Vibration Control

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Module - 7
Principles of Active Vibration Control
Lecture - 1
Basics of Active Vibration Control

Hi, this is Dr. S. P Harsha from Mechanical and Industrial Department, IIT, Roorkee in the course of Vibration Control, we know that we adopted the two main methodology in this, one is the passive vibration control, and second is the active vibration control. Till now, we discussed about the passive vibration control in which the basics that how we can add the features like the spring the mass or the damper straightaway, on the source or on the receiver or on the propagation path to suppress or to control the vibration amplitude.

And also whatever the energy which is being there, due to the excitation feature we can dissipate, we can straightaway transfer and convert into the heat by various ways. We discussed about how we can design the isolator based on the amplitude, based on the frequency of the vibration excitation. And also you see here, the two main properties which we adopted in designing a perfect way of the isolator, like the impedance and the mobility.

And based on these two, we calculate the insertion losses and then you see here, there is a straight designing feature or the procedure for the passive vibration control. And also we have seen that, the individual impact of the spring or the mass or even you see you know like, the damping can have you see you know like the individual feature and can be added straightaway in suppression of the low frequency, high frequency or the resonant condition of the vibration. And even in the mass addition there were two main part, which we discussed the seismic mass and the edit mass.

And you see once these masses are being tuned to the system, the entire system the vibrating mass can lead to the 0 amplitude. So, this is also one of the shielding feature through which we can say that even we can suppress, the entire propagation path with this vibration suppression by adding these things. We discussed these things there, we also discussed about when we are designing the isolator or when we are designing the shock absorber, there is a straight methodology in that.

And when we are talking about the shock absorber, there is a clear integration between the spring and the damper, just to absorb the energy, to dissipate the energy and also to store the energy at the same time. So, that we can control the oscillatory feature of vibration along with you see here, whatever the energy is there we can dissipate and transfer into the heat. So, these passive features which is you know like directly added at the source or the receiver or during the propagation path.

We discussed and we discussed about that how the vibration can be straightaway suppressed and the vibrating mass can be lead towards the 0 amplitude of the excitation. But, sometimes when we have this sophisticated system, we just want that we cannot directly add something to the system because sometimes it is not compatible, sometimes even the service condition or over or the environmental features or even you see whatever the design features are there of the system, does not allow to directly act on such system.

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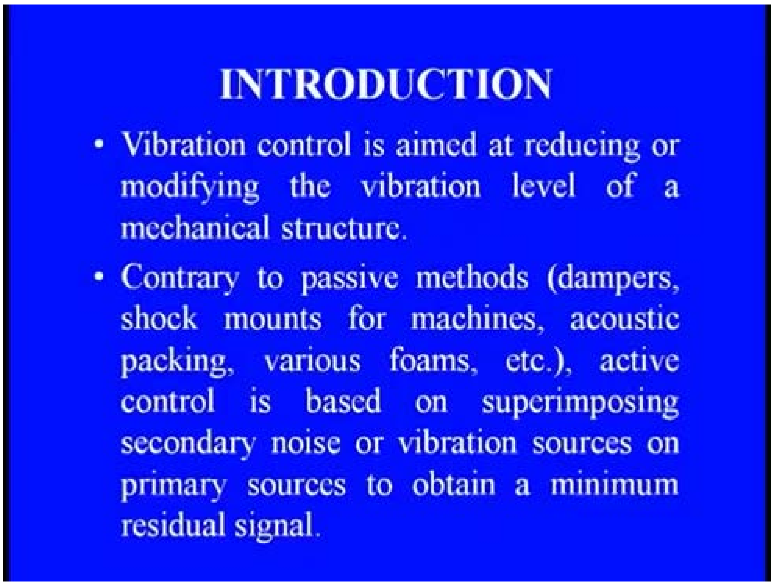

Because, now we need to generate some because ultimately you see this is the force through which entire you know like the excitations are there because of the dynamic feature. So, ultimately we just want that the system should even act, against these frequencies by generating some cancellation forces, so this concept we are going to adopt in the next lectures, which is coming under the broader umbrella of the principles of active vibration control.

So, in this you see here we can say that ultimately our main aim, in the vibration control is to reduce or modify the vibration level at the mechanical structure. So, contrary to this passive methods which we discussed about the you know like the by putting damper or even the shock mounts, in terms of the masses or you know like the acoustic packing when the insulators are being provided, in terms of the propagation of the sound level or the various foams, which were added.

In this active vibration control, the main thing is coming to superimposed the secondary noise or the vibration source, on the primary source to obtain the minimum residual signal. So, ultimately we are trying to adopt the two main sources in such a way that, they will cancel each other, the primary source is the basic excitation force the secondary source is nothing but the cancellation force generation. And then they are trying to balance, so that we can have a minimum residual feature in the signal.

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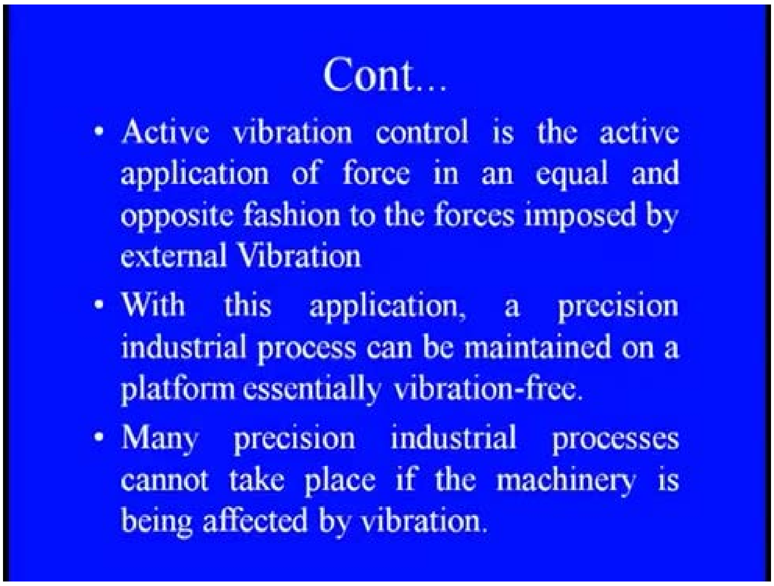

So, the active vibration control is nothing but the active application of the force in an equal and opposite fashion to the force imposed by the excitation vibration. So, whatever the external excitation features are coming in the vibration that can be balanced based on the forced balance criteria. And with this application a precision a précised industrial process can be maintained, not only on the plate form, but also you see here on a specific part of the object. So, many precision industrial process cannot take place if the machinery is even affected by the vibration, by adopting the passive vibration feature. So, we need to adopt the active and passive vibration control, according to the system requirement and the application feature in the system itself.

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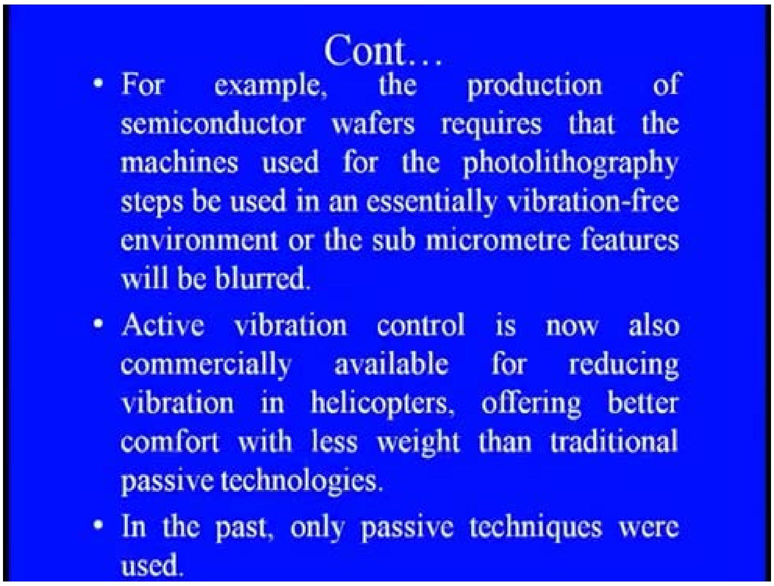

Like example the production of semiconductor wafers, which require the machine to be used for you know like say photolithography steps. And in this particular we just want the vibration free environment or any you know like the sub micrometer features will be blurred. So, in that case you see here, the active vibration control can straightaway adopt there without putting any kind of you know like the feature in these semiconductor wafers.

So, now a days you see here the active vibration control has a greater application for reducing the vibration, like in helicopters, offering better comfort with the less weight than the traditional passive technology. So, sometimes you see here, where we know that by adding something can create a most of you see the inertia forces or some other things, then it is better to use the active vibration control there itself. Because, generally you know like previously when we were thinking about the vibration control, we were only thinking from the spring mass and damper aspects.

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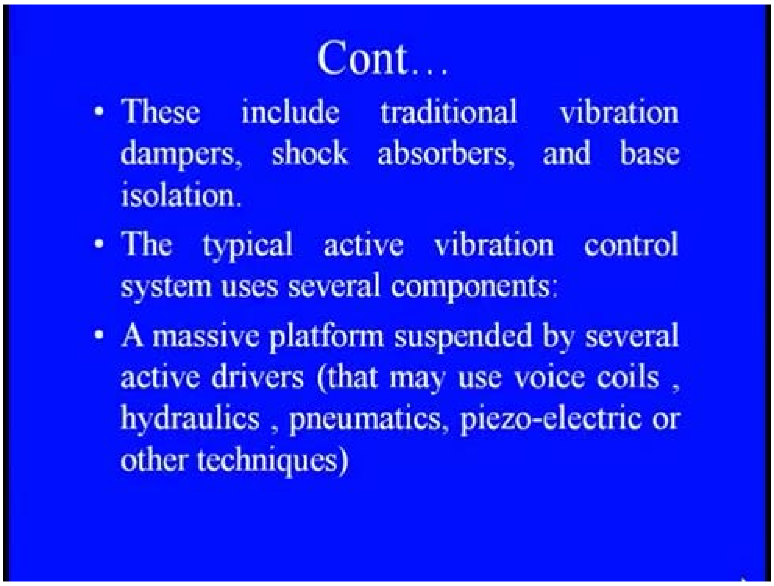

So, in this you see here you know like the traditional vibration all either the shock absorber or the base isolation or the dampers or the we can say added masses, everything was considered in controlling the vibration, wherever it is being there, heavy machinery to small sophisticated machines. So, we can say that there are various components which are directly involved in the active vibration control also because it is not like that, that we can generate a negative force or the counter balance force, through the secondary source at the when the primary source is exciting the system.

So, we need to see that what exactly the requirement is, so if you are saying that a massive platform, which is suspended by the several active drivers. We can say you know like the various coils, hydraulic, pneumatic or the piezoelectric or any other part and through that, that the massive platform can also be whatever you see the excitations are there can be controlled by these things. And even we can put, when we are talking about the sensor or actuator which is the integral part of the active vibration control, without which we cannot even think to guage the amount of forces and to counter balance that, the accelometer is one of the important task in this.

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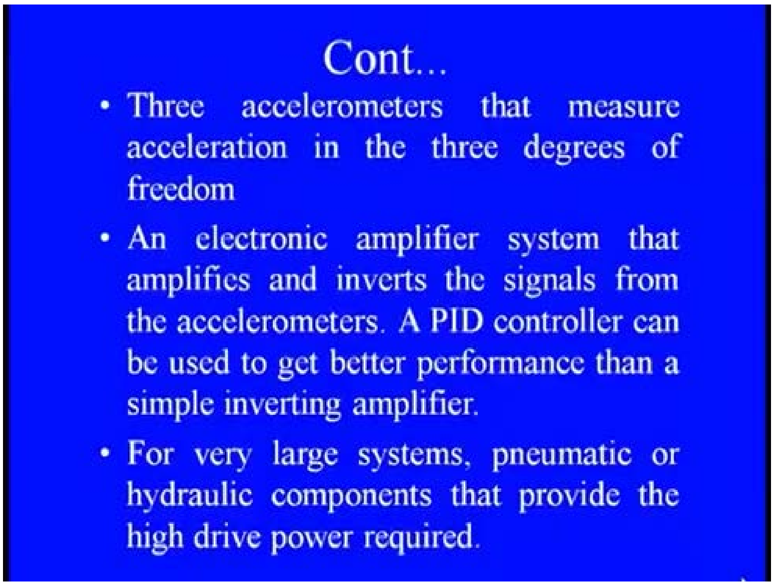

And even the accelerometer either the single axial, means uniaxial to triaxial accelerometers, are effectively being used as the sensor feature. And then whatever the actuation is being required, the actuator the whatever the force is being actuated through these actuators. So, we can use even the electronic amplifier which can amplifies and invert the signal from accelerometer to the required things, and in this you see here you know like we are going to use, the PID controller sometimes you see here which can give a better performance than any kind of simple inverter amplifier.

So, you see here like there are various things which we are going to use in that, so even for very large system, the pneumatic or hydraulic components can also provide a very good smooth or we can say steady state power requirement. So, that can also you know like the featured out, when we are trying to design any kind of even the large or a small vibration problems or you know like the system itself.

So, active methods which can lead to the structure or the parametric modification of the vibration system, using additional energy source. And that is why we are saying that you know like the additional additional energy source is a very active feature that is why it is coming under the active vibration control methods. And this active system can generate the local forces related to the variable assigned to the other system, where the point source is being there to generate the external source signals. So, using this active method appropriate control external power sources can be supplied or even the absorbed energy, due to determined control algorithm can also be put there itself to counter balance the generated forces.

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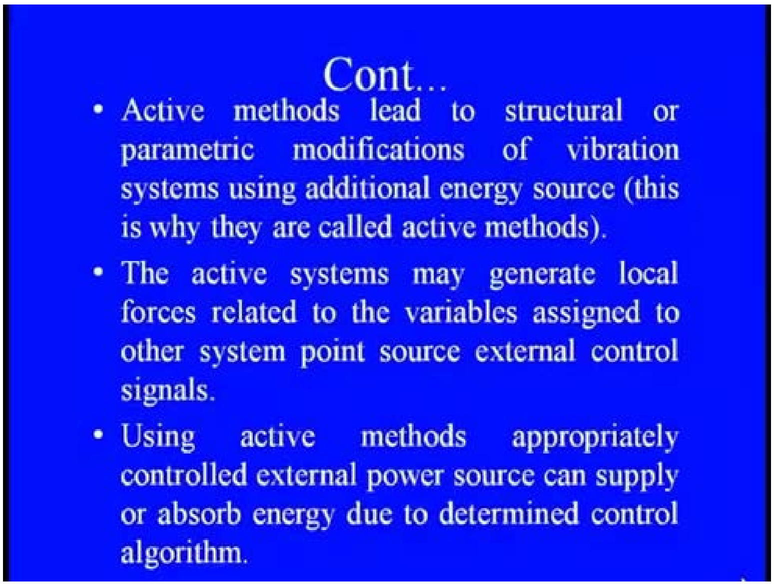

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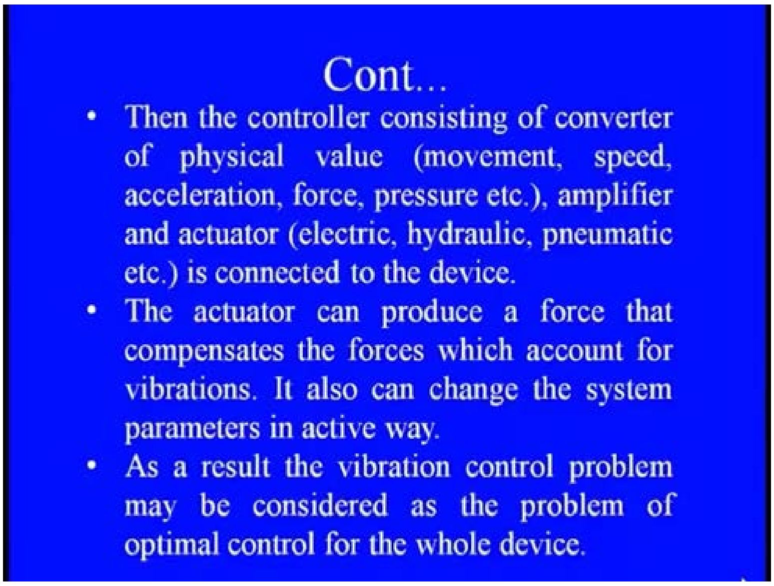

So, in the controller consist of the converter of any physical value, like the various dynamic features are there, either starting from the movement means the displacement the speed or acceleration. So, all three dynamic parameters when we are starting from displacement velocity and acceleration or even the force or pressure, so when we are just trying that our controller should be you know like converting the physical value, and then amplifier or actuator which is even being there as the additional feature and connected to the device.

So, in actuator now when we are talking about the actuator, it can be there as a electrical, feature, hydraulic feature, pneumatic features. So, this is what you see that you know like the straight connection that first it should consist you see, a converter through which we can convert the physical value. And then it should be amplified, in such a way that we can absolutely guage those things, and then the actuator when it is just going to the actuator in terms of. So, these are the three basic devices which are being used under that.

And the actuator can produce a force that is what the required force that towards the component, and the force which account the vibration suppression. And even it can also change the system parameter in the immediate effective active way, so as a result the vibration control problem may be considered as the problem of optimal control for the whole device. So, that is why you see here we need to optimize that you know with these you see the vibration problem, along with all three connectors right from the you know like the converter to amplifier to the actuator part.

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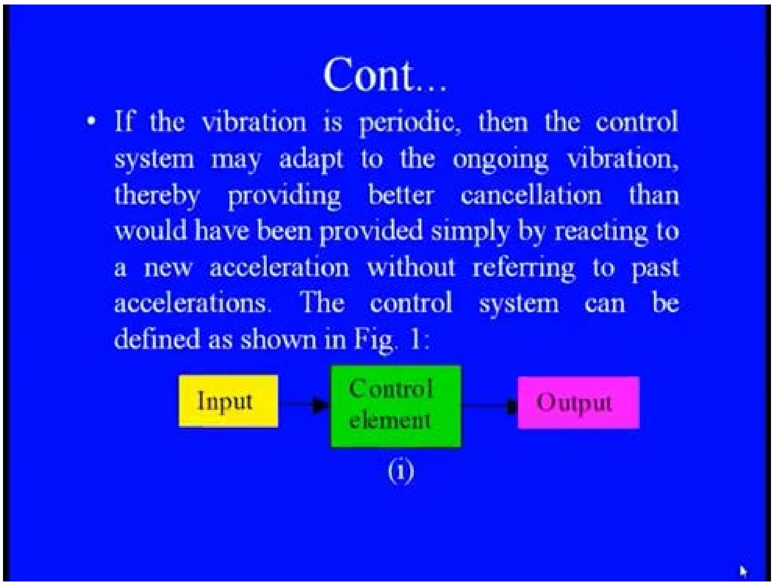

So, in general when we are talking about this, and if we have means the active vibration control and if we have, the periodic vibration feature. Then the control system can be adopted, in such a way that it can you know like provide a better cancellation force, than even when you have some a periodic or some abrupt vibration features. And we can rather referred, this entire periodic system to the acceleration which is being generated, and the counter acceleration which is being you know like provided by these actuators or we can say the sensors like accelerometer.

So, in general if you are defining in a broader way about the active control system, then we have the input and the output, the input may be single or multiple or output may be like that. And then in between the input and output, we have the entire control element which we need to define, the character physical character or any other characteristics you see here of the control element.

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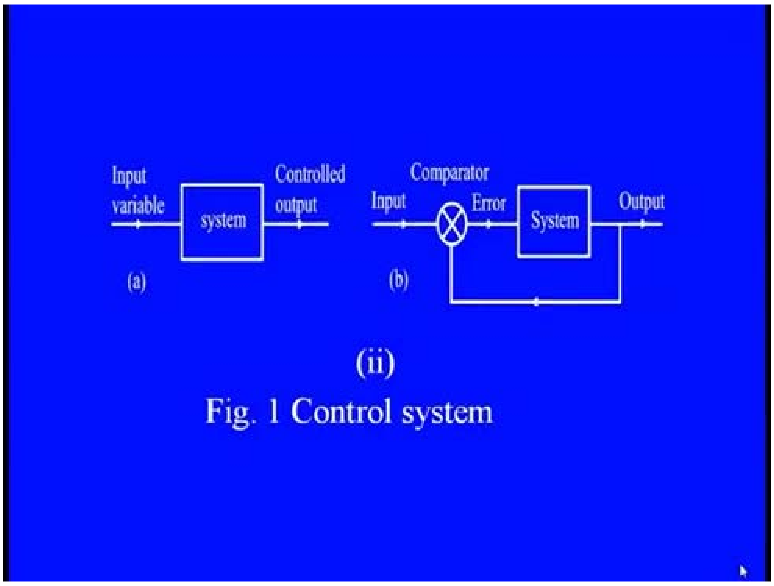

So, when we are talking about you know like the two main control loop particular, one we have the open loop in which as we discussed, we have input variable, we have the controlled output. And this entire control system is being designed in the block as a control system, even we can go for the closed loop as we discussed already in one of the lecture. The closed loop is basically analyzed, the input and output signal and generate the error.

Because, whatever the actual value and the desired value as an output is coming, we can rather compare the things. And then whatever the error is being generated or the created by the various non linear or any the actual feature of the system that can be even amplified, and feeded again to the system. And this iteration will be rounding up till the desired accuracy cannot be achieved, so we need to you know like till that point you see here we need to run the entire system.

So, if you see the b diagram of that, you can see that we have the input straightaway going to the system, the controlled you see the output is coming. But, even if we are not you know like having the desired controlled output, again we can fed back to the system in which you see, we have the comparator the error is generated, and then again this error is feeded to the system itself. So, this is you see here the two main strategy in the control system, one is the open loop, one is the closed loop.

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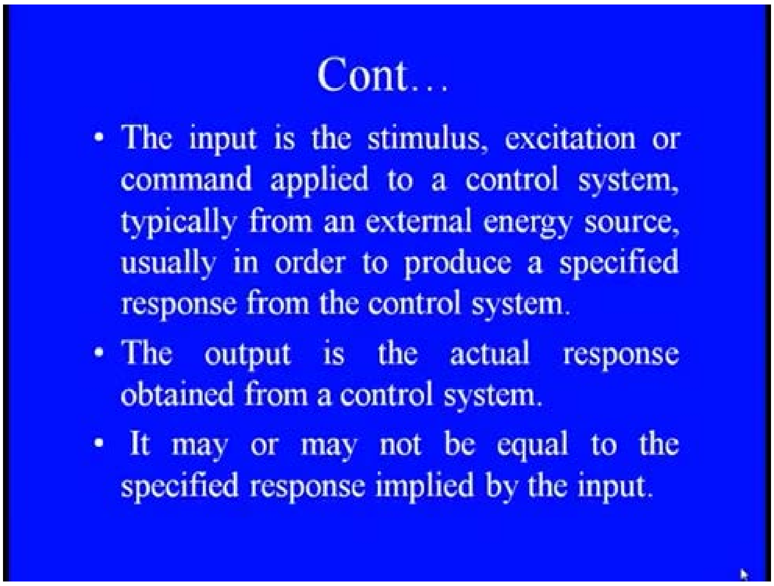

And if this the input is stimulus, excitation or any you know like the command applied to the control system. Typically we can say that you know like from an external energy source, whatever you see the type of sources in order to produce the specified response from the control system, the output is the actual response which is being obtained by the system. So, as I discussed sometimes we may have the desired output, sometimes we may not have the desired output that is what the, we want in the controlled featured.

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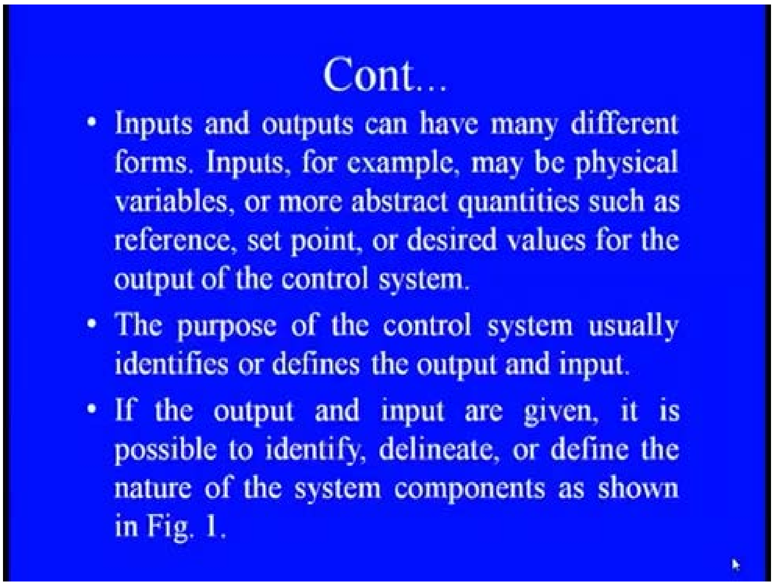

So, input output can have a many different forms, like the physical variables or any we can say those abstract quantities which can be said as the reference or the set point or the desired value, as an output control points are. And the purpose of the control system usually identifies, the relation between or certainly sometimes they are defining the relation between the output, and input and based on that you see here, the accuracy is being defined of the system.

And the output, input system as we discussed already needs to be you know like identify or even the define the nature of system that what kind of you see, the entire physical nature of your input and output signal is, and accordingly the control system is being designed, so that we can effectively control the output according to the desired nature.

The control system may have more than one input as I told you, so sometimes we are talking about the Single Input Single Output SISO, sometimes we can talk about the Multiple Input and Multiple Output MIMO part. And accordingly if we have a single input single output a better accuracy can be achieved by adopting a simple control system. But, when we have the various parametric effect on the system, and we want to control overall the vibration or anything you see here.

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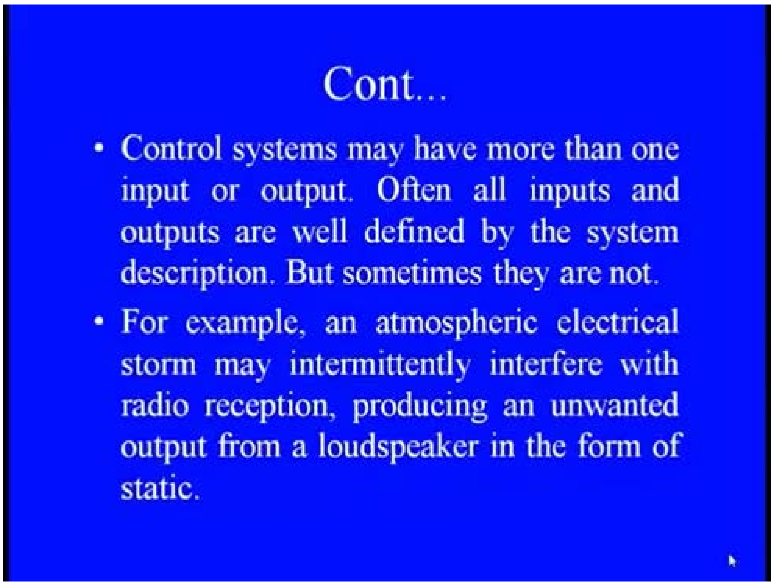

Then we need to go we need to design in such a optimum way of the entire control system. So, that we can effectively have the control on all these input parameters in the range where you see we have the desired, we are looking or we are seeking towards the desired output. So, this is a well defined problem which needs to be defined when we are designing the active control system because ultimately we need to generate the forces through actuation and the sensing feature.

So, example is we have a atmospheric electrical storm that may be you know like intermittently interface with the radio reception. And through that there is a clear unwanted output is being produces from the loudspeaker inform of the static part, and we need to cancel out this noise. So, certainly you see here we know that this unwanted output has to be you know like a filtered out from the, which is coming from the loudspeaker.

So, this noise which is you know like coming as the output as a integral part of the total output, but sometimes for the purpose of simply identifying the system. We can say that you know like especially input producing undesirable output are not normally considered as the input output system, in the system description we need to add some kind of filter may be octo event filter or we need to design the filter, so that we can cancel out these things.

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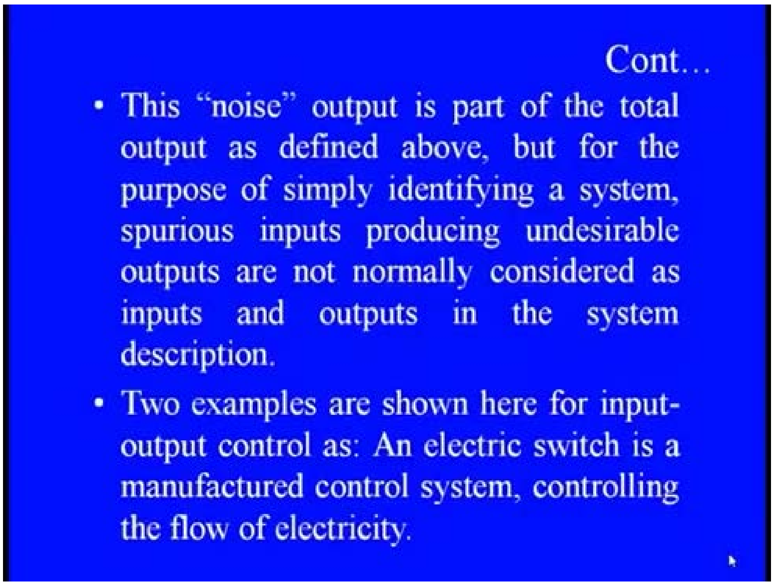

So, now, you see we can say that if we have say the electric switch which is being manufactured based on the control system, the controlling the flow of electricity is one of the input part in that. Because, we know that the electric switch is there is a input and output feature is the electricity only, so we can design the controlling system accordingly.

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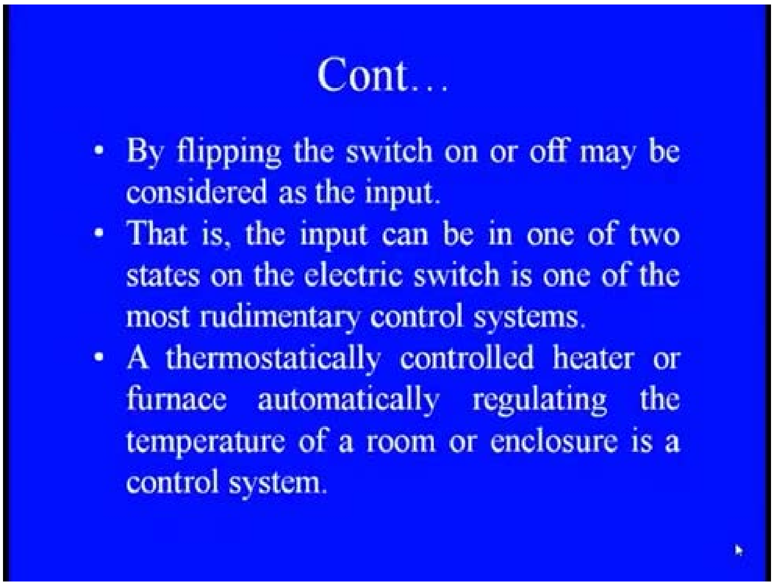

So, by flipping the switch on or off may be considered as the input part, and this is when the input can be you know like in one or two state of the electric switch can be we can say that most rudimentary control system. And a thermo elastically controlled heater or furnace automatically regulate the temperature of the room or enclosure in the control system, when any kind of you know like the noise or any kind of a undesirable effects are coming.

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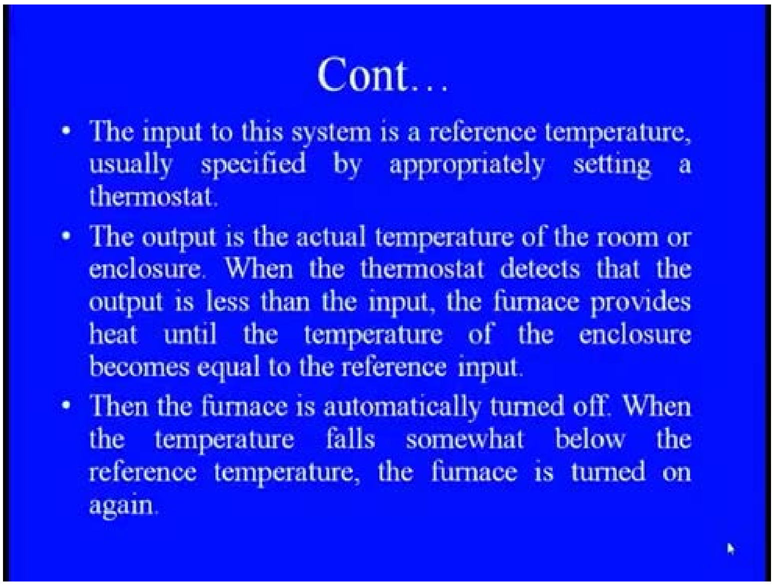

And the input of the system is you know like we can say reference to the temperature, which usually you know like we can say as specified by setting the thermostat. And the output is the actual temperature for such systems of the room or any enclosure, and when the thermostat detects the output, which is less than the input we know that the furnace which is providing the heat, you know like we need to just make we need to increase or we need to enhance the feature.

So, that we can make a proper reference point right from the temperature enclosures, and then the furnace is automatically tuned off. Because, we are setting up to that point and when the temperature falls somewhat below to the reference temperature the furnace is turned on. So, this is you see the automatic feature as we are talking about the automatic control on that, when we are just going with this.

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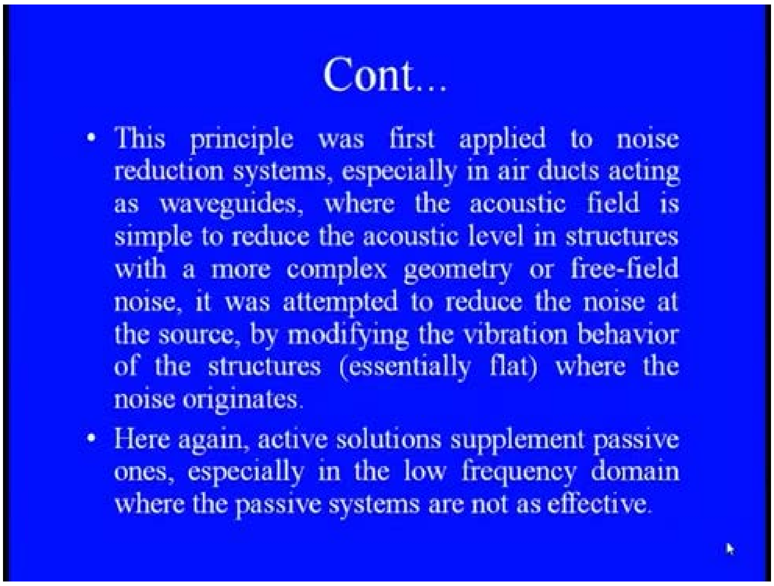

So, this principle was first applied to the noise reduction system, when the air ducts affecting as the wave. You know guides where the acoustic field is being simply to reduce the acoustic level, in the structure when you have the free field noise or any complex geometry, you know like generates the noise. And this was basically attempted to reduce the noise at the source, by modifying the vibration behavior of the structure means you know like when we are just putting the flat or uniform cross section because from where you see this noise was generating.

So, we can say that the active solution is a perfect supplement of the passive one, especially when we are talking about the low frequency domain, where passive systems are not as effective as compared to the active solution. Because, in the low frequency in the passive solution we are always adopting the spring, the spring is a perfect storage device. But, if you want to effectively control the vibration exactly at the source, then this active concept of the vibration in which you see the force has been superimposed on that is a perfect solution as compared to the passive one.

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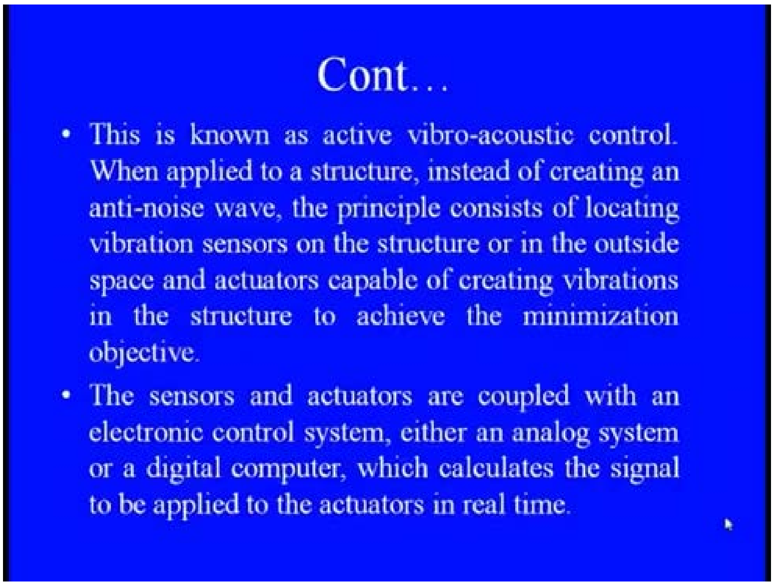

So, sometimes we are saying that this is the active vibro-acoustic control because you see here through that we have not only the control on the vibration feature of the system. But, also whatever the spreading part of the acoustic level is there, that can also be controlled at the source, and when it is being applied to the structure instead of creating an anti noise wave.

The principle consist of locating vibration sensor, on the structure or in outside you know like we can say the space and actuator we can say capable, whatever you see we are saying that whether we are just putting inside or outside. This sensor feature is absolutely like sensing the vibrations, and actuator is capable of creating the vibration in the structure to achieve. The minimum you know like we can say objective function or to reduce in a optimum way the vibration amplitude, at the source itself using this vibration acoustic feature.

And the sensor in the actuators are coupled in such a way that, the we can simply you know like have whatever the sensing feature is coming out, simply you know like amplified and putting in the control to generate, to putting into the this actuator to generate the required force. And this is entire thing is which is being coupled with an electronic control system, either by analogue or digital control, this entire system is you know like calculating, the signal strength particular which is to be applied to the actuator in the real time to generate the force. So, this is you see the entire system in which you see here, the actuator, the sensor and when they are coupled to these electronic system, electronic control system either the digital or analogue form it is capable of producing the n t whatever excitation force you know like to balance out that part.

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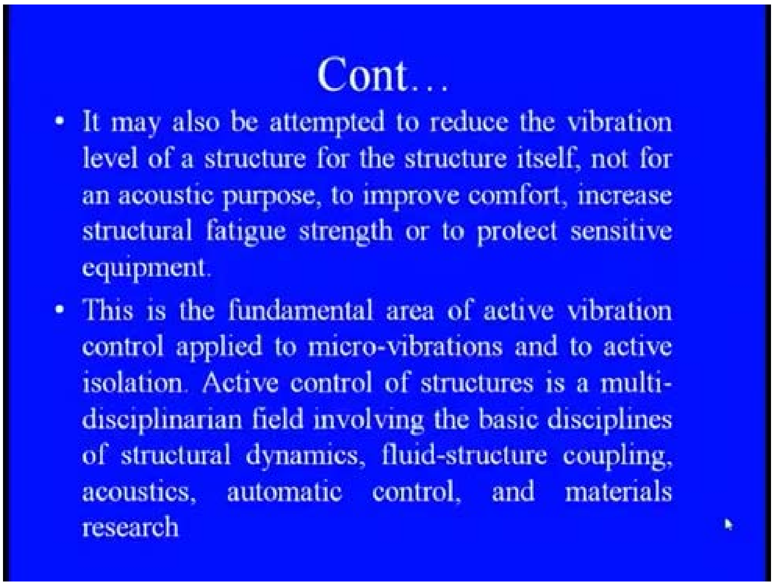

So, we can say that even that can be even attempted to reduce the vibration level of the structure even from the structure itself, not from the acoustic purpose. And through that we can provide or we can improve rather the comfort, we can increase the structural fatigue or we can say, the cyclic loading strength or even sometimes we through that we can even protect the sensitive equipment by suppressing the vibration. So, this is what you see the fundamental area of active vibration control, which can be applied to even the micro vibrations and to active isolations as well.

So, active control of the structure is nothing but a multi disciplinarian field involving the various basic principles right from the structural dynamics, to fluid structural coupling when the fluid the fluid induced vibration is there. And even you see the acoustic or even whatever you see, you know like in the material part when we require some kind of a specific feature in that.

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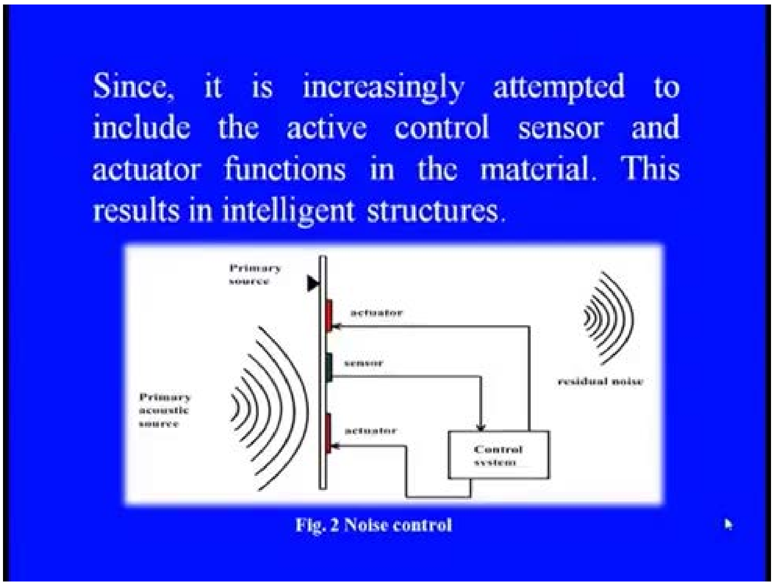

So, we can see that in this where there is a clear exciting you know like the primary acoustic source is there, and when it is being injected or a parted to the surface you can see that, we have a clear sensor in between the green part. And this sensor is being you know like as we discussed already is immediately sense that how much you see the acoustic level or the exciting feature of the vibration is in terms of displacement velocity or acceleration.

Accordingly we can adopt the sensor, one of the basic feature of the sensor is whatever the property which is to be sensed out, it can be straightaway we can say physically put that part. Like if you want to sense the displacement, which is one of the basic dynamic parameter, the displacement probes LVDT, strain gauges these are the perfect devices which straightaway can be used to sense out that or else if we are just looking to sense the vibration, in terms of velocity then the velocity probe can be adopted.

Even because you see here the velocity has a linear dependency not only on the amplitude of these excitation, but also the frequency feature. And when you see we are just going with the accelerometers, which are simply you know like measuring the acceleration feature of the vibrating mass. Then we know that this accelerometer which are simply you know like based on the two specific feature, about the amplitude of the vibration, and the frequency.

Whether we are measuring the low frequency, high frequency because we know that the accelerometer whatever the concept to acceleration it is depending the omega square. So, even you see here this is the non linear variation, the square variation is there of the frequency, which has the direct impact on the acceleration. So, that is why you see you know like we can put even for say, we just want to actuate the sense, the voltage, difference or even we just want to sense the temperature or the force whatever it is you see here.

And then you see here it is going to the controlled system or we need to put you know like some kind of electronic control feature may be analogue or the digital part. And by analyzing the signal, the amount of force which is to be required to generate is being, it is immediately you know like send it to the actuator. And these two actuators, which we are saying that the secondary source are simply like generating the equal and opposite balance, we can say the force and through which we are entirely balancing the structure and it is leading to the excitation 0.

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So, whether we are just talking about the primary acoustic source or you see the residual noise or even when we are talking about balancing of each other for this acoustic feature or for vibration features. The sensor and actuator coupled with the control system, automatic control system or electronic control system provides a clear balancing part through which we can cancel out the noise or the vibration, towards you know like the system itself.

So, there are various you know like the areas where the application of this active vibration control systems are like the fixed wing aircraft, where it is not possible to adopt the spring mass, and you know like the damper immediately at the source of vibration/. Helicopters, in the recent time you see here all the active vibration control strategies are there, the launchers satellite and the military system.

So, you can see that these all areas they have a sophisticated you know like the machinery part, and in which you see here a sophisticated treatment is adopted instead of putting a devices or any additional feature on the we can say the entire vibrating mass. So, when we are talking about the active vibration control, it is not that you see all the time we can simply sense, and you know like put the actuator as a mechanical device and then we are doing this. There is a clear you see here, relation with this concept active vibration control, in which you see force needs to be generated against you see the excitation part. So, the concept comes that you see, why cannot we featured this feature into the material itself. So, that the material will you know like not only act as the passive feature, but also the objective whatever you see you know like the part or this device, the objective itself meets with this material property with this manufacturing object.

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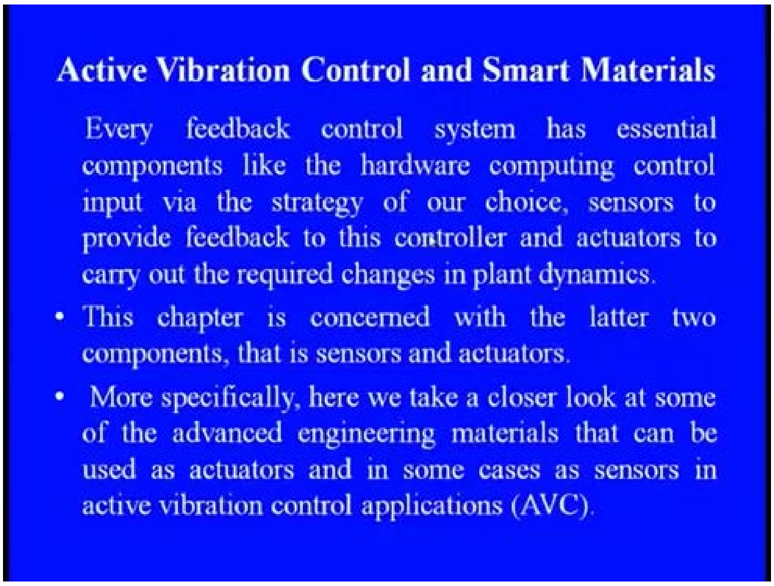

So, every feedback system when we are talking about, they have you know like essentially various components like we can say hardware computing control input or even you see various strategies are there. In which the sensor is providing the entire feedback and the actuator is simply carrying out, whatever the requirement is there in the you know like whatever the dynamic feature of the system is.

So, we can say that we are trying to focus on the sensor actuator and the automatic control part in this. And more specifically if we are saying that, when we are talking about the sensing part the first thing is coming what is the material property in that. So, again you see here, once you sense accurately any parameter as I told you whether the three basic dynamic parameter, like the displacement, the velocity or acceleration or even the force temperature or anything, when material can act as a sensor and sense those features.

And accordingly you see you know like the actuation is being induced by the metal itself against that, it is a perfect way you see here through which we can apply the concept of this active vibration control feature. So, AVC's when we are talking about Active Vibration Control technique, we need to first focus on the sensing feature outside or material itself.

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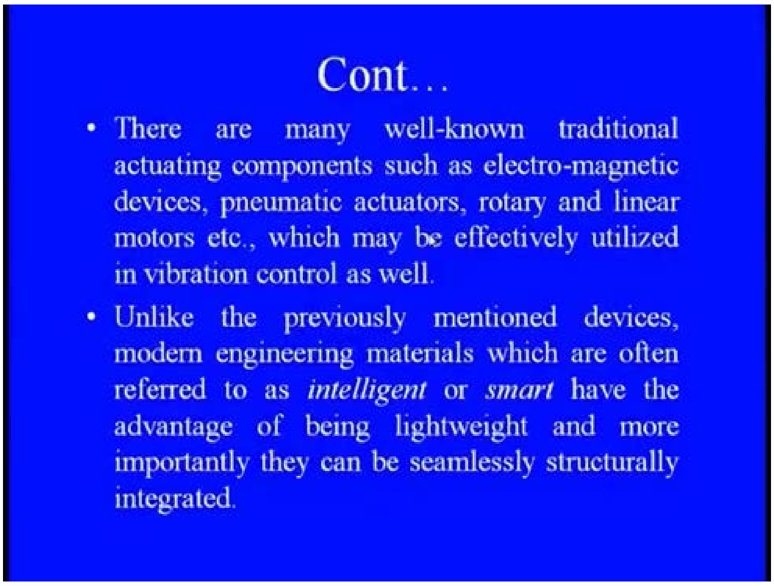

And there are various very well known you know like we can say the traditional actuating components are there. Like the electromagnetic devices through which you see here, whatever the electric features are coming and concept the electro and magnetic field, we can straightaway actuate the system. The pneumatic actuators are there, where we need to use the fluid or the air as you see the actuator feature, the rotating and the linear motors, the servo motors and various other things are there which can be immediately act as the actuator part.

Because, ultimately we need to utilize these features against the excitation feature, so when we are talking about you know like these kind of systems. We can say the when the material or these components are providing, the NT you know like the exciting force we can say the engineering material which can do that is coming under the intelligent material or the smart material. Because, ultimately you see here these materials are doing all these actions sensing to actuation by their own characteristics, the inherent feature, the inherent property.

So, they are acting as you see you know like in the smart way by sensing, and actuating automatically. And whatever the amount of force which is to be required to dampen out the vibration or the noise, they can do by their own featured. So, you see here not only they have this smartness of this kind of sensing and actuating feature, but also you see here they have very light weight.

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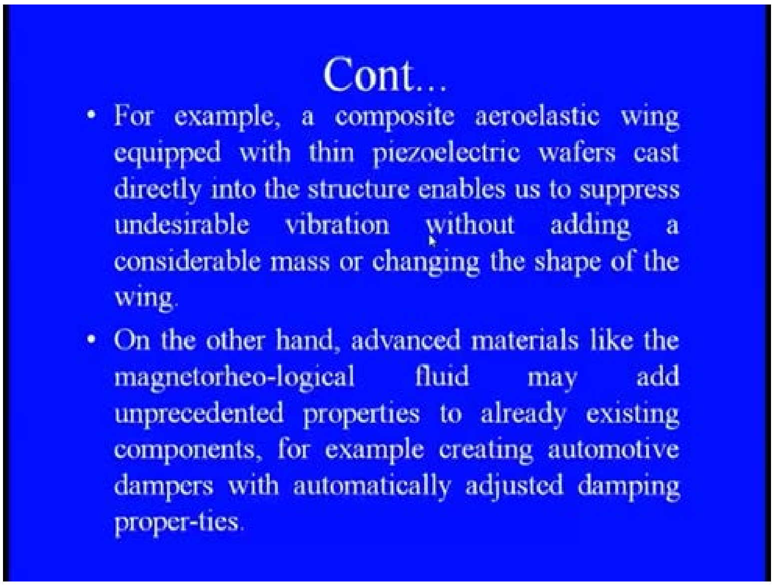

And more importantly you know like that can be even seamlessly just integrated along with the structured part, it is not that you see here we need to put on at something here there itself. They are straightway you see here you know like the most compatible feature of the structure when we are adopting this smart materials.

Like you see when we are talking about say a composite aero elastic wing, which is equipped with the thin piezoelectric wafers. And it is the most compatible feature, when we are simply putting a thin this you know like the piezoelectric wafers along with the aero elastic wing. And when we are casting directly to the structure, it can straightaway suppress the undesirable vibration, without even adding any kind of the seismic or the added mass or even without changing the shape of the entire wing or even without you know like adding any kind of damper or this spring elements.

So, the advanced materials like the magnetorheo-logical fluid, the electrorheo-logical fluid can also be add some special properties which we are saying that unprecedented properties to the existing component. So, that you see here we can create a good amount of damping feature within the from the material itself, and even right from the basic this you know like the automatic vehicles from the cars to you know like railway vehicles and the aircraft parts these MR fluids the magnetorheo-logical. Because you see here the fluid itself has the two main property the rheo-logical and the magnetorheoal featured, when you see the entire suppression of the vibration is being you know like there because of this damping part. So, this damping property is being you know like enhanced with the using of these magneto or electrorheo-logical fluid.

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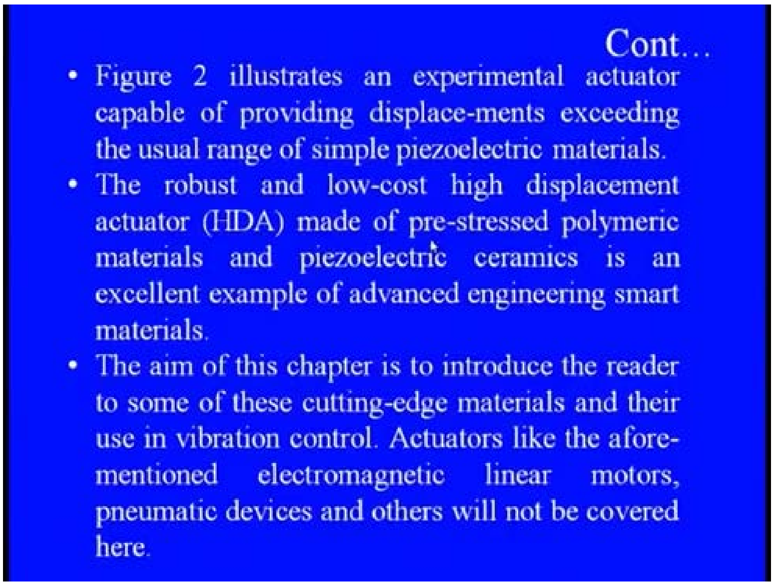

And we know that when we can sense those things in terms of you see the displacement or in terms of you see, you know like the velocity or acceleration by the sensor that can be even actuated accordingly. So, when we are talking about the sensing feature, the smart material is always just use these things like you see as example the piezoelectric material. The robust and the low cost high displacement actuator, generally we are saying HDA, just made the pre stressed this polymetric material and the piezoelectric ceramics is an excellent example of these advanced materials features.

They can be act as a smart material towards this vibration suppression, and the aim of you know like here this entire part is just to give a cutting edge material and their use in vibration control, straightaway. Because, through that we need not to add any special we can say the sensor or actuator part. So, actuator like you see you know like as we discussed about the electromagnetic or you see the light motors or pneumatic devices and others will not you see you know like just putting here. Because, ultimately our main focus is to go towards the smart material part.

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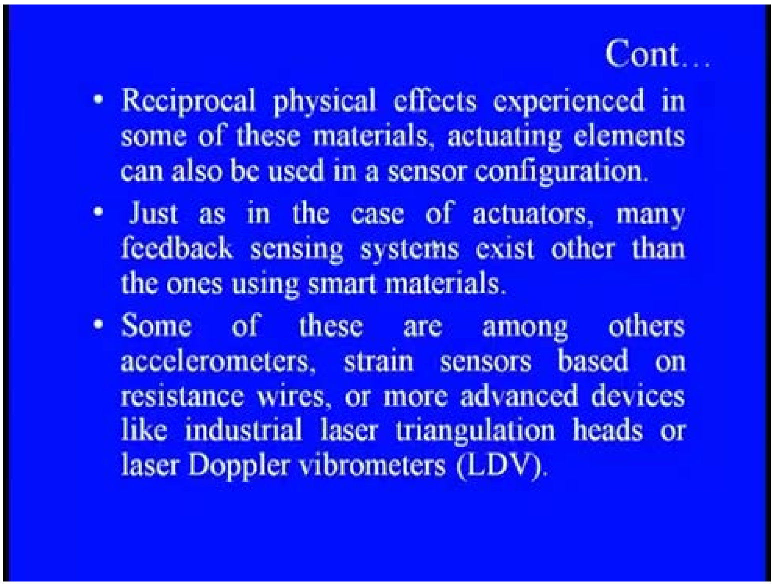

So, you see we know that whatever the reciprocal physical effects which are being coming out from these materials, can be added as the actuating elements and the sensor configuration featured there itself. So, just you see you know like in case of actuators like we discussed, the feedback sensing system is absolutely existing there inside the microstructure of the smart material. And some of these you know like are we can say like the accelerometers, the strain sensors they are even you see which is simply based on the resistance wires or any more advanced device can be straightaway put with the using of say the laser vibrometers for the nano parts and everything you see here that can be straightaway used.

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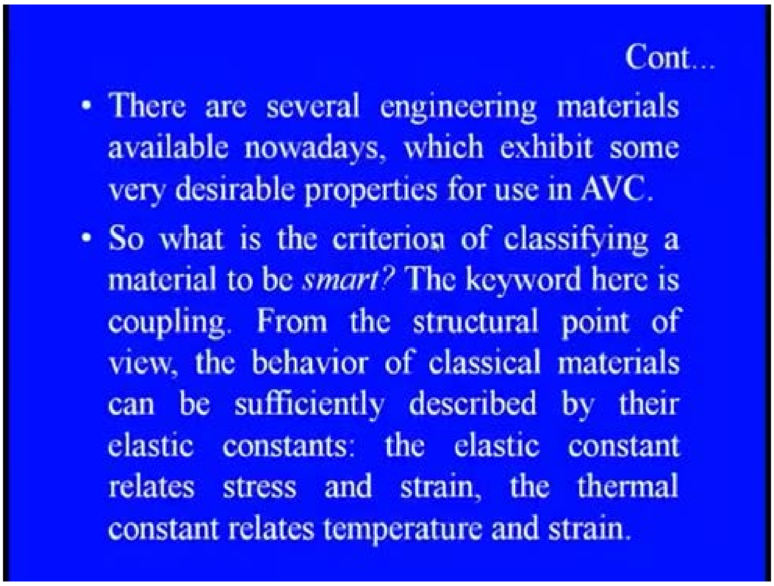

So, there are several engineering materials which are being available now a days, and they are providing the desirable impacts act as a active vibration control part. So, when we are saying that they are the smart materials; that means, you see here they are you know like, they have the smart sensing and actuation features towards that. And when we are just you know like when we are thinking form the structural point of view, the behavior of classical material can also be sufficiently you know like described by the elastic constants, which are simply relating the elastic feature between the force deformation or the stress strain, and along with what are the thermal constant rates are there. That means, you see what exactly the relation with the creeping effect, when you see you know like all these actions are being happening along the strain.

So, the smart material can coupled also with the existing material, and then can also you know like provide the field like the electric charge, the strain or the magnetic field or the temperature, chemical or any lighting part. So, these are the key parameters which are being looking at in this smart materials, first the electric charge, second even the magnetic feature, even the strain part the temperature variation and the chemical and the lighting effect with the microstructure.

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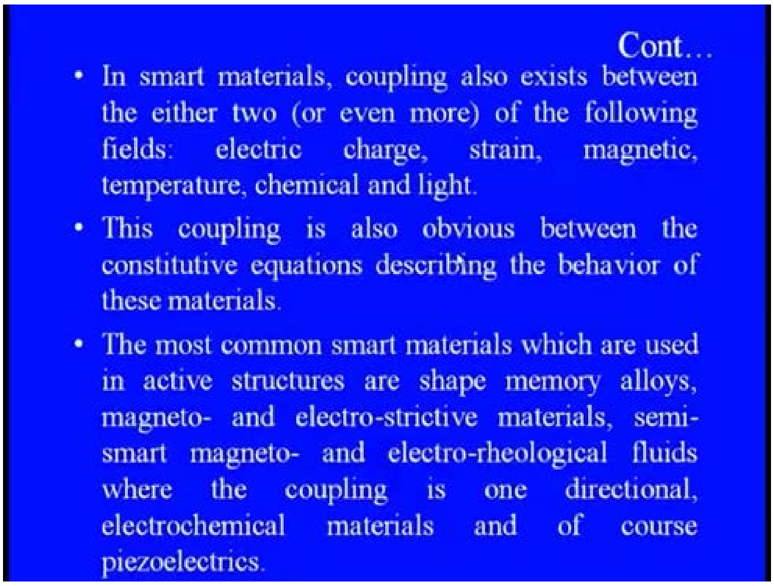

And this coupling is also obvious between, the constitutive equations describing the behavior of these smart materials. And the most common smart materials which are being used in the active structure are the piezoelectric ones, the shape memory alloys, the magneto, and electrostrictive materials the semi smart like the magneto you know like the semi smart materials are there, in which you know like we have the magneto and electro rheological part, the rheological fluids, the piezoelectric materials.

In which you see here, there is a clear coupling in one direction to electrochemical materials and of course, you see here we can say that in the piezoelectric part which direction is being dominating, we can create according to these fields in the piezo sensing and actuating part. So, you see we will discuss about in detail in these you know like the lecture series about the shape memory, piezoelectric alloys, the piezoelectric feature, the shape memory alloy and their effects and the various other smart materials. So, we know that you see you know like these things are very interesting that how the superimposing nature of these materials is creating you see, you know like in terms of the actuations and the sensing part. So, there is again you see we are going to discuss about the effect of these various parametric feature on these smart material.

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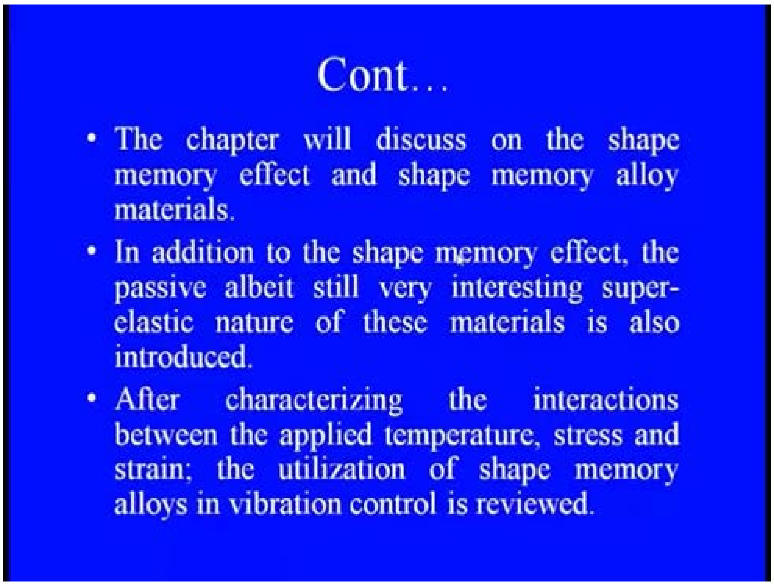

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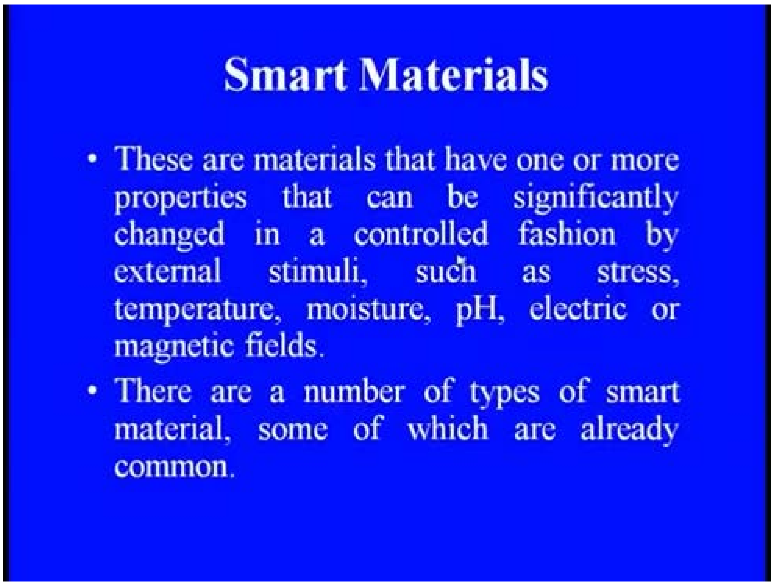

So, under the broad category of smart materials we can say that, there are significantly change in the control fashion by putting these smart materials, such as the stress we just want to control the stress say the temperature, the moisture, the p H value, the electric and magnetic fields they are a real we can say the external stimuli. And they are number of you know like the types of these smart materials are there in that like the piezoelectric materials.

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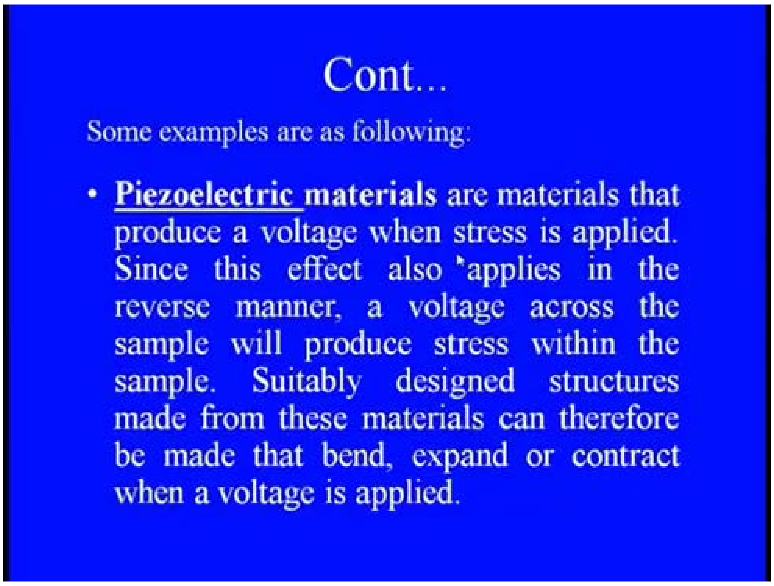

And these materials are nothing but you see we are going to take the detailed feature of that, but right now I am just going to categorize this things. These material that are simply producing the voltage, when the load or the stress is being applied to the system. And since, you know like this effect also applies in the reverse manner, voltage across the sample, across the entire specimen will produce the strain or the stress you know like within the sample.

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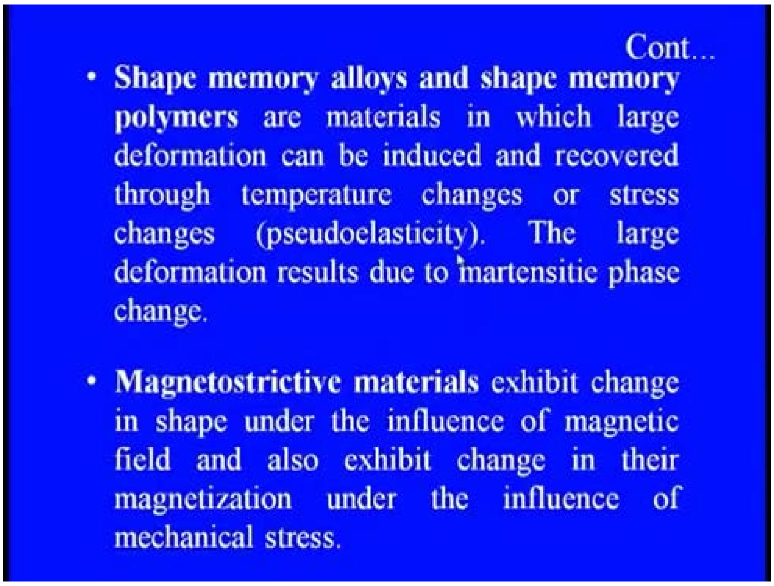

And you see you know like the counter balancing feature is being there because of the piezo nature. Suitably designed structure made from these material can be you know like we can say you know like can be straightaway put on the bending part or we can say it can be even extended, it can be extend you see you know pulling part, it can be even compress the part when the voltage being applied to the system.

Second is the shape memory alloy, and the polymers which are being simply make with the large deformation. And you see we can say that, they can be induced and recovered through the temperature changes or the stress changing, when the pseudo elasticity is being commonly featured with the shape memory alloy. And we know that you see you know like when we are changing these things, even there is a clear change at the microstructure right from you see you know like the basic structure to the even marten site phase of the structure under the large deformation.

We are going to discuss about how these alloys are being framed, and how we can use these even at the real material level. Then we have the magnetostrictive materials which can exhibit, the change in shape under the influence of magnetic field, and also can exhibit the change in their magnetized properties under the influence of this mechanical stresses. And through that the sensing and the actuation features can be coupled together with these changes of that.

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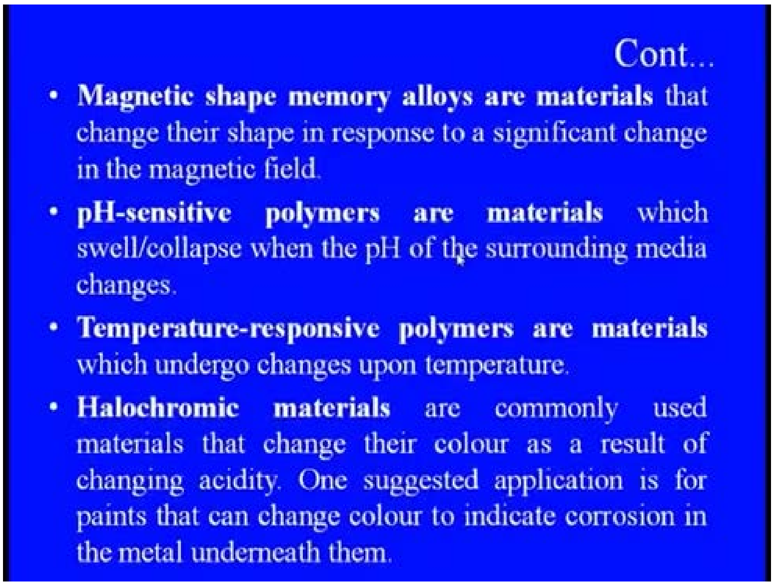

Then we have magnetic shape memory alloys, these are the material that are changing the shape with respect to the significant change of the magnetic field. So, that can also have a clear application in various devices, and then we have the p H sensitive polymers are which are simply swell or collapse, when the p H of the surrounding media is changing. And immediately give the sensing that you see, what exactly the changes are there in the moisture or the p H values outside field.

Even we have the temperature sensing feature like the temperature responsive polymers, which can immediately sense any you know like the changes at even some digital change in the temperatures can be immediately sensed out. We have halo chromic materials, and in that you see here whenever there is a change in the color, immediately you see here there is a change in the acidity part of this material and immediately it will sensed out. So, there are you see you know like various applications are there towards you see the paint, in which you see there is a change in the color to indicate the corrosion feature where the acidic environment is there outside can be immediately sensed out with the using of these sensor.

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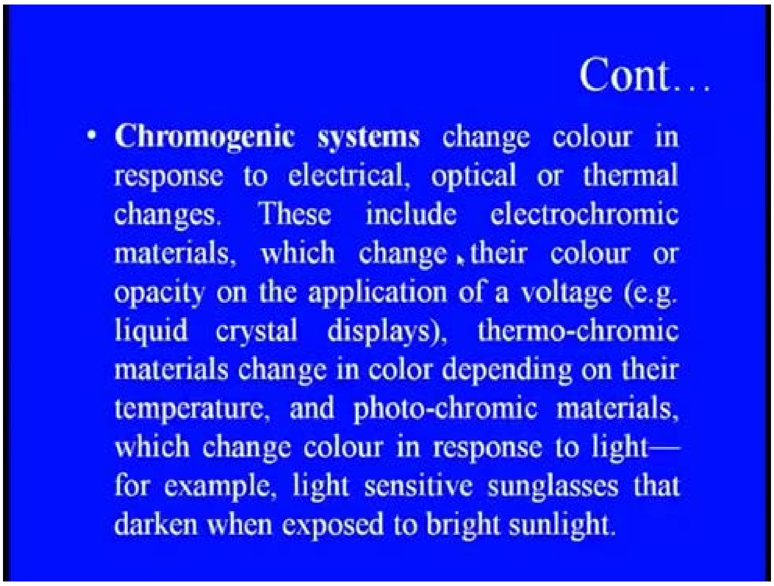

So, chromogenic you see systems in which you see when we are knowing that, there is a change in the color and can be immediately respond to the system, and if the corresponding changes are being occurred, and can be calculated with the electrical, optical or any thermal changes in the material itself. So, these materials are clearly showing the voltage drop when there is a change, in the you know like we can say the color.

And when you see when even the temperature or anything is being changed, the you know like we can say the LCD devices in which the liquid crystal displays are there, we can say the thermo chromic material can immediately find out that what the changes are there in the temperature or the we can say, the photo chromic materials. And through that we can say immediately we can sense out, so these are the smart materials in which you see the clear change is there according to the application itself.

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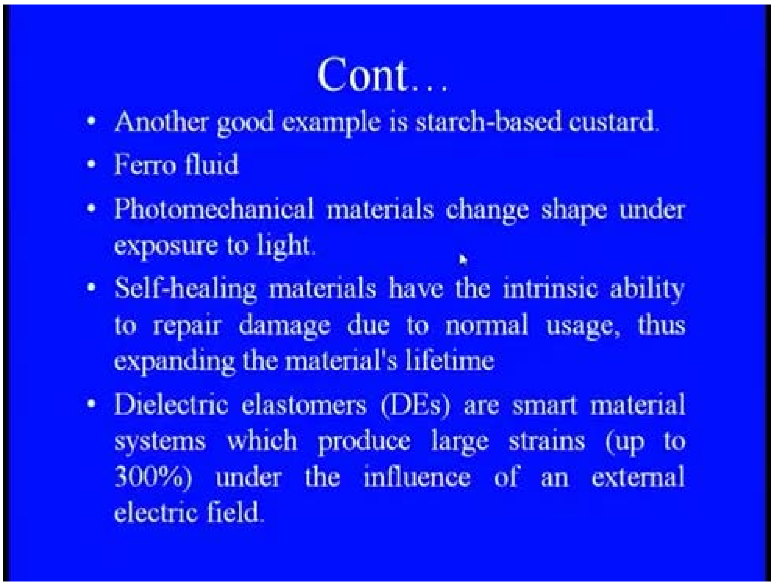

So, you see various other examples are there like you see we can use the ferro fluid, we can use you know like the photo photochemical or photo mechanical materials. Through which we can simply change whatever the shape changes are there, with the light the self heating materials are there. In which you see there is a clear property of repairing the damage due to any materials fatigue or any kind of you see changes are there in their temperature feature.

And even we have the dielectric elastomers, in which you see we have not only you see the elastic features in the smart material itself. But, they can also you see here produce the large strain, because of the dielectric part in that and they can straightaway influence entire electric field with the using of this concept. So, these are you see the smart sensing and devices actuators, in which you see there is a clear coupling between you see the you know like the sensing and actuating feature. And then can produce the you know like whatever the restrictive features against the excitation force.

So, in this chapter you see here we discussed about the basic concept of active vibration control, and what is the requirement of this active vibration control is also being discussed. And then in the later stage we discussed about that you know like how we can produce this active vibration control because sometimes when we are looking that the basic devices are the sensing actuations and the we can say electronic coupled system. But, all the time you see there is not feasible to do that, so we need to use the in-gradient property of the material, through which we can sense the variety of the parameters. And the same time you see here, the material property itself you see excite against that in which the actuation features are being there. And in the next lecture now, we are going to discuss about we will take you see the individual material about the piezoelectric or the shape memory alloy, and we will try to analyze the active vibration controls with the using of these materials.

Thank you.