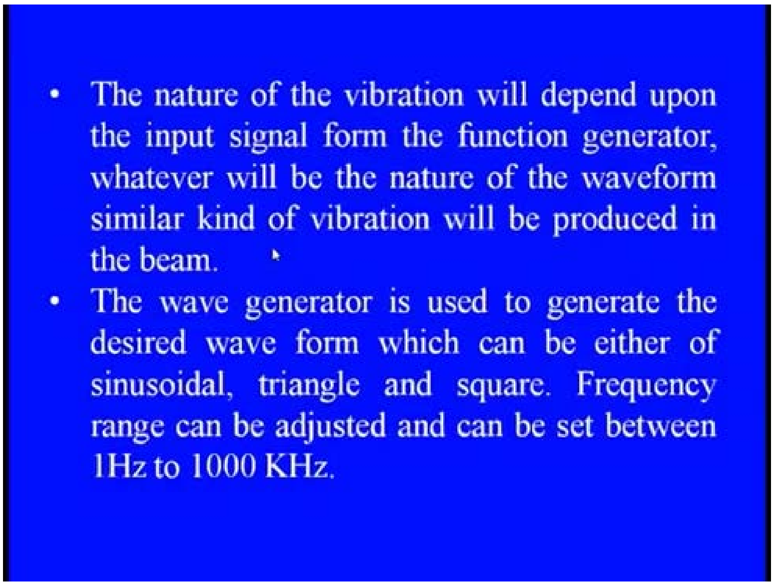

And the nature of vibration will straightaway depending on how the input signals are being there through these function generators. Where you see you know like the nature of wave form, whether it is you see you know like the sinusoidal part or the sine or the triangular part, has the similar kind of vibration and that can be straightaway produced in the beam itself. And the wave generator is used to generate the desired wave form, which can be either you see all this part which we discussed. And even in that you see, what are the frequency ranges are there right from even 0.5 hertz, which is being there in the motion sickness part in the human being to even you know like the 1000 kilohertz for any spindle vibrations, and even high range of vibrations part.

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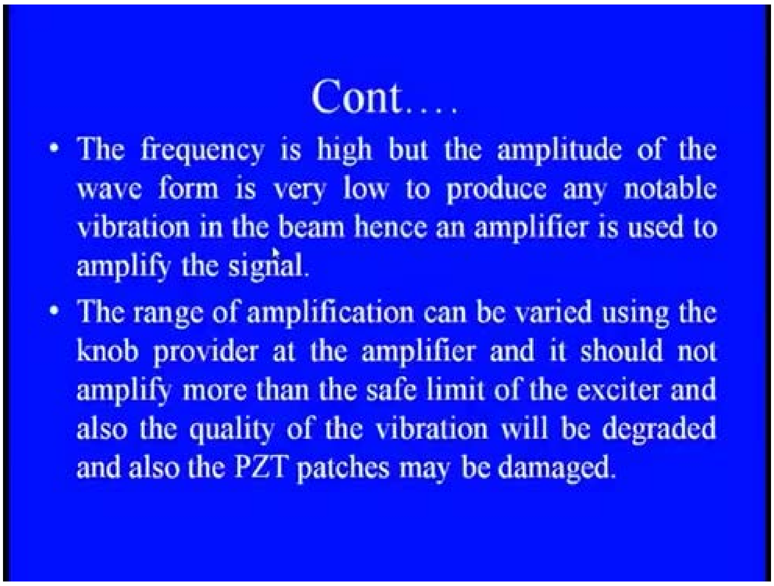

If the frequency is high, but the amplitude of the wave form is very low to produce any notable vibration of the beam, then amplifier is certainly required to amplify the signals. So, irrespective of whatever the frequencies are there, we need to amplitude of the vibration, and the range of amplification can be varied using the knob provider at the amplifier.

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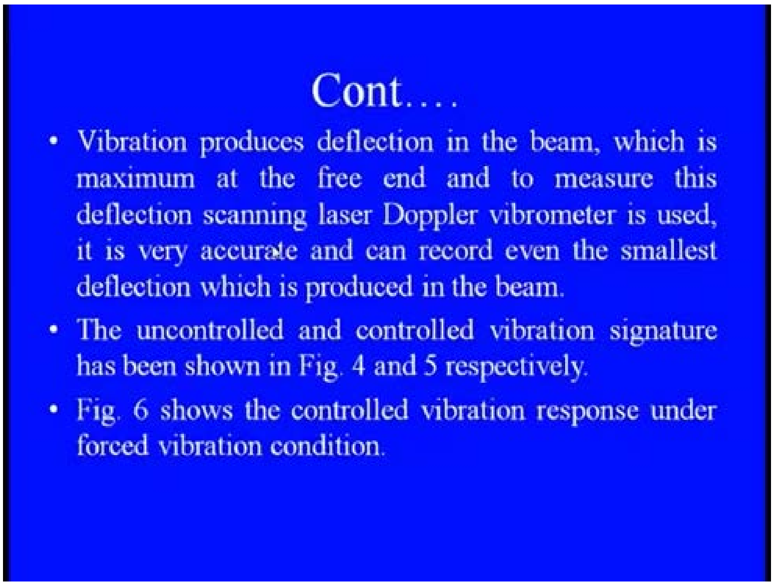

And then we need to check it out that, what exactly the PZT patch which we are you know like putting as sensor and actuator is really a required part. So, that you see even it should not you know like quantify entire things, so that you see there is a clear damage to our PZT part.

And the vibration which is you know like produces through the deflection of beam, even can be maximised at the free end, and to measure this deflection. We can use the scanning laser Doppler vibrometer, which gives a very accurate and even it can record the smallest deflection of the vibration which is being produced and even at the nano level when we just want to see. The carbon nano tube based you know like this cantilever or the simply supported beam or even the bridged part, the laser droplet vibrometer is as perfect device to use that. The uncontrolled and controlled vibration signature can be even be even get and we can see those things.

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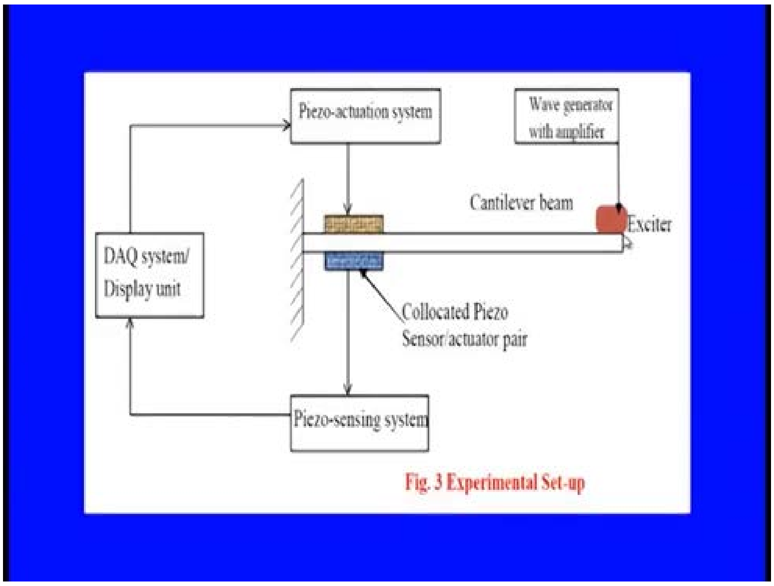

So, this is what the structure which I am talking all about, we have a simple aluminium based substrate the structure. And then you see here this cantilever bean which is fixed on one end, and this free on other hand is simply you know like having the exciter, and through which you see we know that, the wave generator part is there, the exciters are there, we can generate either sinusoidal wave feature, the triangular wave feature or even the square wave feature.

And whatever the wave features are there on that cantilever beam, it is simply being you know like provide the excitement in the entire beam. And this excitement now, is being coupled the entire system is being coupled with this you see here, we have the two main part the piezo actuation system, and piezo sensing system. So, on lower part where when apply the load here, there is clear you know like the deflection in the entire beam, and this you know like the bending feature in that, is clearly you know like sensed using this collocated piezo sensor pair.

So, this piezo sensing you can see that this clearly you know like here, whenever you see the mechanical this pressure or any kind of forces being applied there, it is a clear you see the voltage generation is there. And when this voltage generation is there we know that, even though it is very high frequency and the frequencies are being very high, if the amplitude is low, we need to adopt some kind of amplifications. So, you see here you know like the after this piezo sensing feature, we need to adopt the amplifier and simply feuded to the data acquisition system or the display unit.

And once you see you get you know like the amplified part, then you see it has to be fed back to this piezo actuation system, this actuator is exactly opposite means 180 degree the phased out to the sensor. So, you see here when it is feeded to that actuator, an equivalent you know like whatever the opposite force is the reactive forces are being supplied.

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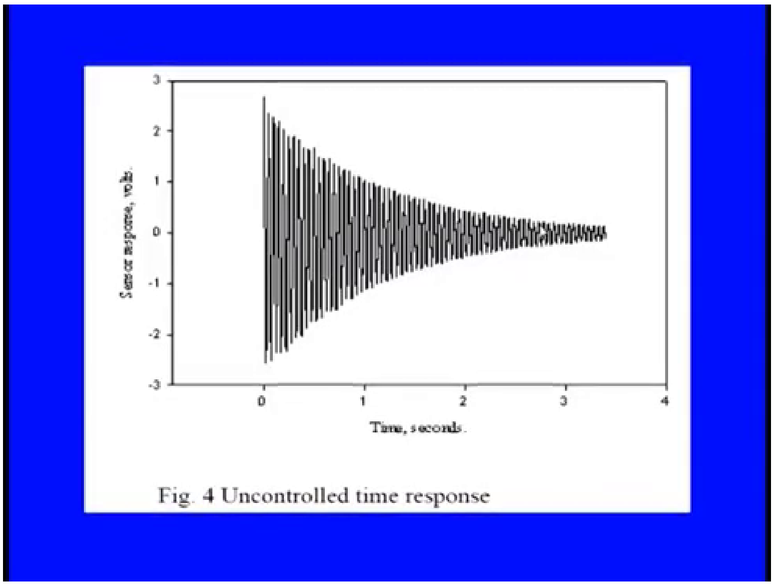

Fig. 4 Uncontrolled time response

So, that through that we can simply control the beam excitations, so this is what you see you know like a controller is there, and you know like even in that we can provide the gained value, and accordingly you see we can change the signal strength. And we can simply you know like correct our, whatever the error is there in between the input of sensor and output of actuator sorry the output of sensor and input of actuator.

So, this is the uncontrolled vibration you know like when we do not have the control unit entire, if we just remove this part. Then we have the vibration signature you can see that we have the transient feature there itself, and then you see here after that time you see it is just going to the steady state part. But, this is a clear vibration spectrum is there towards this part.

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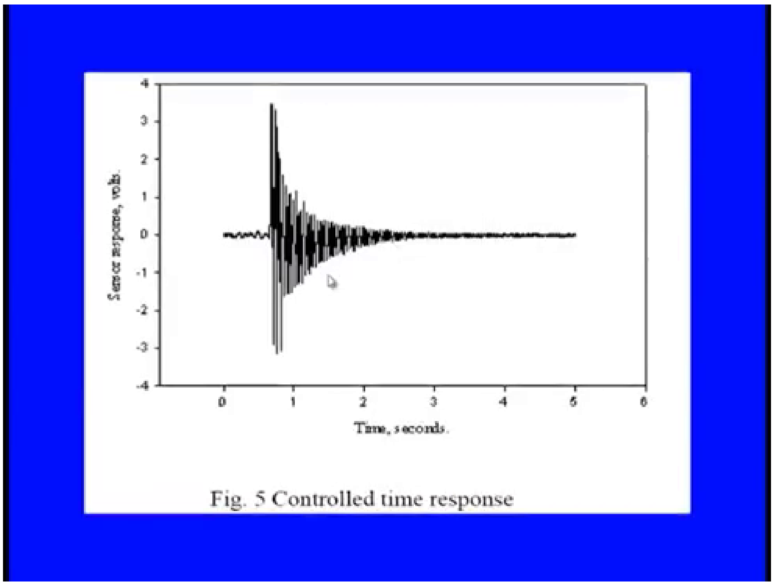

And we are now adopting the control unit there itself, then you can see clearly that initially though it has a transient feature. But, once you see the correcting measures are being there by the actuator, the vibration is immediately you know like we can say suppressed. So, you see here though this is you see exponential decays are there with the oscillatory feature, and you see the sinusoidal features, so if the sinusoidal wave form is there, then you see you know like immediately it will be dampened out at the quicker time.

And then you see have a almost you see 0, this vibration amplitudes are there in terms of even the displacement or acceleration at the our vibrating mass. So, this is one of the unique method, when we are using the smart structures as the sensor, and the controller and you see here for separation of vibration, they can be effectively used on this part.

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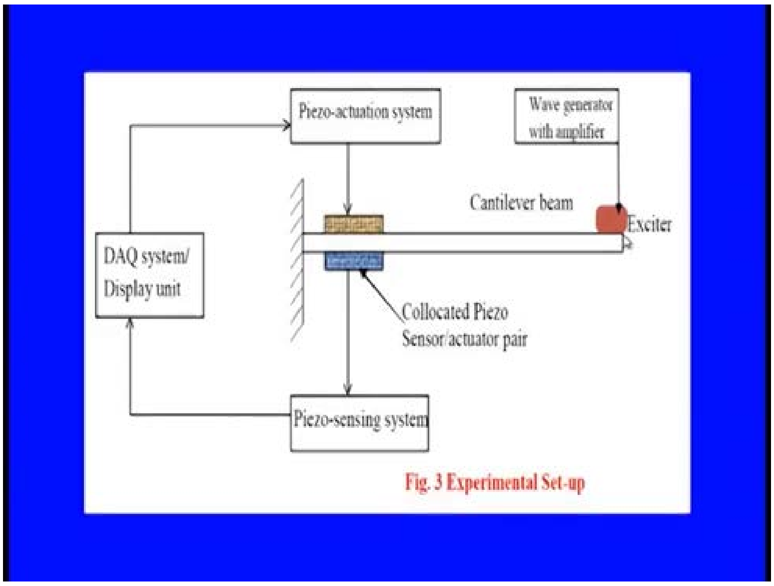

So, either when we are talking about this design which is there on your screen in which you see here, we have a sensor and actuator which are being keeping exactly opposite to each other. And the entire control unit is being putting together in such a way that, when we are changing the gain value according to the strength of this, you know like the signal or according to whatever the force excitation, we can even achieve smoother control on the vibration of this. Not only in these you know like the cantilever beam of even this metallic form.

But, even if we have the inflatable structure or any kind of structure, which we are using in you know like the this space part we of any profile, not only the straight one even we have a circular profile or elliptical profile or any kind of irregular surface profile. These PZT patches can be acted as the sensing, and actuator part and can be immediately you see with this control unit, we can effectively control the vibration which is coming under the active vibration control part.

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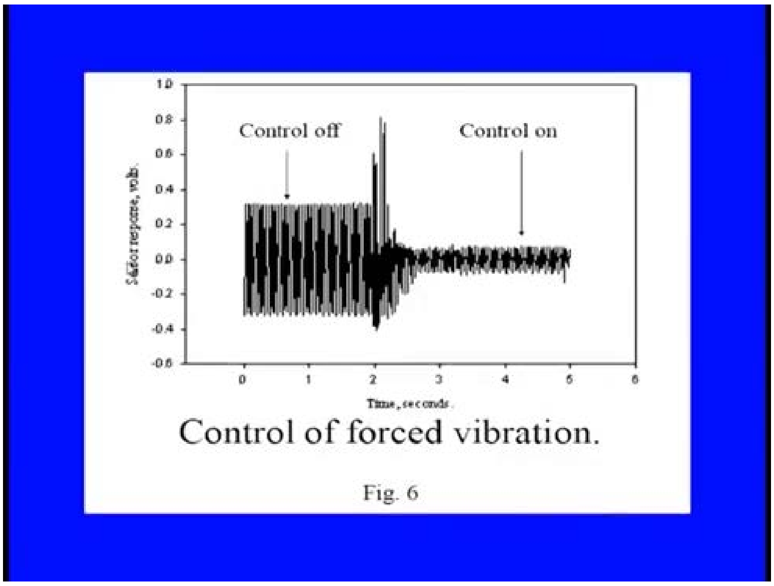

So, you see this was you see one of the we can say effective control on this vibration, and we are talking about now the forced vibration. Then you can see that right from you see the controlled, you know like this controlling part when we have even you see the steady state vibration, and the entire controlling is of. That means, we are sensing the vibration on the external excitation you see F minus F t, which I shown in the equation this is what you see the entire feature.

In this we have the huge amplitude of the vibration at that, but once the controller is on you can see the drastic change in to the excitation vibration amplitude. And because of this we can say that this is a clear effective part of the actuator, which is simply you know like actuated the force, for suppression of this you know like whatever the vibration, which is being there at the exciting force at F and what are the F t is coming. So, F minus F t the cancellation part is very effective, and that can be show here in the measurement of these vibrations.

So, this is the beauty of this system in which you see we are saying that, you can clearly see that when the control unit is not working, means the sensing, amplification and actuation you see the vibration. Even at the steady state form, they are clearly you see at that and when this is working there is a clear drastic, deduction in the vibration when the entire unit is being on.

So, in this lecture we mainly discussed about that you see how the vibration can be suppressed out, with the using of the PZT patches or PVDF means the ceramic based material or the polymer based material or even you see here, we can use the P v as you see you know like the this as a sensing feature and the actuating feature. We also conducted you know like this experiment, in which it was very clear that when we have a cantilever beam, and what is the potential occasion where we can adopt the sensor.

And we can apply the actuator and the entire control unit with the gain value in or other you know like, the signal generator we can even rather control effectively. The we can say the this vibration, at any amplitude or we can say at even at the any low or higher frequencies. So, the in this lecture you see we discuss mainly about the active vibration control part, in which the accelerometers which are providing the sufficient knowledge towards you see the vibration part, and then we can suppress those things accordingly the vibration part.

In the next lecture you see we are going to discuss about, the you know like the different kind of materials which is being used as you see, you know like the smart materials and they have a active application in the vibration control part. So, again you see under the principles of active vibration control, the smart structure have a lots of applications towards that. So, till that you see we mainly discussed about the piezoelectric featured right from the basic principle to the application point of view to the accelerometers.

And in the next lecture now, we are going to discuss about the smart structure which have you know like direct application, right from the magnitude rheological fluid to electro rheological fluid to shape memory alloy, they have a direct application towards the vibration controller part.

Thank you very much.